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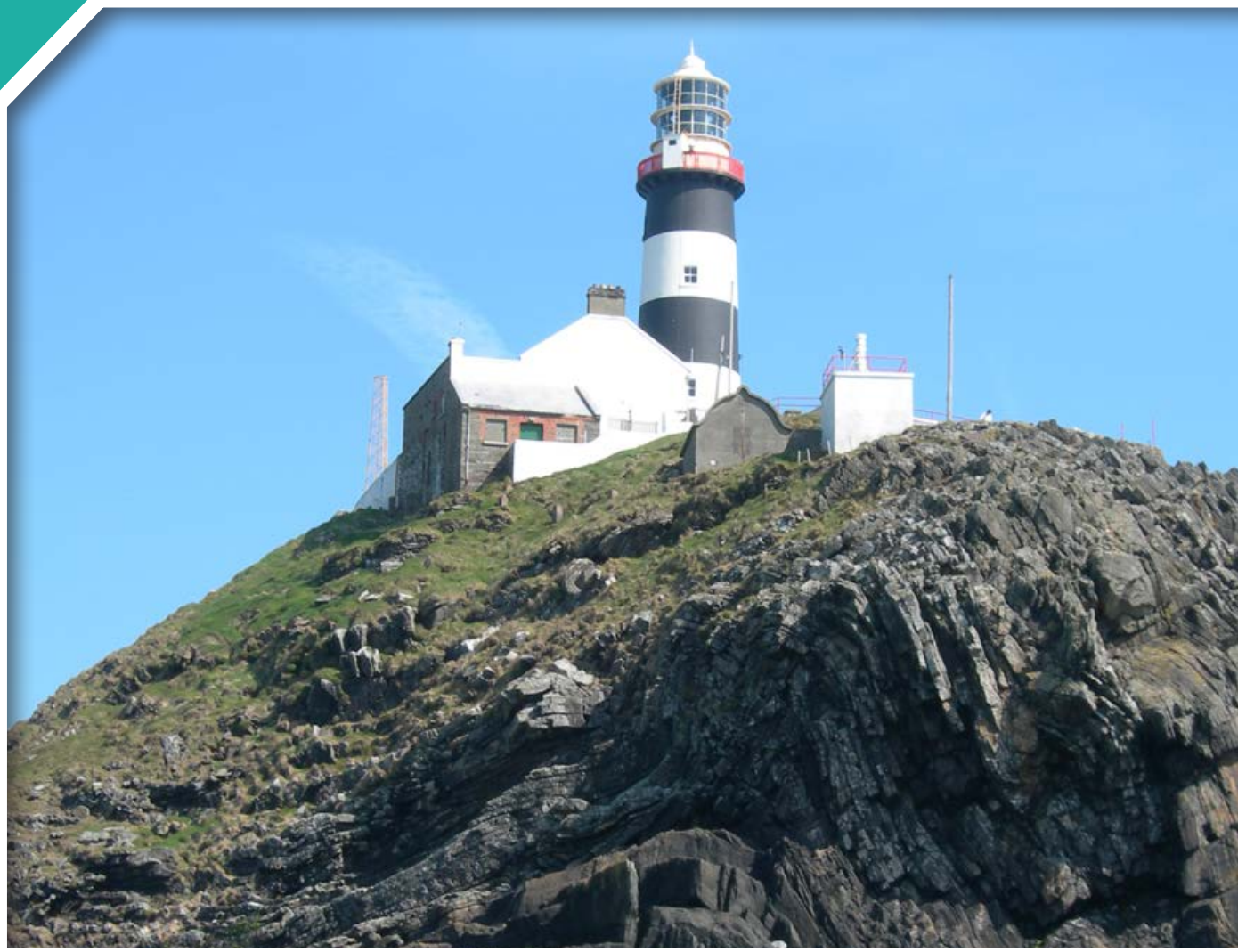
Policy Coherence in Adaptation Studies: Selecting and Using Indicators of Climate Resilience

Authors: Stephen Flood, Ned Dwyer and Jeremy Gault



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Government of Ireland

ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) is responsible for protecting and improving the environment as a valuable asset for the people of Ireland. We are committed to protecting people and the environment from the harmful effects of radiation and pollution.

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EPA RESEARCH PROGRAMME 2021–2030

Policy Coherence in Adaptation Studies: Selecting and Using Indicators of Climate Resilience

(2018-CCRP-DS.16)

EPA Research Report

Prepared for the Environmental Protection Agency

by

MaREI Centre, Environmental Research Institute, University College Cork

Authors:

Stephen Flood, Ned Dwyer and Jeremy Gault

ENVIRONMENTAL PROTECTION AGENCY
An Ghníomhaireacht um Chaomhnú Comhshaoil
PO Box 3000, Johnstown Castle, Co. Wexford, Ireland

Telephone: +353 53 916 0600 Fax: +353 53 916 0699
Email: info@epa.ie Website: www.epa.ie

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DISCLAIMER

This report is based on research carried out/data from October 2019 to September 2020. More recent data may have become available since the research was completed. Note: this research considered the Draft Climate Action and Low Carbon Development (Amendment) Bill 2020, which has since been amended and re-published. Please refer to the Climate Action and Low Carbon Development (Amendment) Bill 2021 (https://www.gov.ie/en/publication/984d2-climate-action-and-low-carbon-development-amendment-bill-2020/).

The Indicators Database developed by the research project is available on request from EPA Research.

The EPA Research Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Project Partners

Dr Stephen Flood
MaREI Centre
Environmental Research Institute
University College Cork
Cork
Ireland
Email: stephen.flood@ucc.ie

Dr Jeremy Gault
MaREI Centre
Environmental Research Institute
University College Cork
Cork
Ireland
Email: j.gault@ucc.ie

Dr Ned Dwyer[1]
MaREI Centre
Environmental Research Institute
University College Cork
Cork
Ireland
Email: n.dwyer@ucc.ie

1 Now at Randbee Consultants, ned.dwyer@randbee.com

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Executive Summary

The Policy Coherence in Adaptation Studies project combines an analysis of international best practice and approaches to the development of climate change indicators, co-designed by key stakeholder representatives, to identify a tailored suite of Ireland-relevant climate adaptation indicators. Priority climate hazards were identified, through a process of review and stakeholder consultation, as relating to sea level rise, coastal storms and pluvial and fluvial flooding, and extreme events (extreme heat, extreme wind, wildfires, drought and frost). Informed by a review of different indicator typologies and keeping the risk-based perspective in mind,[2] the typology adopted here is based on a set of climatological, impact, implementation and outcome indicators.

The establishment of the Climate Change Advisory Council, the National Adaptation Steering Committee, climate action regional offices and annual reporting on the most recent approved climate action plan in person by sectoral Ministers to the Oireachtas provides key governance institutions and policy structures to support the implementation, monitoring and evaluation of climate adaptation objectives, as set out within the National Adaptation Framework and supported by the Climate Action and Low Carbon Development Act 2015 [and updated with the 2020 Climate Action and Low Carbon Development (Amendment) Bill].[3] The development and use of climate change adaptation indicators is a clear opportunity to enhance this monitoring, reporting and evaluation framework, and will provide an important component of this climate policy and governance structure.

Indicators need to be designed with sufficient sensitivity (i.e. the ability to capture significant environmental and socio-economic impacts and changes), robustness and longevity to be fit for purpose. On the basis of these important characteristics, a co-design process, involving stakeholders from relevant state agencies and regional and national government, identified a suite of 127 recommended indicators. Ninety-one of these were identified as priority – 15 are climatological indicators, 23 are impact indicators, 32 are implementation indicators and 21 are outcome indicators. A full list of indicators is tabulated in Appendix 1, with the description of each indicator, its sectoral relevance, potential data source and data availability, and priority.

This report reflects on the challenges of indicator selection and the steps taken along the way to successfully navigate them. Challenges in ensuring effective stakeholder uptake and indicator implementation are considered, and a pathway towards implementation is proposed. As a result of this study the following recommendations are made:

- The co-created recommended indicator set should form an input to the monitoring, reporting and evaluation of climate change adaptation actions for Ireland. An agreed subset of these indicators should be implemented in a pilot study.
- A full scoping exercise on the dataset characteristics[4] is beyond the scope of this project, but it would need to be carried out prior to implementation of the indicator set.
- The most appropriate existing state body should be identified to oversee the detailed development and implementation of the indicator framework.
- A National Framework for Climate Services should be established and have as part of its remit the authority to identify, evaluate and recommend appropriate data for indicator calculation. Qualitative data should also be incorporated to

2 A risk-based approach places emphasis on the biophysical nature of the climate hazard. This then allows assessment of the potential impact of this risk on socio-ecological systems and the adoption of measures to reduce this risk to an acceptable level (IPCC, 2012).

3 Note: this research considered the Draft Climate Action and Low Carbon Development (Amendment) Bill 2020, which has since been amended and re-published. Please refer to the Climate Action and Low Carbon Development (Amendment) Bill 2021 (https://www.gov.ie/en/publication/984d2-climate-action-and-low-carbon-development-amendment-bill-2020/).

4 Dataset characteristics include accuracy (correctness of detail), completeness (comprehensiveness) and reliability (whether the information contradicts other trusted sources).

ensure the comprehensiveness of the indicator framework.
- Collecting data demands significant resources. Therefore, the selection of indicators should be driven by pragmatic decisions related to data availability.
- Implementation of, and reporting, on indicators should be aligned with existing reporting requirements to streamline reporting burdens and avoid duplication of reporting obligations. Moreover, synergies with disaster risk management, sustainable planning and the green infrastructure agenda should be identified.
- Appropriate financial and human resources should be allocated to ensure uptake and adoption of the indicator framework.
- A comprehensive capacity building and communications programme should be implemented in relation to the climate adaptation indicators to engage with all relevant stakeholders, especially those in local authorities and government departments that will be responsible for implementing adaptation actions. Climate Ireland would be well placed to support this activity in its role as a research service that connects and integrates scientific research, policymaking and adaptation practice for the purposes of enhancing adaptation decision making in Ireland.

1 Introduction: Why Indicators?

1.1 Measuring and Monitoring Climate Resilience

The concept of resilience has gained traction internationally in recent years (Flood and Schechtman, 2014; Doorn *et al*., 2018). The term was first grounded in law and politics before moving into the sciences and humanities and being adopted by social science and sustainability science (Alexander, 2013; Flood and Schechtman, 2014). Resilience is defined by the Intergovernmental Panel on Climate Change (IPCC) in its special report *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* as:

> The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.
>
> (IPCC, 2012)

Broadly speaking, resilience is considered from an ecological resilience perspective when examining natural systems, biodiversity and natural capital, from a development resilience perspective when examining livelihoods and food security within a human development context, and from a socio-ecological perspective in relation to climate change adaptation (Quinlan *et al*., 2016). Socio-ecological resilience is measured internationally with a range of frameworks, toolkits and guidelines, the majority of which are grounded in the application of indicators (Quinlan *et al*., 2016). For example, the Resilience, Adaptation and Transformation Assessment Framework by O'Connell *et al*. (2015) provides an overarching framework to operationalise concepts of resilience, adaptation and transformation in the context of broad global policy domains. The International Union for Conservation of Nature uses qualitative indicators providing guidance on developing climate change-resilient strategies and plans, under themes including diversity, self-organisation and adaptive governance, and sustainable infrastructure (IUCN, 2014).

In an Irish context the concept of resilience forms a key component of the 2018 National Adaptation Framework (NAF) (DCCAE, 2018a). Climate change creates cascading impacts across socio-ecological systems globally, including in Ireland, that test the resilience of key systems (Dwyer, 2013; IPCC, 2014, 2018; Nolan, 2015; Nolan and Flanagan, 2020). Climate change is best conceived as a threat multiplier that increases the probability of significant biophysical and associated socio-economic impacts across scales. Documented and projected climate change impacts in Ireland are associated primarily, but not exclusively, with sea level rise, increasing impacts when extreme weather events occur, increased prevalence of both drought and flooding conditions and events, biodiversity loss, changes in species distribution, and an increased number of pests and diseases (Dwyer, 2013; Nolan, 2015; Nolan and Flanagan, 2020). The NAF references the work of the IPCC in linking the concept of resilience with climate change adaptation and draws on research exploring what a climate-resilient Ireland might look like (IPCC, 2014; Shine, 2018). Climate resilience is defined within the NAF as:

> The capacity of a system, whether physical, social or ecological, to absorb and respond to climate change and by implementing effective adaptation planning and sustainable development (including governance and institutional design) to reduce the negative climate impacts while also taking advantage of any positive outcomes. This will allow the system to either return to its previous state or to adapt to a new state as quickly as possible.
>
> (DCCAE, 2018a)

It is important to note that resilience indicators, adaptation indicators and preparedness indicators are often used interchangeably. Resilience indicators specifically consider the ability of a community to cope with immediate climate change impacts and its long-term ability to adapt (adaptive capacity) (Engle *et al*., 2014). Preparedness indicators are often referenced within disaster risk reduction literature to refer to the ability of communities to respond to extreme weather

events (English *et al*., 2009). Adaptation indicators focus more on building long-term adaptive capacity than short-term response capacity.

To track progress in implementing adaptation actions and, more importantly, to evaluate the outcomes of such action, it is necessary to ensure that a monitoring, reporting and evaluation (MRE) system is in place. Climate adaptation indicators, when properly designed and implemented, are valuable measures to incorporate into an MRE system and can provide information on the level of resilience of the system.

1.2 The Potential Role of Indicators in Irish Climate Adaptation Policy

An indicator is a characteristic or variable that helps to describe an existing situation and to track changes or trends over a period of time. An indicator can provide either qualitative information, for instance on the degree of development and implementation of a policy process, or quantitative information, such as the amount of funding dedicated to the policy (adapted after Mäkinen *et al*., 2018). An opening justification for indicators is the fact that that which is not counted and measured doesn't count. This is reflected in standard government budgeting and more recently in green accounting principles including natural capital accounting (DPER, 2019).

Significant research and experience in climate adaptation indicators has been gained internationally; however, another country's system cannot be simply adopted and implemented in Ireland. Each country has a specific set of physical, environmental, governance and socio-economic conditions, which requires that a nationally appropriate set of indicators is developed. Building on this international research and experience in the development of climate adaptation indicators, Kopke *et al*. (2018) identified a set of criteria to develop nationally relevant indicators. They proposed 70 indicators with a focus on the sectors of agriculture and the marine and fisheries, and they suggested almost 200 additional indicators for other sectors. That study was primarily desk based and there was a recognised need to build on the authors' recommendations, by strongly engaging with stakeholders and practitioners to refine the indicator set and also to explore issues of implementation within an MRE framework.

1.3 The MRE Framework and the Need for Evaluation

MRE is increasingly acknowledged as a key component of adaptation policymaking and this is reflected in the growing number of MRE systems being designed and implemented at national level in Europe (EEA, 2015; Mäkinen *et al*., 2018). Monitoring, reporting and evaluation are distinct yet closely linked processes, as defined by the European Environment Agency (EEA, 2014).

Monitoring is the continuous process of examining progress made in planning and implementing climate adaptation action and can include the drivers that frame vulnerability and resilience. Reporting captures the formal process whereby monitoring and/or evaluation information is communicated. This can often be across scales of governance. The reporting process can help to facilitate the assessment of adaptation performance and support learning at a range of scales. Evaluation refers to an objective and systematic assessment of the effectiveness of climate adaptation plans, policies and actions, which is often framed in terms of the impact of reducing vulnerability and increasing resilience.

MRE is envisaged in the sectoral plans and local authority strategies, which were developed in line with the NAF, laying out the approach for the implementation of adaptation actions. Yet indicators are addressed only in terms of performance indicators. This leaves a gap in regard to capturing information on the evolution of climate, the impacts of change, and measuring climate resilience and outcomes. There is significant potential to develop, evaluate, adopt and implement a set of climate adaptation indicators that can inform Irish adaptation policy over the medium to longer terms. Moreover, a well-designed set of adaptation indicators can help to identify whether or not the aim of achieving a climate-resilient Ireland is being addressed in reality. They can do so by providing a means to measure and quantify status and progress from climate impacts to adaptation actions and then to adaptation outcomes. This report builds on work done and proposes a final set of 127 indicators (see Chapter 5 and Appendix 1) that were co-created in close consultation and engagement with a wide range of relevant stakeholders, and it looks at how such indicators may be taken up in the national MRE process.

1.4 Report Outline

The rest of this report is structured as follows. Chapter 2 outlines the various types of indicators that are considered internationally. It outlines the research methodology employed to develop these and provides details of the stakeholder engagement process. Chapter 3 provides a synthesis of relevant research and experience across Europe, and on a global basis, in terms of indicator selection, adoption and implementation, and it highlights some of the key lessons learned that can inform the process in Ireland. Chapter 4 explores the policy context in Ireland in relation to climate adaptation and suggests where and how indicators could sit within and inform it. Moreover, it looks at issues related to the data needed for the calculation of relevant indicators, issues of scale (local to regional to national to international), sectoral concerns and the need for comprehensive stakeholder engagement in the process. Chapter 5 documents the co-design process with stakeholders and presents the suite of proposed indicators in terms of the hazards identified as priority. The chapter also outlines a roadmap for implementation of the selected indicator set, with the full final set of indicators tabulated in Appendix 1. Chapter 6 discusses the challenges encountered in the indicator development process in ensuring stakeholder uptake and use, and in implementation. Chapter 7 draws out the main conclusions and provides a set of recommendations building on the work carried out here.

2 Navigating Climate Adaptation Indicators

Indicators serve different policy processes, from providing background information on climate change to assessing impacts and identifying adaptation needs (EC, 2018a; Street and Jude, 2019). Thus, climate adaptation indicators may serve a range of purposes, including characterising the state of a natural or socio-ecological system, tracking progress in the implementation of an adaptation strategy or plan, monitoring the spending of adaptation funds, mainstreaming adaptation in different sectors and communicating adaptation information to policymakers, to mention but a few (Harley and van Minnen, 2009). Therefore, it is important from the outset to identify where the focus of any suite of adaptation indicators lies and ask what policy outcomes are prioritised.

The approach taken by the Policy Coherence in Adaptation Studies (PCAS) project has been to combine a literature review of the current state of play and approaches to the development of climate change indicators with co-design by key stakeholder representatives from relevant state agencies and regional and national government to create a tailored suite of Ireland-relevant climate adaptation indicators (Figure 2.1). In designing the indicator suite, a risk management approach was taken. This approach places emphasis on the biophysical nature of the climate hazard. This then allows assessment of the potential impact of this risk on socio-ecological systems and the adoption of measures to reduce this risk to an acceptable level (IPCC, 2012).

The literature review focused on both European and international approaches to understand the criteria that should be applied to the identification and selection of climate adaptation indicators and to determine the criteria upon which to frame an indicator set for Ireland. This process developed a typology of climatological, impact, implementation and outcome indicators based on indicator approaches outlined in section 2.1. The four indicator types take the approach of Vallejo (2017) by looking at climate hazards and impacts, adaptation processes and adaptation outcomes.

2.1 Types of Indicators

The need to integrate adaptation actions across sectors and agencies to inform society's response to climate change, and to be able to understand and monitor the efficacy of actions, has led to growing interest in the design and implementation of indicators for adaptation (Mäkinen *et al*., 2018). Indicators are required to capture:

- direct climate impacts/risks (e.g. changes in the frequency of flood events);
- indirect climate impacts/risks (e.g. losses, damages, costs);
- adaptation responses and actions (e.g. number of kilometres of firebreaks installed);
- adaptation processes (e.g. establishment of an action plan, setting up of an implementation group);

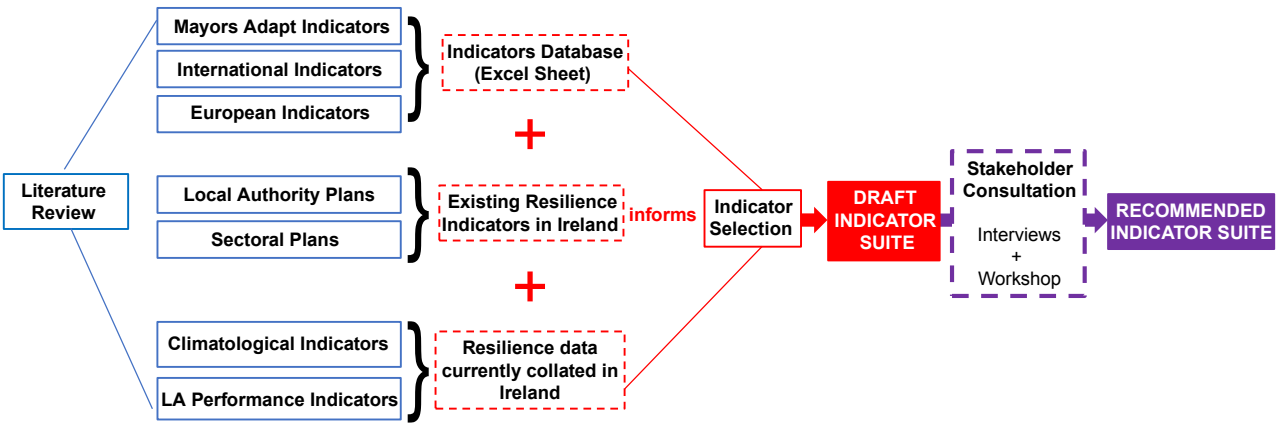

Figure 2.1. Project research method overview. LA, local authority.

- adaptation impacts (vulnerability, exposure, adaptive capacity), including equity and rights determinants.

Given the complexity of climate change and climate change adaptation, different types of indicators have been developed and used for different purposes. Nonetheless, as outlined by Kopke *et al*. (2018), there are generally three categories of indicators that can be applied in the adaptation process. These are:

1. *Process-based indicators*: these define the key stages in a process that could realistically be expected to contribute to positive adaptation outcomes, without specifying those outcomes at the outset (e.g. indicators that illustrate that a process is under way, such as the formulation of a coastal adaptation planning committee).
2. *Output-based indicators*: these follow the direct results of an adaptation policy or action, without assessing whether these results actually lead to better adaptation outcomes (e.g. indicators that an output has been achieved, such as X km of upgraded sea defences).
3. *Outcome-based indicators*: these seek to define an explicit outcome or result of the adaptation action, indicating a reduction in vulnerability or better adaptive capacity (e.g. indicators that show that a coastal community is now less vulnerable to coastal inundation). Outcome indicators can be considered at different points in time. Therefore, it could be concluded that, as a result of adaptation measures, a coastal community is currently less vulnerable to coastal flooding and that it is likely to be less vulnerable for the next 25 years (taking into account climate projections); however, it may be less certain if that outcome will be achieved in, say, 2070. As a result, a useful way of considering this issue in MRE is to assess progress towards outcomes.

Although this typology of indicators is relevant to the formulation and implementation of policy actions, indicators for measuring progress in adaptation present challenges in being both context specific and cutting across all sectors of the economy, while concurrently addressing long timeframes and uncertainty, which makes setting agreed targets difficult (EEA, 2014).

The design of indicator systems for monitoring and evaluation of climate change adaptation is a relatively recent activity at national level, leading the Climate Change Expert Group (CCXG) on the United Nations Framework Convention on Climate Change (UNFCCC) to propose that the process of adapting to climate change should increase understanding of climate risks, improve the effectiveness of adaptation measures and increase accountability under the UNFCCC through:

- “climate risks” indicators, which embrace climate hazards, climate impacts, exposure and adaptive capacity;
- “adaptation processes” indicators, which look more at the implementation of strategies and plans and the allocation of resources;
- “adaptation outcomes” indicators, which look at the actual results of adaptation policies and plans.

(Vallejo, 2017, p. 16)

Other typologies have been built on a range of criteria, such as the different sectors with which indicators are associated or the perspective that an indicator might have (e.g. “adaptation perspective” – indicators intended to measure a specific aspect of climate change, “policy cycle perspective” – indicators designed to measure a process, output or outcome of an adaptation policy) (EEA, 2015). Finally, indicators can also be defined according to function (type 1) or content (type 2) (Box 2.1) (IPCC, 2014; EEA, 2015). Indicator function describes inputs, processes, outputs and outcomes. Content indicators are focused on issues such as exposure, adaptive capacity, sensitivity, vulnerability and hazards.

Irrespective of the type of indicator, it is important to assess whether it is a “good indicator”. For good sustainability indicators, the key elements of the “SMART” criteria (Doran, 1981; McCarthy *et al*., 2012; Maxwell *et al*., 2015; Kopke *et al*., 2018; Shine, 2018) are often considered useful, in that indicators should be **S**pecific, **M**easurable, **A**chievable, **R**elevant and **T**imely. Focusing on the criteria for ecological indicators, Dale and Beyeler (2001) suggest that indicators should:

- be easily measured;
- be sensitive to changes in stresses on the system;
- respond to changes in stress in a predictable manner;

Box 2.1. Types of adaptation indicators

Indicator function (type 1)

- Input indicator – an indicator that provides a measure of resources, both human and financial, devoted to a particular adaptation activity, programme or intervention.
- Process indicator – an indicator that tracks progress in adaptation policy processes and actions.
- Output indicator – an indicator that relates to the direct results of an adaptation policy or action, without assessing whether these results actually lead to better adaptation outcomes.
- Outcome indicator – an indicator that seeks to define an explicit outcome or result of an adaptation action. Outcome indicators may also assess the level of success of specific adaptation measures, indicating, for example, a reduction in vulnerability or improved adaptive capacity.

Indicator content (type 2)

- Exposure indicator – an indicator of the exposure of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure, or economic, social or cultural assets in places and settings that could be adversely affected.
- Adaptive capacity indicator – an indicator of the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences.
- Sensitivity indicator – an indication of the degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect. In the disaster risk reduction (DRR) policy domain and knowledge communities, this is called “vulnerability” (EEA, 2017, section 1.4 and Box 1.3).
- Composite vulnerability indicator – an indicator that provides a metric characterising the vulnerability of a system by combining, with or without weighting, several indicators assumed to represent vulnerability. This includes indicators that combine two or more indicators of exposure, sensitivity and/or adaptive capacity. In some cases in the literature, this has been described as a “vulnerability index indicator”.
- Hazard indicator – an indicator of the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

Source: Based on EEA (2015) and IPCC (2014) glossaries.

- signify an impending change in the ecological system in an anticipatory manner;
- predict changes that can be averted by management actions;
- provide integrative coverage of the key gradients across the ecological systems;
- have a known response to natural disturbances, anthropogenic stresses and changes over time, and a low variability in that response.

Harley and van Minnen (2009) focused specifically on adaptation indicators and identified a set of criteria critical for their development. These include:

- availability – existence of both appropriate data and indicators;
- potential availability – availability of reliable data that can support the development of indicators in the future;

- representativeness – availability of indicators that are suitable for measuring progress on the important or determining factors (rather than secondary issues);
- continuity – regular availability of indicators.

Finally, in the context of MRE of climate change adaptation (e.g. Gudmundsson *et al*., 2009; EEA 2015), it is important to remember that:

- There is no one-size-fits-all indicator.
- The purpose and objective of an adaptation MRE system drives what a good indicator might be.
- A set or portfolio of indicators is usually required to create an accurate picture of adaptation progress.
- Quantitative indicators are more effective when combined with qualitative information.
- There is an inevitable reliance on proxy indicators.
- Outcome indicators often do not show progress over relatively short periods of time.
- It is essential to understand the assumptions and limitations of the indicators, the associated framework and the uncertainties and possible risks in using them.

There is uncertainty as to the degree of climate change that will occur and in relation to the specific impacts. The IPCC itself highlights uncertainty in the language it uses and identifies adaptive management as one approach to incorporating uncertainty in adaptation planning and implementation. Indicators themselves must be selected and implemented with uncertainty in mind, and this is why an iterative and flexible approach is required. The initial set of indicators implemented will need regular revision. It is to be expected that over time some will be retired from use while new indicators will be adopted, reflecting the need for an adaptive management approach.

The outcome from reviews of the development of indicator sets to support climate change adaptation is that, while there is recognition that adaptation indicators can contribute to objectives that cross sectoral and agency boundaries, it is important that they meet nationally relevant contexts, and this will shape the entire development of indicator sets (Mäkinen *et al*., 2018).

2.2 Methodology for Selecting Appropriate Indicators for Ireland

Understanding of the criteria that shape the selection and design of indicator sets was applied to an analysis of actions from Irish sectoral and local authority climate change adaptation plans. These were then compiled under an indicator typology as climate impacts, adaptation actions or adaptation outcomes. Climatological indicators from international, European and Irish literature sources were compiled, as were local authority performance indicators. Examining local authority performance indicators provided insight into the reporting areas of local authorities and where they may align with adaptation indicators.

Once this initial review was completed, a screening process was carried out to identify indicators with particular relevance within the Irish context, considering Irish climatological characteristics and climate hazards experienced. A climate hazard is defined here as a physical process or event that can harm human health, livelihoods or natural systems. This process enabled the identification of a typology of four climate change adaptation indicator types that were comprehensive, but not overcomplicated, and specific to Ireland (Figure 2.2).

The four indicator types are defined below:

1. Climatological indicators capture information about observed climatic conditions, e.g. temperature, rainfall and extreme events.
2. Impact indicators capture information about the observed impacts of climate variability and change on socio-ecological systems, e.g. the number of properties damaged by floods.

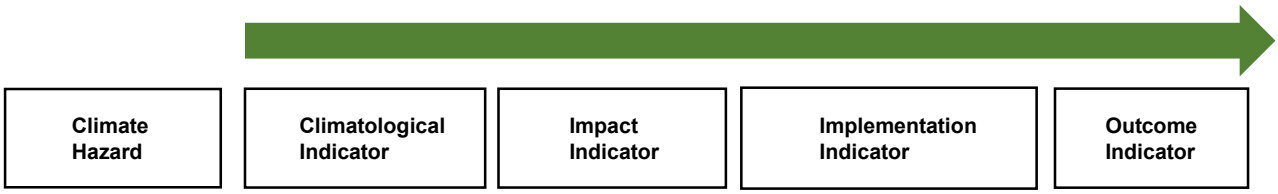

Figure 2.2. Climate change adaptation indicator typology.

3. Implementation indicators provide information to help track the implementation of adaptation actions or strategies.
4. Outcome indicators provide information to help track the outcome of results of adaptation actions or strategies.

This typology was applied to the possible metrics that could form an adaptation indicator suite for Ireland, grouped under three major sets of climate hazards: (1) pluvial and fluvial flooding; (2) extreme events (extreme heat, extreme wind, drought and frost); and (3) coastal flooding and erosion. These hazards were deemed to be priority within the Irish context – thereby providing the national specificity as documented in existing literature, reports and adaptation plans and strategies (Coll and Sweeney, 2013; Desmond *et al*., 2017; Climate Ireland, 2019; Flood *et al*., 2020). This hazards grouping provided stakeholders with the opportunity to see how climate hazards create impacts relevant to a number of sectors, government agencies, climate action regional offices (CAROs) and local authorities.

These research strands were combined to compile a draft suite of relevant climate adaptation indicators (this draft is to be made available through SAFER) that was taken forward for stakeholder validation and revision through a set of semi-structured interviews and an online workshop.

2.3 Stakeholder Engagement in the PCAS Project

Co-design and co-production with stakeholders involved in the knowledge supply chain from data generation to user have been shown to be important in the design of climate indicators and climate services to ensure that climate information is used effectively and appropriately (Kotova *et al*., 2017; Vincent *et al*., 2018; Bremer *et al*., 2019; Wyborn *et al*., 2019). Stakeholder participation has also been a key factor in the development and evolution of an indicator suite deemed most appropriate for use within an Irish context in the PCAS project. Following a preliminary desk-based research exercise, an initial indicator set was co-designed with key stakeholder representatives from relevant state agencies and regional and national government (Figure 2.1), and subsequently shared with the participants of an online workshop to allow an additional round of feedback and prioritisation before arriving at a recommended adaptation indicator suite for Ireland (see Chapter 5, Appendix 1).

2.4 Identifying Stakeholders

To identify an appropriate set of stakeholders, who represented the knowledge supply chain and users for climate indicators in Ireland, the project team consulted with Climate Ireland, representatives of three interrelated thematically relevant Environmental Protection Agency (EPA) research projects (BCOMAR, SDGs4I, and Enhancing the Integration of Disaster Risk and Climate Change Adaptation in Irish Emergency Planning[5]) and the Project Steering Committee. These informal consultations provided an important sounding board to share ideas and receive critical feedback on the project approach. Consultation was also carried out with external stakeholders including the CAROs, the EPA and the Climate Change Advisory Council adaptation sub-committee, and relevant government departments and state agencies. These stakeholders were considered relevant, as, under the NAF, and in the actions and governance arrangements detailed in the 2019 Climate Action Plan (Government of Ireland, 2019a), they hold responsibility for implementing climate change adaptation and, in that respect, the responsibility for measuring its progress.

2.5 Stakeholder Details

This section outlines the stakeholders consulted as part of the PCAS project and their association with climate change adaptation and climate indicators. Four CAROs were established in 2018 in response to Action 8 of the 2018 NAF (DCCAE, 2018a), with the purpose of driving climate action at regional and

5 BCOMAR (Building Coastal and Marine Resilience) aims to use comparative studies in Ireland to develop a participatory methodology for supporting bottom-up engagement in climate change adaptation (https://www.marei.ie/project/bcomar/ – accessed 10 May 2021). SDGs4I is concerned with the Sustainable Development Goals and focuses on SDG 17: Partnerships for the Goals, to enhance policy coherence within Ireland for sustainable development (https://www.marei.ie/project/sdgs4i/ – accessed 10 May 2021). Enhancing the Integration of Disaster Risk and Climate Change Adaptation in Irish Emergency Planning: https://www.marei.ie/project/integration-disaster-risk-climate-change-adaptation/ (accessed 10 May 2021).

local levels. The composition of the four CAROs was determined by geographical and topographical characteristics, vulnerabilities and shared climate risks experienced across local authority areas. The four CARO regions, constituent local authorities and associated lead authorities are presented in Table 2.1 (additional details are available in Appendix 2).

Other government departments and agencies that hold responsibility for implementing climate change adaptation and were consulted as part of the PCAS project are shown in Table 2.2 (additional details are available in Appendix 2). These were consulted as they each lead one or more of the sectoral climate change adaptation plans (Climate Ireland, 2020). This subset of government departments and agencies provided a broad range of perspectives on priority climate change impacts, adaptation actions and the requirements of an indicator set for Ireland. It should be noted that indicator-related actions outlined in sectoral adaptation plans were taken on board in the development of the indicator suite, i.e. by considering climate hazards in the climate change adaptation indicator typology (Figure 2.2), a cross-sectoral approach was taken to avoid duplication of indicators.

2.6 Stakeholder Consultation Process

Eleven video conference interviews were held with representatives from the CAROs and sectoral representatives (Tables 2.1 and 2.2). The interviews followed a semi-structured format anchored around a set of questions supported by the draft adaptation indicator suite, which was made available through a Microsoft Excel spreadsheet. Each of the semi-structured interviews was framed around a series of questions to facilitate comparability (Table 2.3). The rationale for each question is also provided in the table.

Table 2.2. Government departments and agencies consulted as part of the PCAS project[a]

Department/agency	Adaptation plan lead
Office of Public Works	Flood risk management
Department of Agriculture, Food and the Marine	Seafood, agriculture, forestry
Department of Health	Health
Department of Culture, Heritage and the Gaeltacht and National Parks and Wildlife Service	Biodiversity, built and archaeological heritage
Department for Transport, Tourism and Sport	Transport infrastructure
Met Éireann	
Irish Water	
EPA	

[a]Department names are those in use for the duration of the project.

To facilitate understanding and discussion, the draft adaptation indicator suite referenced in question 3 was grouped under the three major sets of climate hazards (pluvial and fluvial flooding, extreme events, and coastal flooding and erosion) that were identified in the literature as being of particular importance for Ireland. The draft indicator suite was then shared with key stakeholders prior to holding online semi-structured interviews with the purpose of co-selecting the indicators considered to be most fit for purpose within an Irish context. For each of the draft indicators, feedback was collected on indicator relevance, feasibility, validity and priority for use within an Irish context. Included in the process was a prioritisation exercise to highlight those indicators deemed to be of highest priority for Ireland. The outcome of this process was the generation of a revised draft suite of adaptation indicators that included prioritisation of indicators and some additional indicators, or indicator amendments, as suggested by the interviewees.

Table 2.1. The four CARO regions, constituent local authorities and associated lead authorities

CARO	Constituent authorities	Lead authority
Atlantic Seaboard North	Donegal, Galway City, Galway, Sligo, Mayo	Mayo County Council
Atlantic Seaboard South	Clare, Cork City, Cork, Kerry, Limerick	Cork County Council
Eastern and Midlands	Carlow, Cavan, Kildare, Kilkenny, Laois, Leitrim, Longford, Louth, Meath, Monaghan, Offaly, Roscommon, Tipperary, Waterford, Westmeath, Wexford, Wicklow	Kildare County Council
Dublin Metropolitan	South Dublin, Fingal, Dún Laoghaire-Rathdown, Dublin City	Dublin City Council

Table 2.3. Semi-structured guiding interview questions

	Question	Rationale
1	Tell me a little about your current role (how long in the position, area of expertise)	To understand background, professional interests, knowledge of climate change adaptation and priorities of interviewee
2	What are your priority climate hazards and key risks for your area of concern/sector?	To identify the key issues of concern to the interviewee
3	From the list of adaptation indicators (in the attached Excel sheet) please highlight (in green) all those you think are of priority to Ireland and that would support evaluation of adaptation actions/suites of actions to address the climate risks and hazards identified above	To aid the prioritisation exercise and help to identify indicators that are prioritised by a number of interviewees
4	From the list of adaptation indicators (in the attached Excel sheet) please provide details of additional potential priority indicators currently not listed that address the climate risks and hazards identified above	To identify any additional indicators not considered that may be relevant to the particular sector, based on the knowledge and experience of the interviewee
5	Do you see adaptation indicators as providing value for monitoring and evaluating climate change adaptation action? Please elaborate	To ascertain the level of interest and engagement of the interviewee with the indicator and MRE process and gain additional insights on their priorities
6	Are there existing goals and targets you want to achieve in your area of interest/expertise that could complement or inform adaptation indicators? If so, can you list some examples?	To identify how indicator identification and selection could complement the interviewee's existing priorities
7	Where do you see adaptation indicators linking between your area of interest and other sectors/interests? For example, connections between biodiversity and flood risk management	To identify existing synergies and working relationships and the potential for additional cross-sectoral collaboration

These indicators were then presented to stakeholders at an online workshop to gain additional feedback and suggestions, and to build understanding around issues of implementation. The interviewee stakeholders were joined by the Project Steering Committee, the project team and a number of academic researchers with expertise in the area. The objectives of this workshop were to:

- present an overview of the project, including the proposed draft indicator suite and the selection process;
- provide participants with the opportunity to validate and/or provide additional feedback on the proposed draft indicator suite in a plenary discussion;
- obtain consensus on the indicator suite and identify key issues for indicator implementation.

The outcome of the stakeholder co-design process led to the selection of the final recommended indicator suite, linked to relevant hazard areas and aligned with their sectoral relevance. The recommended indicator suite is described in Chapter 5 and detailed in Appendix 1.

3 Adaptation Indicators

3.1 Overview of Adaptation Indicators in Europe

Under the research agenda on adaptation and climate change, set out in the European Union's (EU) Green Paper "Adapting to Climate Change – Options for EU Action" (EC, 2007), a recommendation is made to develop indicators to measure the success of adaptation actions. The subsequent White Paper "Adapting to Climate Change: Towards a European Framework for Action" (EC, 2009) reiterates the call to develop adaptation indicators (at EU and Member State level) to improve the monitoring of the impact of climate change, including vulnerability, impacts and progress on adaptation by 2011.

The adoption of the EU Strategy on Adaptation to Climate Change in 2013 (EC, 2013a) is considered a key milestone for European adaptation policy development and implementation. This strategy reports that indicators and monitoring methodologies for adaptation actions were in only the early stages of development. Under Action 1 (of 8) the European Commission encourages all Member States to adopt comprehensive adaptation strategies and recommends the development of adaptation preparedness scoreboards, identifying key indicators for measuring Member States' level of readiness by 2014. Furthermore, the strategy emphasises the criticality of monitoring and evaluating climate change adaptation policies, reporting that the focus (at the time of writing) was still on monitoring impacts rather than adaptation actions and their effectiveness. The strategy also states that the Commission would develop indicators to help evaluate adaptation efforts and vulnerabilities across the EU, using LIFE funding and other sources.

The EU Adaptation Preparedness Scoreboard is an initial pass at determining progress of the implementation of the EU Adaptation Strategy. The first evaluation was carried out in 2017–2018 (EC, 2018b). The exercise provided a high-level overview of adaptation actions across all EU Member States, examining 11 main performance areas across the steps of the adaptation policy cycle.[6] It is important to remark that it should be seen as an initial screening or stocktake of progress to catalyse more far-reaching and bold climate action implementation ambition (EC, 2018a). Each EU Member State produces its own Adaptation Preparedness Scoreboard. This report draws on the information provided in the Irish fiche (Scoreboard report) (EC, 2018c).

A new EU Adaptation Strategy, building on the 2013 strategy, was adopted in early 2021. The blueprint makes the case for further efforts to measure resilience to climate change linked to a more ambitious monitoring and evaluation system (EC, 2020a). The blueprint suggests the development of relevant indicators to help measure adaptation progress that could be comparable across countries with similar types of climate hazards and related adaptation actions and policies.

The next section takes a more detailed look at national climate adaptation indicators in the EU in the light of the policy framework put forward at EU level.

3.1.1 National indicators

In parallel to developments at the European level, progress has also been achieved at the national level. By the end of 2018, from when the last European-wide assessment is available, 28 countries (25 EU Member States, including Ireland, and three EEA member countries) had adopted a National Adaptation Strategy (NAS), and 17 countries (15 EU Member States, including Ireland, and two EEA member countries) had developed a National Adaptation Plan (NAP) (EEA, 2019). Fourteen countries had an MRE system in place or under development, as reported by the EEA in 2017 (EEA, 2015, 2017). In some of these countries, the EU Adaptation Strategy has acted as a springboard for setting up a national strategic framework for adaptation or starting its implementation, as they developed their NAS and/or

6 Steps of the EU adaptation policy cycle: (1) preparing the ground; (2) assessing risks and vulnerabilities to climate change; (3) implementing adaptation action; and (4) monitoring and evaluation.

NAP either in anticipation of or in response to the adoption of the strategy (e.g. Greece, Italy, Poland, Slovakia). Some front-runner countries (UK, Germany, Scotland), however, had started to develop policies and actions in this field much earlier.

A review by the European Commission of National Energy and Climate Plans (NECPs) underscores the importance of integrated energy and climate planning in driving forward the green transition and promoting economic recovery across the EU (EC, 2020b). Indicators are referenced in the NECPs specifically in relation to energy poverty. The development of energy poverty indicators was also listed as a planned measure within the Irish NECP (DCCAE, 2020a). Reference was also made to indicators capturing developments in clean technology. However, the review reported that most plans lack quantitative indicators, making comparisons between countries challenging. The NECP discusses adaptation reporting and the Climate Action Charter for Local Authorities rather than adaptation indicators specifically (DCCAE, 2020a, pp. 22–23).

Although encouraging steps have been made by European countries to move through the stages of the adaptation policy cycle, there is still considerable variation among them. Progress also varies among countries that are at the same stage of the adaptation policy cycle. For example, among the 14 countries with an MRE system in place or under development ("Step 6: monitoring and evaluation" of the adaptation policy cycle) (Table 3.1), the majority of them have focused primarily on aspects of monitoring and reporting, with evaluation of adaptation policies starting only recently, and still in only a few countries (EEA, 2015, 2019).

Although several countries are working on adaptation indicators (e.g. Belgium, Sweden, Spain, Netherlands), and hence new information is expected to become available in the near future, currently only five European countries have an operational set of indicators in place (Austria, Finland, Germany, Scotland and the UK). Uptake of adaptation indicators is challenging for two reasons: (1) the efficacy of indicators is dependent on data, and few countries have statistics agencies with the longevity and robustness of data to construct time series to enable forward predictions of how changes (planned and unplanned) will alter current trajectories; and (2) statistics agencies are set up to report current data and not to anticipate how those data will change in the future, either through elements that alter existing pathways or through elements that represent a change in practice (i.e. society changing behaviour to reduce carbon footprints), and may be unable to in any case (Bours *et al.*, 2014; Shah and Section, 2018). This is because adaptation is essentially alterations and changes to business-as-usual practices at individual and collective levels and across public and private sectors. Moreover, it is difficult to anticipate what the impact will be and how individuals will maintain, or respond to, the consequences of their changes. In the case of European countries, tracking and reporting adaptation policy progress and effectiveness and enhancing learning and accountability have been identified as the main purposes of national MRE systems (EEA, 2015; OECD, 2015). The particular purpose of an MRE system for adaptation often influences the overall approach and specific methods used (EEA, 2015). Countries frequently acknowledge the potential of setting flexible systems, which combine both qualitative and quantitative information from multiple sources, for providing a robust, consistent and contextualised description of adaptation progress. In terms of methods, countries have expressed a high level of preference for including indicators of climate change adaptation in MRE systems, as is reflected in other recent reports on adaptation policies (Hammill and Dekens, 2013, 2014; EEA, 2015; OECD, 2015; Vallejo, 2017).

Regarding the five countries identified by the EEA as having progressed in indicator development, it is useful to analyse them in terms of their indicator development process, the indicator typology adopted, how data needs were addressed, prioritisations and governance framework. Table 3.2 shows a synthesis of information on these issues for the five countries, as drawn from Mäkinen *et al*. (2018), and this can help inform the approach for Ireland.

A key element in the development of the indicator sets in these examples is that a process of co-creation was undertaken, involving policymakers and experts from relevant bodies. Such a process helps to underpin relevance and buy-in across scales, sectors and government both in terms of the selection process and during implementation.

There is no standard typology of indicators adopted across countries. The typology adopted is dependent on the intended goals, the relationship to the national

Table 3.1. MRE systems across a number of European countries

Country	Status of indicator sets and types of indicators being developed
Austria	An indicator system for monitoring and reporting on adaptation for 14 sectors, outlined in the Austrian Adaptation Strategy, has been developed. It includes 45 qualitative and quantitative indicators to monitor the processes, outputs or outcomes of adaptation interventions
Belgium	The measures in the approved Flemish Adaptation Plan (part of the Flemish Climate Plan 2013–2020) are evaluated annually in a progress report. A scale of progress is established for each measure. The future NAP will take a similar approach, with each action linked to qualitative or quantitative indicators. Other, more specific, plans have an in-built monitoring system in which weather events will trigger adaptation measures (e.g. the heat wave and ozone peak plan)
Finland	Evaluations of the NAS (2009, 2013) applied a five-step scale to indicate the level of adaptation in different sectors. There are 24 indicators organised in seven thematic indicator areas. They monitor impact, risk, implementation and decision making
France	Annual monitoring of progress is undertaken for 19 areas and one cross-sectoral theme outlined in the NAP (2011–2015). For each area and theme, an action sheet outlines one to six actions, each comprising several components that must be undertaken in that area, totalling 84 actions and 230 measures. These actions can be broadly categorised as (1) production and dissemination of information, (2) adjustment of standards and regulations, (3) institutional adaptation and (4) direct investment (from OECD, 2015)
Germany	Indicator system for reporting on climate change impacts and adaptation areas outlined (in the NAS). A total of 102 indicators – 97 for impacts and adaptation and five overarching indicators (e.g. awareness of the public, research funding, international funding, funding for municipalities)
Ireland	This report continues the development of climate adaptation indicators, building on work by Kopke *et al.* (2018). Moreover, since 2016 adaptation has been included in the annual transition statement. Adaptation has also been included in all Climate Change Advisory Council annual reviews
Lithuania	The planned MRE system will be indicator based and linked to the NAP (3-year cycle). It will focus on six main sectors. Indicators are likely to be qualitative
Malta	No information available specifically on indicators. Monitoring of the NAS (2012) is conducted through the screening of Malta's National Environment Policy under the sections related to climate change
Netherlands	In total, 41 adaptation indicators (qualitative and quantitative) are under development/consideration, but not all will necessarily be used in the end
Scotland	In total, 105 adaptation indicators were created, linked with themes of natural environment, buildings and infrastructure networks, and society. The system was established in 2016 to inform and analyse risks identified for Scotland in the UK's Climate Change Risk Assessment and show progress towards objectives set out in Scotland's Climate Change Adaptation Programme
Slovakia	Slovakia is in the process of developing adaptation indicators
Spain	Spain is in the process of developing an impact, vulnerability and adaptation indicator system
Switzerland	Switzerland is not planning to develop any new indicators, but is planning to use existing datasets that provide information on adaptation and/or the development of climate-related risks or vulnerabilities. The status of indicators varies between sectors in the adaptation strategy (some are completed, some are in development, some sectors have not started to determine indicators)
UK	As part of its statutory role to evaluate the progress of the National Adaptation Programme, the UK Committee on Climate Change has developed a set of 118 indicators focused on vulnerability, exposure and actions rather than impacts. These indicators are complemented by research and analysis undertaken by an adaptation sub-committee and presented in the evaluation report and previous non-statutory progress reports

Source: Compiled from information in EEA (2015), Climate-ADAPT (2020a) and Mäkinen *et al*. (2018).

policy landscape and the adaptation frameworks in place in each country. Nonetheless, there is generally a mix of impact indicators, implementation indicators and outcome indicators. The new EU Adaptation Strategy (2021) may see the beginning of alignment between typologies of national systems (EC, 2020a).

In general, the indicator sets chosen are based on existing data, and available data tend to be a mix of quantitative and qualitative information. There is a reluctance to propose the collection of new data, and this is evident from the MRE systems presented in Table 3.1. The preference is to repurpose data already collected for other reasons, limiting the need for additional resources for new data collection.

The selection of the indicator sets relies to some extent on pragmatic decisions related to data availability, alignment with other evaluation frameworks and the potential of the indicators to allow assessment of progress. In all cases revisions of the indicator sets are envisaged, so it is seen as better to get a

Table 3.2. Selected key aspects in indicator selection across five European countries

Country	Development process	Indicator typology	Data needs	Prioritisations	Governance framework
Austria	Literature review, followed by expert knowledge, including stakeholder workshops and interviews	Adaptation process, output and outcomes	Use of existing data already in use for other reasons	No prioritisations reported, but in 2020 a revision and update of the initial 2014 set was to take place	Part of the MRE for the NAS and NAP, which also includes self-assessments
Finland	A participatory process with more than 50 experts. Consultations with data providers and other stakeholders	Impact indicators, risk indicators, implementation and decision-making indicators	Availability of well-established data sources was a key selection criterion	Existing data sources; transparency and comprehensibility across sectors; connections with sustainable development indicators. Iterative process	NAS/NAP in place but indicators not aligned to structure of NAP. Focused on key climate impacts and risks for Finland
Germany	A participatory process with experts from agencies and scientific and private institutions. Cooperates with Ministry of Environment and Environment Agency	Impact indicators, response indicators, over-arching indicators	Existing data to be used	No prioritisations reported, but data availability is a prerequisite and, if possible, adaptation measures should already be under way	Report every 4 years, through indicators, on progress in implementing the NAS
UK	An adaptation sub-committee, within the statutory committee on climate change, led development of the indicator set, drawing on experience in developing other environmental indicator sets	Vulnerability, exposure and actions for four identified priority areas	Reliable data available	Ability to track trends; ability to provide robust assessment of vulnerability or exposure to a climate risk, actions in place or impact	Every 2 years, used in report on national progress on adaptation to climate change
Scotland	A participatory process with experts from agencies and academia; also included policymakers	Indicators of risk and opportunity, indicators of impact and indicators of adaptation action	Spatial and non-spatial quantitative and qualitative data at varying scales	No prioritisation reported but fits within an indicator framework devised for the country	Annual reporting on progress

system and set of indicators in place and, through an iterative approach, review, fine-tune and update them. In all cases the selection and implementation of a set of indicators lies within a policy and governance framework, which requires regular reporting, thereby ensuring that there is accountability and an ongoing assessment of both the indicator measures and the utility of the indicators themselves.

3.1.2 Pan-European indicators

The evaluation of the EU Adaptation Strategy highlights areas for improvements in the next iteration of the strategy and includes a number of references to indicators. In terms of coherence, the evaluation highlights the opportunities to link with global developments such as the Sustainable Development Goals, the Sendai Framework on Disaster Risk Reduction and the Convention on Biological Diversity. All of these have developed sets of indicators, some of which are highly relevant to monitoring progress in climate adaptation. The report also calls for aligned societal indicators to map the socio-economic impacts of climate change and adaptation policies, in other words outcomes of policy implementation. It says that climate adaptation impact and outcome indicators have been built into the next iteration of the Common Agricultural Policy, given the significant EU budget allocated to agriculture. This should help facilitate cross-policy coherence.

At the municipality level, across the EU, an interesting and relevant development has been the establishment of the Mayors Adapt commitment (Climate-ADAPT, 2020b). This voluntary commitment seeks to engage and support cities in adapting to climate change and was launched in 2014. As of 2020, nine Irish local authorities across Dublin, Cork and Limerick have signed up to the Mayors Adapt climate adaptation action plan. As part of its monitoring and reporting framework, which was developed in collaboration with practitioners from local and regional authorities, a set of indicators is incorporated. These are divided into three major subsets: vulnerability, impact and outcome indicators. Table 3.3 shows the categories or sectors included in each subset of indicators. The full set of indicators can be accessed through the Mayors Adapt reporting guidelines (Covenant of Mayors, 2016).

Nineteen vulnerability indicators were selected, covering climate vulnerability, socio-economic vulnerability and physical and environmental vulnerability. The climatic indicators are related to temperature and precipitation, the socio-economic indicators attempt to highlight marginal and vulnerable population groups, and the physical and environmental indicators focus on land use, transport infrastructure and resource use, such as water availability and energy consumption.

The 24 impact-related indicators are wide ranging and are linked to specific socio-economic sectors such as infrastructure, land use planning, health, environment, agriculture and tourism. For example, there is an indicator quantifying damage to infrastructure due to extreme weather; a health indicator capturing deaths due to extreme weather; an agricultural indicator looking at changes in water abstraction; and a tourism indicator looking at changes in tourist flows.

The 23 outcome-related indicators are also linked to sectors, with some of them cross-cutting, but there is no clear connection from specific impact indicators to the outcome indicators. For example: under *Land use and planning* some indicators look at sealed surfaces and connected green and blue areas; under *Water* there is an indicator for quantifying the change in storage of rainwater; and under *Agriculture and forestry* changes in crop yield as a result of adaptation measures are captured. Cross-cutting indicators include the number of awareness-raising events and levels of investment in adaptation research, for example.

All of the Mayors Adapt indicators are quantitative in nature and require the availability of comprehensive and up-to-date datasets and, in some cases, projections to be calculated. A strength of the Mayors Adapt initiative is its combined approach to capturing mitigation and adaptation actions at a city scale. As the initiative provides a wide range of freedom in terms of indicator creation, this also allows flexibility and the design of indicators specific to the needs and issues of cities/local authorities. However, this same flexibility makes a detailed comparison of indicators between cities/local authorities challenging.

Table 3.3. Typology of indicators used by Mayors Adapt signatories

Vulnerability type indicators	Impact-related indicator sectors	Outcome-related indicator sectors
Climatic	Buildings	Buildings
Socio-economic	Transport, energy, water, waste, ICT	Transport, energy, water, waste, ICT
Physical and environmental	Land use planning	Land use and planning
	Health	Environment and biodiversity
	Civil protection and emergency	Agriculture and forestry
	Environment and biodiversity	Tourism
	Agriculture and forestry	Other
	Tourism	
	Other	

ICT, information and communications technology.

3.2 Overview of International Adaptation Indicators

An overview of international adaptation indicators is presented here to complement the review of indicators in Europe. This provides insights on indicator development and implementation in a number of countries with differing socio-economic situations and at various stages in relation to climate adaptation policy and action. Examples are taken from the USA, Canada and a number of countries in Africa and the Pacific region.

3.2.1 USA and Canada

The US Environmental Protection Agency released the fourth edition of its climate change indicators

report in 2016 (US EPA, 2016). The report focused on climatological indicators, listing 37 indicators capturing changes observed from long-term records related to the causes and effects of climate change. Indicators are categorised under weather and climate, oceans, snow and ice, and greenhouse gases. The report also examines the connections between climate change and human health, providing seven indicators reporting on heat-related deaths, heat-related illness, heating and cooling degree days, reported rates of Lyme disease, reported rates of West Nile virus, length of growing season, and changes in length of ragweed pollen season. The US EPA reporting also includes seven indicators that examine impacts of climate change on ecosystems: wildfire extent, changes in stream flow, changes in stream water temperatures, water levels in the Great Lakes, changes in bird wintering ranges, changes in marine species' distribution, and first leaf and bloom dates. All of the US EPA's indicators are based on publicly available data from government agencies, academic institutions and other organisations. The US EPA screened and selected each indicator using a standard set of criteria that considers usefulness, data quality and relevance to climate change.

There appears to be no set of dedicated indicators for climate change adaptation at the federal level within the USA. However, states and counties are responsible for developing climate change adaptation plans. For example, in Oregon State, an update to its Climate Change Adaptation Framework completed in 2021 includes a recommendation to develop and monitor a set of adaptation indicators (Oregon.gov, 2021). Similarly, in California's Climate Adaptation Strategy (California Natural Resources Agency, 2018) the need for indicators, or metrics as they are called in the document, is highlighted. The report calls for metrics to monitor changing climate conditions and to track the performance of specific plans or investments, in terms of both resilience to climate change and meeting management objectives. These could be considered impact and implementation indicators, respectively. The impact metrics address climatic, socio-economic (including health) and physical (built and natural) environment aspects. The implementation indicators focus on policy and actions across a wide number of sectors, including agriculture and forestry, water, coasts, urban areas and transport infrastructure, and cross-cutting issues such as training on adaptation planning and agencies that have achieved sustainability. The health impacts of climate change is a recurring theme in the above-mentioned federal and state frameworks and plans, and, in a study carried out in the US Pacific Northwest (Doubleday *et al*., 2020), a set of climate change adaptation health-related indicators were proposed. These encompass climatic indicators, such as frequency of extreme events and related impacts, for example morbidity and mortality, and implementation indicators, such as the number of partnerships with other agencies and bodies and assessment of risks to health infrastructure. Many of the proposed indicators focus on implementation or measurement of actions, with no evident highlighting of outcome-type indicators.

In Canada in 2017, an Expert Panel on Climate Change Adaptation and Resilience Results was charged by the federal government to advise it on measuring overall progress on adaptation and climate resilience (Government of Canada, 2018). As part of its mandate the Expert Panel was asked to recommend a suite of indicators to measure progress on adaptation and climate resilience in Canada. The panel proposed 54 indicators across five key areas identified in Canada's framework to address climate change, build resilience and grow the economy (Government of Canada, 2016). Similarly to the USA, indicators related to human health and well-being are a key priority. There is a set of indicators focused on more vulnerable regions and, interestingly, these address slow-onset impacts, such as coastal erosion. Another set of indicators is more related to extreme weather events such as flooding. There are indicators to determine the resilience of infrastructure, in which the concept of infrastructure is all encompassing and includes traditional, cultural and natural, new, existing, critical and non-critical infrastructure. The final set of indicators measures how effectively both scientific information and traditional knowledge are being used to address climate adaptation issues. This set of indicators has the ambition to address issues of inclusiveness and the incorporation of potentially marginalised communities.

This final recommended suite includes both qualitative and quantitative indicators required to "reflect the complexities and uncertainties inherent in climate change impacts and adaptation" (Government of Canada, 2016, p. 14). The Expert Panel advises that the recommended indicators can be used to measure

aspects of process, outputs or outcomes that stem from monitoring adaptation.

The report also outlines a monitoring and evaluation programme that aims to evaluate the effectiveness of adaptation action in reducing climate change vulnerability and risk. Their six-step monitoring and evaluation process covers:

1. purpose and context;
2. development of indicators;
3. data collection;
4. data analysis and evaluation;
5. communication of results;
6. continual improvement.

3.2.2 Africa

The 2018 report *Climate Change Adaptation in Africa: UNDP Synthesis of Experiences and Recommendations,* published by the United Nations Development Programme (UNDP), provides a valuable snapshot of adaptation actions carried out over 15 years across Africa, including the development and use of adaptation indicators (UNDP, 2018). The report discusses indicator use in a number of case studies across the continent. Based on its analysis, the UNDP outlines a framework that African countries should use to guide their climate adaptation. It calls for improved technical and analytical skills in order to have the critical mass of people to generate pertinent data; it also highlights the need for co-creation through stakeholder engagement, the need to involve the private sector and business entities, the need to embed adaptation actions into policy, and the need to produce appropriate technical information to inform policymaking and planning. The need for indicators is associated with the monitoring framework required in the policy development and implementation steps.

In a case study related to Rwanda and the Comoros Islands (off the coast of Mozambique), the focus for adaptation indicators was on quantifying vulnerability. Levels of vulnerability were ascertained at a household or community level based on self-assessment by community members. Such an approach encountered issues of understanding and the ability to assess one's own situation, and it highlights the challenges of communicating complex issues about climate change and adaptation to the general public.

In Malawi, the UNDP is working with local and regional government to generate and implement adaptation indicators to screen development project proposals to ensure that proposals will be accepted only if they promote adaptation to climate change. At a district level, locally appropriate adaptation indicators will be developed and tied to budget allocation to incentivise the roll-out of adaptation initiatives in development planning. Such indicators could be considered implementation indicators. This approach attempts to ensure that future developments are climate proofed and can also help in ensuring policy coherence across sectors.

South Africa's Climate Change Adaptation Strategy (Department of Environment, Forestry and Fisheries, 2019) incorporates a monitoring and evaluation system that is predicated on tracking progress. To achieve this, it envisages a set of indicators to highlight progress on each of 12 strategic outcomes. Furthermore, it identifies the data and information needed to determine progress and it proposes a traffic light system to evaluate progress. Such an evaluation system allows easier incorporation of qualitative outcomes, as well as quantitative ones, and is a pragmatic approach to dealing with data gaps.

3.2.3 The Pacific

The Secretariat of the Pacific Regional Environment Programme (SPREP) and UNDP publication *Mainstreaming Climate Change Adaptation in the Pacific: A Practical Guide* provides an excellent overview of how Pacific Island nations are integrating climate change risks into their national and sectoral strategies and plans and their budgetary processes (SPREP and UNDP, 2013).

In case study islands (Cook Islands, Nauru, Tonga, Tuvalu and Vanuatu), the approach is associated with reducing the vulnerability of populations by focusing on both improving livelihoods and environmental management. To achieve this, there is a drive to improve adaptive capacity in terms of human, financial, physical and natural resources by implementing adaptation measures that will reduce climate hazards and also have benefits across other areas.

A series of indicators identified for monitoring and evaluation of adaptation actions at a strategic level by UNDP-GEF (Global Environment Facility) were categorised under coverage indicators, impact indicators, sustainability indicators and replication indicators. An example of each can be found below:

- coverage – policies, plans or programmes introduced or adjusted to incorporate climate change risks;
- impact – stakeholders' behaviours in using adjusted processes, practices or methods for managing climate change risks, assessed by questionnaire-based surveys or other evidence;
- sustainability – availability of skills and resources necessary to continue adaptation after conclusion of project (at relevant scale);
- replication – the number of relevant networks or communities with which the lessons learned are disseminated.

The coverage and replication indicators could be considered to be measures of implementation of policies, while sustainability indicators tend to measure longer-term outcomes of actions taken.

Another informative example of a national adaptation plan is the Kiribati Joint Implementation Plan for Climate Change and Disaster Risk Management, which was launched in 2019 (Government of Kiribati, 2019). The plan contains 330 climate adaptation actions aligned with existing national priorities. Each of the actions has associated performance-based indicators that combine both qualitative and quantitative information. The monitoring and evaluation framework set out in the plan details over 200 indicators associated with actions across 12 strategies. The 12 strategies are related to strengthening good governance, improving relevant information generation and management, improving resilience across key sectors, including water, food, energy, infrastructure and emergency response, and capacity building and encouraging co-creation through stakeholder engagement and partnerships.

The indicator set is extremely comprehensive and covers a range of climate impacts, implementation and outcomes. Interestingly, there is a strong focus on education, engagement with marginalised and vulnerable groups, and considerations of gender issues across the range of actions. Indeed, one of the actions is to develop a gender sensitivity indicator as part of the inclusiveness strategy.

In 2014, New Zealand's Massey University developed a series of environmental health indicators for New Zealand (EHINZ, 2020). Climate change and human health were included among the environmental indicator suite measures that are being used by the New Zealand Department of Health. Health impacts of climate change were considered under three headings:

1. direct (including physical injuries or death caused by extreme events);
2. indirect (focused on effects occurring when a changing climate alters biological processes, such as water-borne diseases or respiratory problems);
3. diffuse (health effects that happen when people need to substantially change their lives as a result of climate change, such as mental health issues associated with displacement due to sea level rise).

In addition, climatological indicators related to temperature and precipitation measures are used in relation to determining health impacts.

In 2016, the New Zealand government established an adaptation technical work group, comprising experts from the private and public sectors, to provide coordinated expert guidance on how New Zealand could best adapt to the effects of climate change (Ministry for the Environment, 2020). The government's 2018 report makes a number of recommendations on monitoring and reporting for adaptation actions (Ministry for the Environment, 2018). It recommends the use of adaptation indicators co-designed by physical and social science experts, indigenous groups and adaptation practitioners. Furthermore, it recommends that central and local governments include climate change in their performance management through the use of performance indicators. This is highlighted as of particular importance in developing consistent, climate-related financial disclosures useful to investors, lenders and insurance underwriters in understanding material risks. Finally, it recommends that measures that reflect the impacts of climate change on the indigenous (Maori) people are reflected in cultural indicators. Cultural indicators of climate change can be used to more deeply understand climate change

impacts and lead to indigenous adaptations at a local level.

3.3 Lessons Learned from the Literature

3.3.1 Frameworks for indicators

An MRE framework, as part of the bigger picture within climate adaptation policy, is a prerequisite for the development and implementation of adaptation indicators. However, the existence of a framework is not of itself sufficient to ensure that evaluation of adaptation policy and actions takes place. Often only monitoring and reporting is carried out, as evaluation is a more complex task. Nonetheless, building in an evaluation component is vital to determine the success or otherwise of policies and actions and to facilitate updates and improvements where necessary. Although an important characteristic of adaptation indicators is their consistency and longevity, because this allows for comparability tracking from a baseline, any indicator suite should allow for revision and evolution. For example, national adaptation plans and frameworks are normally revised every 3–7 years to capture updates in scientific knowledge and to permit the amendment or escalation of adaptation actions as deemed necessary. This iterative process can offer an opportunity to revise, update, or replace adaptation indicators in line with shifting climate risks or impacts. To facilitate this process, an MRE framework should ideally include adaptation indicators that are linked to, or reflective of, adaptation actions as set out in national adaptation plans and frameworks.

An impactful MRE framework also includes regular reporting protocols and responsibilities. Indicator reporting is documented in the reviewed frameworks to take place every 1–4 years. This reporting process can also include ongoing self-assessment and iteration, as discussed above. Reporting responsibilities are formalised within national adaptation strategies, frameworks or plans and are ideally made legally binding under the umbrella of appropriate climate legislation.

3.3.2 Indicator typologies

The vocabulary used to describe indicator typologies varies across countries, yet common threads can be identified. Climatic indicators, which capture the state of an evolving climate, tend to underpin almost all of the systems in place. Measures that capture vulnerability in socio-economic, built and natural environment systems are common across countries. Impact indicators are widely used to quantify the effects of climate change across sectors and communities. Implementation or action indicators are extensively used to track progress in implementing adaptation policy and specific actions. They tend to capture processes. Outcome-related indicators are not as widely used, as it can be more difficult to identify specific changes due to the implementation of climate adaptation actions alone, as there may be cross-over with other policy areas. Yet they are vital elements of any evaluation system, as they inform on the success or otherwise of any actions taken.

Although the majority of indicators tend to be quantitative in nature, the concomitant use of qualitative indicators is advocated. These can help complete the stories in relation to climate adaptation needs and effects and they can also help inform us in the absence of suitable information to construct quantitative indicators. In one case study analysed, the use of a traffic light system was proposed, which can help to indicate levels of progress even in the absence of specific quantitative information. This combination of qualitative and quantitative indicators can therefore increase the comprehensiveness or coverage of an indicator suite.

3.3.3 Sectors addressed

In most countries indicators are aligned with sectoral priorities, which usually cover a full range of socio-economic areas. In a number of instances the health sector is highlighted, as it is often related to more vulnerable populations, where there can be more severe impacts, especially during extreme weather events. In most instances there is a selection of cross-cutting indicators, which are independent of specific sectors but may be related to training, communications, sustainability and partnerships, among other things.

The indicator development and implementation process can also foster complementarity and build important links between sectors in terms of sharing of information and understanding of common climate hazards and impacts that cascade across a range of

sectoral areas. The use of cross-cutting indicators can tease out and capture these connections.

3.3.4 Data requirements

The academic and policy literature documents the need for quality, reliable and long-term data to calculate indicators (McCarthy *et al*., 2012; EEA, 2017; Shah and Section, 2018). Given the cost and resource requirements of initiating new data collection schemes, the use of existing datasets is favoured. Such data may be collected for reasons other than climate monitoring, but can be repurposed and used as part of a climate adaptation reporting and evaluation system. However, in some cases the collection of new data may need to be contemplated. The challenges of and resources required in setting up such an observational programme on a sustainable basis should not be underestimated. Furthermore, the robustness and reliability of both existing and new data are important considerations when developing indicators. An evaluation of fitness for purpose of the datasets identified needs to be carried out prior to potential implementation.

Data, a combination of spatial and non-spatial and quantitative and qualitative in nature, should be easily accessible and usable. The scale of the data employed for indicator calculation should be appropriate – often the challenge is in securing good-quality data at local scale. Access to data may require buy-in and support from relevant agencies, where an identified need for a specific indicator can make the case for data sharing. Tapping into existing relationships and networks can also facilitate data access and sharing. For example, existing relationships between research institutions and government departments or agencies can help to facilitate data-sharing agreements. Nonetheless, it is vital to identify and clarify data flow pathways and responsibilities as well as putting in place any data-sharing agreements that may be required. This will help in minimising data gaps and avoiding duplication and misunderstandings between the organisations involved.

3.3.5 Stakeholder engagement and communication

The participation of stakeholders and the need to communicate indicator findings are vital in the design and implementation of an adaptation indicator suite (Bours *et al*., 2014; Vallejo, 2017; Doubleday *et al*., 2020). Relevant stakeholders identified include government departments, state agencies, academic researchers, communities, the private sector and civil society. Established best practice is to engage stakeholders in a co-design process in which their expertise and on-the-ground experience is used to help shape and select adaptation indicators (Bours *et al*., 2014; Street and Jude, 2019). The process can be coordinated by engagement with an expert panel or committee established for the specific purpose of adaptation indicator development. Community engagement is highlighted both in developing world contexts and in countries with significant indigenous groups where documenting community needs, relating to livelihoods, can help to shape adaptation actions and in turn help to shape adaptation indicators. Private sector stakeholder involvement can help provide important insights into financial risks, for example; however, public disclosure of private sector risks can prove challenging because of the sensitivity of information from a business competition perspective.

Communication of indicator values or findings plays an important role in documenting climate impacts and adaptation actions and outcomes for a range of audiences, from policymakers to sectors, local governments and the general public (Mäkinen *et al*., 2018; Street and Jude, 2019). The need for capacity building is also highlighted (Street and Jude, 2019). Messaging should be clear and concise to provide an overview or snapshot of climate impact and adaptation actions and outcomes, as well as tracking developments across time. Timely communication can help foster a culture of transparency, document present or future risks, and increase the visibility and uptake of indicators. In this way communication can help to clearly provide the evidence needed to support appropriate adaptation responses, including the allocation of funding and personnel.

4 Informing Indicator Selection for Ireland

Indicator selection in Ireland is informed by a series of interrelated issues, including policy context and the need for coherence; alignment with other relevant indicators, both nationally and at the European level; issues of scale, from local to national to European; the availability and management of data; and best practice from other jurisdictions that have already been through the selection process.

4.1 Irish Policy Context

In 2009, Irish climate adaptation policy development received impetus from the publication of the European Commission's White Paper entitled "Adapting to Climate Change: Towards a European Framework for Action" (EC, 2009). As a result, the Department of the Environment, Community and Local Government drafted the non-statutory National Climate Change Adaptation Framework in 2012 (DECLG, 2012) (Figure 4.1).

The *National Policy Position on Climate Action and Low Carbon Development* (DCCAE, 2014) restated the importance of ensuring that appropriate adaptation measures are implemented and set out the need for a clear mandate for government departments, agencies and local authorities to develop and implement sectoral and local adaptation plans. The Climate Action and Low Carbon Development Act 2015 (hereafter the 2015 Climate Act) set out the legal basis for Ireland's climate policy framework, designed to deliver the overall vision of a transition to a carbon-neutral, low-emission and climate-resilient society and economy by 2050 (Government of Ireland, 2015). The subsequent

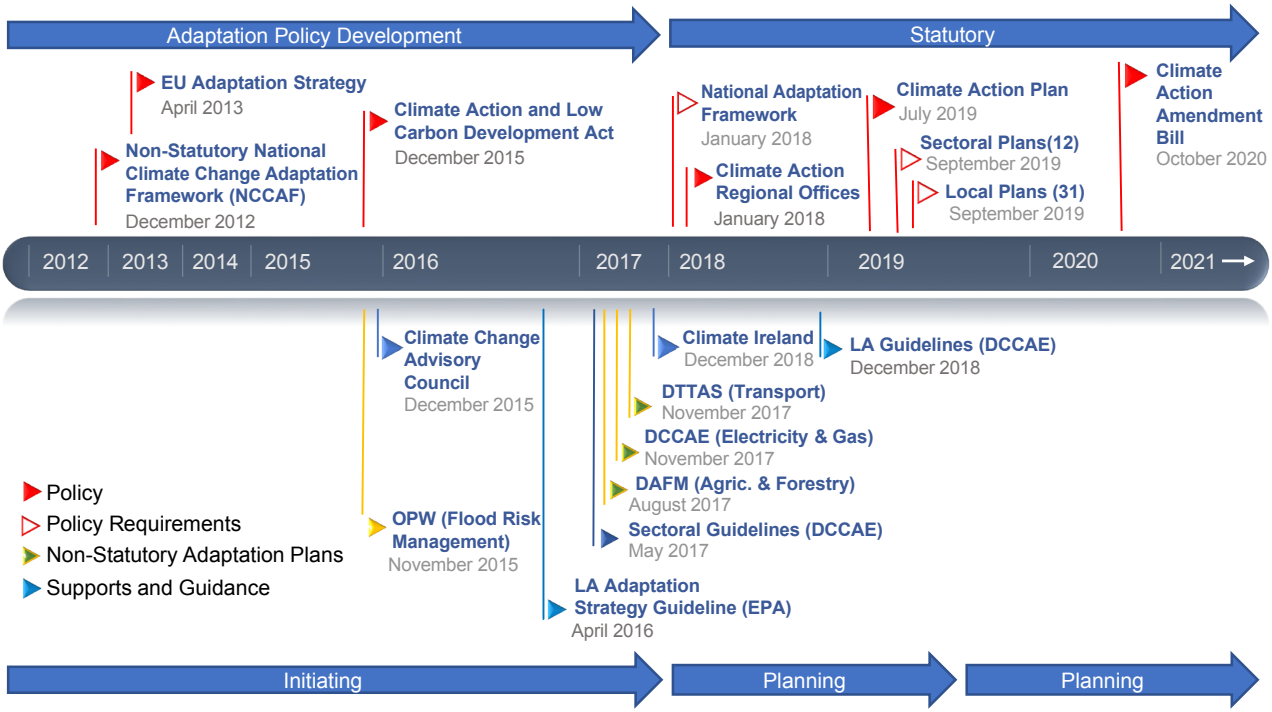

Figure 4.1. Evolution of Irish climate policy. DAFM, Department of Agriculture, Food and the Marine; DCCAE, Department of Communications, Climate Action and Environment; DTTAS, Department of Transport, Tourism and Sport; LA, local authority; OPW, Office of Public Works. Note: this research considered the Draft Climate Action and Low Carbon Development (Amendment) Bill 2020, which has since been amended and re-published. Please refer to the Climate Action and Low Carbon Development (Amendment) Bill 2021 (https://www.gov.ie/en/publication/984d2-climate-action-and-low-carbon-development-amendment-bill-2020/).

NAF, published in 2018, provides a strategic policy focus to ensure that adaptation measures are taken across all sectors and levels of governance to increase Ireland's preparedness for, and reduce its vulnerability to, impacts of climate change (DCCAE, 2018a). The NAF seeks to build long-term[7] resilience to climate change impacts through adaptation planning and by considering Ireland's more immediate responses to the shorter-term impacts of climate change. The NAF also outlines the need for developing climate change indicators to support the monitoring and evaluation of climate actions. The NAF must be reviewed by December 2023 at the latest.

In October 2020, the Climate Action and Low Carbon Development (Amendment) Bill was published (DECC, 2020).[8] The Amendment Bill strengthens the 2015 Climate Act by establishing carbon budgets and improving oversight through a climate action council. Although the main focus of the amendments covers mitigation, there will be some impact on the existing regulatory framework for adaptation. For example, annual revisions of the Climate Action Plan will potentially lead to greater ongoing consideration of adaptation measures at national level. The Bill also introduces a requirement for all local authorities to prepare individual climate action plans that incorporate mitigation and adaptation measures. It also gives a stronger oversight role for the Oireachtas through an Oireachtas Committee.

Established under the 2015 Climate Act, the Irish Climate Change Advisory Council (CCAC), is an independent body tasked with assessing, and advising on, how Ireland is to make the transition to a low-carbon, climate-resilient and environmentally friendly economy. The CCAC provides contributions in the form of critiquing, informing and shaping Ireland's response to climate change (CCAC, 2020a). The Council also contains a non-statutory adaptation sub-committee to specifically consider matters relating to climate change adaptation. Under the Climate Action and Low Carbon Development (Amendment) Bill 2020 (DECC, 2021), it is proposed to give additional powers to the CCAC to provide for carbon budgets and a decarbonisation target range for certain sectors of the economy, to provide for reporting by government Ministers to a joint committee in relation to climate, and to provide for local authority climate action plans. The CCAC in its most recent annual report (CCAC, 2020b) notes that the lack of an agreed set of indicators is a weakness in relation to progressing the Climate Action Plan and the NAF. It recommends the establishment of an agreed set of indicators for assessing policy effectiveness. Moreover, it calls attention to the importance of this PCAS project in helping to establish a robust set of climate adaptation indicators for adoption by government.

In 2018, under the NAF, the Department of Communications, Climate Action and Environment (DCCAE) established the CAROs. The CAROs are tasked with enabling more coordinated engagement across the whole of government and providing for vertical and horizontal integration of adaptation considerations, with funding of €10 million provided for an initial 5-year period. Their establishment further acknowledges the important role that local authorities play in planning for and implementing climate adaptation actions. The Climate Action and Low Carbon Development (Amendment) Bill 2020 charges local authorities with developing local authority climate action plans that specify both mitigation and adaptation measures. These are to be updated on a 5-yearly basis. CAROs will also have a role in supporting local authorities with their plan development.

In July 2019, the Irish government released the Climate Action Plan, setting out a series of actions to achieve adaptation and mitigation targets (Government of Ireland, 2019a). The plan focuses on mitigation targets; however, it does outline three specific adaptation actions:

1. build sectoral resilience to the impacts of climate change through delivery of sectoral plans, as required under the NAF (Action 181);
2. build local/regional resilience to the impacts of climate change through delivery of local authority

7 When considering the immediacy of climate risks, the following timescales are employed in this report: short (< 5 years), short to medium (6–20 years), medium to long (21–50 years) and long (> 50 years).

8 Note: this research considered the Draft Climate Action and Low Carbon Development (Amendment) Bill 2020, which has since been amended and re-published. Please refer to the Climate Action and Low Carbon Development (Amendment) Bill 2021 (https://www.gov.ie/en/publication/984d2-climate-action-and-low-carbon-development-amendment-bill-2020/).

adaptation strategies, as required under the NAF (Action 182);

3. put in place arrangements to ensure that Climate Ireland is developed to its full potential as an operational support for climate adaptation and climate action in Ireland (Action 183).

By the end of 2019, 12 sectoral adaptation plans and 31 local authority adaptation strategies had been completed. The local authority adaptation strategies and the sectoral plans were developed in parallel, which may have limited the opportunity for cross-sectoral consultation and collaboration during their development. However, it should be acknowledged that the National Adaptation Steering Committee encourages cross-sectoral consultation where possible. Implementation of the Climate Action Plan, which will be updated each year by the government, is monitored by a Climate Action Delivery Board that reports quarterly on the implementation of the Plan and annually on barriers, challenges and key lessons. The Board is jointly chaired by the Secretary General to the Government and the Secretary General of the Department of the Environment, Climate and Communications (DECC).

The CCAC provides independent expert advice to the government, and the Climate Action Delivery Board's focus is on monitoring implementation rather than the evaluation of climate policy in practice. With the establishment of the CCAC, the Climate Action Delivery Board, CAROs and annual reporting on the most recent approved climate action plan in person by sectoral government Ministers, the key governance institutions and policy structures are in place to support the implementation, monitoring and evaluation of climate adaptation objectives, as set out in the NAF and supported by the 2015 Climate Act. Consideration needs to be given to how climate change adaptation indicators fit into this governance framework and support the delivery of climate action objectives. Moreover, consideration should be given to the frequency of indicator reporting to ensure that the process is not overly onerous. Annual reporting on indicators may not be optimal in terms of measuring progress across slow-moving variables, as meaningful patterns may only emerge after a number of years. For example, the UK reports on its climate change adaptation indicators every 2 years and Germany reports every 4 years.

4.2 Aligning with Other Relevant Indicator Sets and Reporting Requirements at EU and National Levels

From 2021 onwards the European Commission's Energy Union and Climate Action Regulation requires detailed reporting on adaptation actions to be submitted every 2 years by Member States, including updates on progress made on implementation, adaptive capacity and monitoring and evaluation (EU, 2018). This also includes detailed reporting on climate hazards, impacts and actions taken at sectoral level. These ongoing requirements for reporting to the EU strengthen the case for using national adaptation indicators to support and streamline this process. There is an existing requirement to report on adaptation measures as part of the national communications required by signatories to the UNFCCC, although specific indicators are not required (DCCAE, 2018b). Furthermore, a global stocktake on mitigation and adaptation actions under Article 14 of the Paris Agreement is scheduled for 2023 and is recommended to be carried out every 5 years (UN, 2015). Currently, the DECC holds responsibility for reporting on behalf of the Irish government. Alignment of this process with the European Commission's Energy Union and Climate Action Regulation reporting requirements could reduce reporting burdens.

Climate change adaptation should not be carried out in isolation from other policy areas. It is necessary to exploit synergies and avoid implementing actions in one area that may have undesired consequences in another. Indicators can help in the monitoring of such processes. Nationally, climate change adaptation indicators have the potential to provide policy co-benefits. For example, there are strong potential co-benefits between enhanced monitoring of climate change adaptation and emergency planning, where increasing linkages and integration between the two agendas is considered best practice internationally (Solecki *et al*., 2011; Siders, 2016; Banwell *et al*., 2018). There are also clear connections between climate change adaptation and sustainable development, in the context of developing green infrastructure and sustainable planning (EC, 2013b, 2019a; Government of Ireland, 2018).

Addressing climate change is identified as one of Ireland's highest strategic priorities within the

government's National Risk Assessment (Government of Ireland, 2019b). The importance of better alignment between emergency planning and climate change adaptation is also identified in the NAF and in the 2020 CCAC Annual Review (DCCAE, 2018a; CCAC, 2020b). At the end of 2020, the Office of Emergency Planning published *Strategic Emergency Management (SEM) Guideline 4 – Climate Change Adaptation* (Government of Ireland, 2020). The guidelines, drafted by the DECC, provide a high-level overview of adaptation policy, climate change impacts and adaptation resources available at national level, which are aimed at lead government departments under the Strategic Emergency Management National Structures and Framework. An ongoing EPA-funded project (Enhancing Integration of Disaster Risk and Climate Change Adaptation into Irish Emergency Planning)[9] is also examining this topic and aims to contribute to the research by providing examples of best practice from case studies, as well as examining challenges and opportunities in the integration of climate change adaptation and disaster risk management (DRM) into Irish emergency planning. In addition, sustainable development, through implementation of the European Commission's 2013 strategy – "Green Infrastructure: Enhancing Europe's Natural Capital" (EC, 2013b) – is also highly relevant to climate adaptation action and DRM as framed in the European Green Deal (EC, 2019b). The restoration of biodiversity is a central plank in Europe's vision to become a disaster-resilient, climate-neutral continent. As noted in the Green Infrastructure Strategy, ecosystem-based approaches provide means and measures that harness the adaptive forces of nature, and are widely applicable, economically sound and effective tools to combat the impacts of climate change (EC, 2013b; EC, 2019a). It is vital that indicators used for reporting on climate change adaptation and biodiversity restoration are aligned and complementary to ensure coherency in policy actions.

Climate change adaptation indicators can also function as indicators for DRM (United Nations Statistics Division, 2014). For example, impact indicators focused on pluvial and fluvial flooding provide important information for emergency response management and DRM. It has been noted internationally, and by the Department of Finance in Ireland, that mobilisation of financial resources to support climate change adaptation and DRM in a coordinated manner would lead to a more efficient use of funds (United Nations Climate Change Secretariat, 2017; Greene *et al*., forthcoming). Currently, a number of indicators associated with DRM are in development by the Irish Central Statistics Office, in collaboration with Ireland's Hub for Sustainable Development Goals[10] and Met Éireann (CSO, 2020). Initial scoping work has been carried out to develop indicators that document the number of deaths by natural disasters and economic losses attributed to disasters. The work was informed by participation in a United Nations Economic Commission for Europe Task Force on Measuring Hazardous Events and Disasters. The next step in the process will be calculating the costs of each event by analysing media and insurance reports, and advances in this area should be considered in relation to climate change indicator development.

The National Biodiversity Data Centre has developed a series of national biodiversity indicators to support the Aichi Biodiversity Targets[11] (Biodiversity Ireland, 2020). Thirty-two headline indicators are supported by 71 sub-indicators (National Biodiversity Data Centre, 2019). Eight focal areas were identified for the indicators, including two areas that relate to climate change impacts and adaptation: (1) threats to biodiversity; and (2) benefits derived from biodiversity and ecosystem services. Many of the indicators[12] reported under these focal areas are relevant to climate change adaptation and can capture the impacts of climate change by proxy, i.e. as an indirect measure that captures climate impacts in the absence of a direct attribution. However, further research is needed to differentiate climate drivers from those of habitat loss or other biodiversity stressors.

Strong connections should also be made between climate change adaptation indicators and sustainable

9 See: https://www.marei.ie/project/integration-disaster-risk-climate-change-adaptation/ (accessed 10 May 2021).

10 See: https://irelandsdg.geohive.ie/ (accessed 10 May 2021).

11 In 2010, leaders from 196 countries met in Japan to agree on a list of 20 goals, known as the Aichi Biodiversity Targets, to help conserve the world's biodiversity, promote sustainability and protect ecosystems.

12 A total of 18 sub-indicators were not reported on for the 2018 status and trends report.

planning practices. The National Development Plan 2018–2027, which sets out priorities underpinning the implementation of the *National Planning Framework: Project Ireland 2040* (Government of Ireland, 2018), provides an established means through which climate change adaptation objectives can be integrated and implemented at local level. As planning legislation already requires different levels of the planning process to address climate change, the National Planning Framework represents a key opportunity to ensure that the climate implications of spatial choices are fully considered and addressed in a coherent manner. Intelligent planning decisions can reduce both climate and disaster risk impacts. Climate change adaptation indicators can provide an evidence base to inform more responsible planning practices. A clear example would be limiting development near river floodplains to reduce property flood risk. However, to determine if this is being implemented in practice and if it is effective, monitoring is required. This type of planning action can be captured through impact, implementation and outcome adaptation indicators.

Furthermore, the Office of the Planning Regulator notes the inclusion of mandatory objectives for climate (mitigation and adaptation) in development plans under section 10(2)(n) of the Planning and Development Act 2000 (OPR, 2019). The key consideration in the Act for climate change adaptation was in relation to flood risk management (OPR, 2019). Specific reference was made to the Flood Risk Management Guidelines (DHLGH, 2009).

The National Planning Framework outlines a statutory requirement for regular progress reviews and updates (Government of Ireland, 2018). A Climate Action Strategy is a component of each of the three regional spatial economic strategies (for each of the regional assemblies – Southern, Eastern and Midland, and Northern and Western). These strategies reference the implementation of prioritised climate actions, in accordance with the guiding principles of the NAF, as regional policy objectives, but stop short of recommending climate change adaptation indicators. Indicators are already specifically mentioned in relation to measuring economic and population growth across the respective regions. However, a clear opportunity exists for more explicit reporting on adaptation actions using a comprehensive set of agreed climate change adaptation indicators.

4.3 Issues of Scale

Adaptation actions are often local processes that are measured and reported across scales, through aggregation from local to national or national to regional or global (Leiter, 2015; Leiter *et al*., 2019). Monitoring and evaluation needs often require indicators to be assessable across sectors, issues and scales over time. However, aggregated indicators lose detail (Bours *et al*., 2014; Hammill *et al*., 2014; Leiter *et al*., 2019), and therefore there is a compromise to be reached between the level of aggregation and the context sensitivity of adaptation metrics (Bours *et al*., 2014). Leiter *et al*. (2019) argue that adaptation processes are often inseparable from development objectives and require similar approaches to establish and use indicators or metrics. The case is made that, similarly to sustainable development, there is strong potential to create adaptation indicators that allow a certain degree of comparability and standardisation within sectors and themes, and that these higher level indicators need to be used alongside more context-specific local ones to provide a full picture (Bours *et al*., 2014; Hammill *et al*., 2014; Leiter *et al.*, 2019). Therefore, climate change adaptation indicators need to capture actions at the local level while also facilitating reporting at the national and international scales.

In a sense, indicators at different scales need to work together and be comparable with each other by achieving a level of coherency and consistency across scales. In the Irish context, adaptation actions are reported at the national level, regional level (through the CAROs), sectoral level and local authority level. The issue of roads provides a good example. Within Ireland local authorities manage regional and local roads. Transport Infrastructure Ireland (TII) manages the national primary and secondary road network. The information required to capture indicator information for roads across the entire country requires consistent and comparable measuring and reporting of climate impacts, adaptation implementation and adaptation outcomes across the entire road network from multiple sources with potentially different data collection policies or none at all.

Climate change adaptation indicators also need to be comparable across the same spatial scales. Therefore, it is important that local authorities compile their indicators using comparable data sources and

consistent techniques. For example, currently data on coastal erosion (and accretion) is recorded by local authorities with coastal areas. However, without standardised data recording methods in place it is challenging to capture comparable coastal erosion information between coastal counties.

In addition, data coverage and its resolution can provide challenges. For example, data appropriate for local-scale reporting may not be available at appropriate spatial resolution, and compromises on the scale reported may be necessary to provide accurate measurements. As noted in Chapter 3, it is preferable to work with existing datasets and align the relevant indicator to the data available. For example, when considering rainfall data, there is a good density of rainfall stations, with almost 500 rain gauges across the country; however, wind speed is measured at just 23 weather stations (Met Éireann, 2020a).

These issues of scale, data availability, quality, reliability, coherency and consistency should ideally be captured within a framework for data availability, collection and calculation that could be contained within a National Framework for Climate Services (NFCS).

4.4 Data Access and Availability

Access to relevant, good-quality data to calculate the indicators is vital. Ideally, the data should be publicly available and usable without restriction, in order to be transparent and facilitate reuse and checking. The 2019 Data Sharing and Governance Act has increased the obligations of public bodies to make public data available (Government of Ireland, 2019c). Data required for indicator calculation are a mix of climatic data measuring physical characteristics, such as air temperature and stream flows, physical data, such as coastal protection and flood alleviation works, socio-economic data, such as the number of vulnerable households in a floodplain, and environmental data, such as the area under forest. Such data are measured and held by a range of organisations; some of the key access portals are shown in Table 4.1. Other than climate, many of the other data are not explicitly collected with climate adaptation in mind; therefore, their fitness for use needs to be determined prior to application. Moreover, it is important that data collection and storage is long term and sustainable to ensure that the indicator calculation is feasible into the future. Often, data collection equipment and methodologies change, which can lead to discontinuities and inhomogeneities in datasets. Therefore, regular validation and long-term data curation is also necessary. Requirements for data in terms of precision and accuracy may be more onerous for climate studies than for some other operational needs; this needs to be considered in the case where data to be used in indicator calculation are being collected and used for other purposes.

Table 4.1. Selection of key public data portals and data types available for national climate change adaptation indicators

Data portal	Description	Data types available
Met Éireann	Contains climatological data for a range of climate variables including historical data (hourly, daily, monthly), re-analysis data, long-term datasets and 30-year averages	Climate
Climate Ireland	Contains data on climate observations, climate projections and climate hazards, and a reference library of research projects undertaken at national and international levels that can support the process of adaptation planning	Climate, some spatial
Central Statistics Office	Contains national census statistics and statistical databases on the environment, economy, people and society	Socio-economic, environmental, some spatial
Data.gov.ie portal	Contains over 10,000 datasets categorised across 14 themes, which include environment, agriculture, housing and health	Socio-economic, environmental, sectoral, some spatial
Irish Spatial Data Exchange	Hosted by the Marine Institute and contains over 1200 datasets holding data for 24 organisations including the EPA, the All-Island Research Observatory, the National Biodiversity Data Centre and a wide range of government departments	Climate, socio-economic, environmental, all spatial
Ordnance Survey Ireland	Through its GeoHive portal, provides data on a range of topics including education, health, transport, population and heritage	Topographic, socio-economic, all spatial
Environmental Sensitivity Mapping	Provides a wide range of datasets in support of strategic environmental assessment	Physical, socio-economic, environmental, all spatial

Other datasets can be available at a national or sectoral level. For example, information on severe weather events has been collected and made available through the National Directorate for Fire and Emergency Management (Department of Finance, 2019; Government of Ireland, 2019d). The national health and social care data collections (available from the Health Information and Quality Authority) provide a catalogue of health and social care data and information on how it can be accessed (HIQA, 2017). Data are also available at a regional or city scale, such as on the Dublinked platform that provides a range of publicly available local authority spatial data for the Dublin region. Examples of datasets are spatially explicit flood inundation data, the sustainable urban drainage systems (SUDs) register, and tree locations and species. Data held by local authorities are connected with their areas of responsibility, including transport and roads, water services, planning and housing. Certain datasets are also held by private entities, such as flood insurance claim data. Although these data may not be made available at a spatially explicit level owing to customer privacy concerns, insurance claims values can be averaged over an area to provide valuable information.

In 2019, the Department of Finance issued a consultation paper calling for greater transparency in relation to flood risk data (Department of Finance, 2019). Citing the work of Surminski (2017), a proposal was made to establish a comprehensive data platform to act as a tool in supporting flood resilience and climate change adaptation.

An important issue for indicator development, documented in Chapter 3, is to ensure that climate change adaptation indicators are as simple as possible to avoid complex calculations and the use of a wide range of datasets. Keeping indicators simple also supports clear communication and makes them understandable and accessible to a wide range of stakeholders.

4.5 Potential Indicators for the Co-selection Process

This draft indicator suite for the co-selection process was built with reference to existing climate adaptation indicators in Europe and further afield, drawing on the lessons learned from them on indicator frameworks, typologies for indicators, sectoral coverage, data requirements and stakeholder engagement and communication, as outlined in Chapter 3.

4.5.1 Indicator implementation framework

MRE is envisaged in the NAF and the sectoral plans, and local authority strategies lay out the framework for the implementation of adaptation actions. As actions will be implemented at these levels, this is also where ownership of measuring relevant adaptation indicators needs to be taken. An indicator measurement framework needs to be designed and established. It should align with the next iteration of sectoral and local plans. This is vital to avoid duplication or conflicts in reporting mechanisms and additional work for sectors and local authorities. There will be an important role for the responsible agencies in harmonising data collection, updating national level guidance, providing indicator data, aggregating results and assuring quality.

4.5.2 A risk-based indicator typology

The NAF states that adaptation actions must be risk based, and informed by existing vulnerabilities and an understanding of projected climate change. Therefore, developing an indicator typology from a risk perspective is an appropriate approach and reflects the NAF and the existing sectoral adaptation planning processes. Although individual indicators may be the same, irrespective of the approach taken, how they are grouped may differ under alternative approaches. Furthermore, the national risk assessment (Flood *et al*., 2020) underpins a risk management approach by providing a national-scale overview of priority climate change risks in accordance with existing and strategic policy directions. Irish priority climate hazards were identified through a review of the literature, strategies and reports, including *A Summary of the State of Knowledge for Climate Change Impacts for Ireland* (Desmond *et al*., 2017). These findings were corroborated and refined through stakeholder feedback in workshop settings. Priority climate hazards were thus identified as relating to sea level rise, coastal storms and pluvial and fluvial flooding, and extreme events (extreme heat, extreme wind, wildfires, drought and frost).

Present and future climate impacts were then captured under these three headings to generate a

suite of climate impact indicators. In line with a risk management approach and best practice, the indicator typology forms a sequential chain starting with relevant climatological indicators, linked to present and future climate impacts (captured with impact indicators), moving through to implementation indicators that report on adaptation actions to mitigate against climate impacts, and ending with climate outcome indicators to track the outcomes of adaptation actions or strategies, as explained in Chapter 2. In line with international best practice, in which quantitative and qualitative indicators are considered to increase the comprehensiveness and coverage of the indicator suite, adaptation actions set out in local authority climate change adaptation strategies and sectoral climate change adaptation plans are reflected in the suite of indicators put forward for the co-selection process.

4.5.3 Assigning sectoral relevance

Existing suites of adaptation indicators were compiled on a sectoral basis and then cross-tabulated with a review of priority actions as set out in the climate change adaptation sectoral plans and local authority climate change adaptation strategies. Subsets of draft indicators were then compiled across sectoral and local authority groupings so that thematically relevant draft indicators could be shared with sectoral, state agency and CARO stakeholders for feedback and review. In addition, cross-cutting indicators were also identified across sectoral themes linked with climate adaptation mainstreaming, training, partnerships, and intersectoral working groups and committees.

4.5.4 Data sources and characteristics

For each draft indicator proposed, a potential existing data source and its access conditions were identified and reported. A full scoping exercise on the dataset characteristics[13] is beyond the scope of this project, but it would need to be carried out prior to implementation of the indicator set. Data sources include government and state agency repositories, research project outcomes and case studies. Where possible, datasets with national coverage were used, but in some cases only case study data exist. These can be useful as a starting point to show indicators' potential and help fine-tune data characteristics. Publicly available data were prioritised. It is important to carefully consider how qualitative data are sourced and tracked when including qualitative indicators in the draft climate adaptation indicator suite. It is important to note that, although some indicators may be particular to a specific sector in their measurement, the information can be relevant across multiple sectors (e.g. the impact of vegetation fires on built heritage). Moreover, it is important to determine which agency is responsible for collecting and collating data. This is not a trivial task and should be specified as part of the framework for data availability, collection and calculation. More detail on the qualitative data sources consulted is provided in the draft indicator suite document (available on SAFER).

4.5.5 Ensuring stakeholder engagement

Building on European and international experience and involving a wide cohort of stakeholders is central to the development of all climate change adaptation indicator suites. Similarly to other international indicator suites, the Irish indicators were co-selected through stakeholder engagement throughout the process. As described in Chapter 2, stakeholder engagement was captured through informal consultation with stakeholders and researchers, presenting and receiving feedback from the climate change adaptation committee of the CCAC, semi-structured interviews with CARO and sectoral representatives, and an online workshop.

The series of interrelated issues considered in this chapter were used to help inform the indicator selection process. Chapter 5 draws on the issues addressed, thus providing the lens through which the co-designed, recommended indicator suite was formulated, building on the foundation of a risk-based indicator typology.

13 Dataset characteristics include accuracy (correctness in detail), completeness (comprehensiveness) and reliability (does the information contradict other trusted sources).

5 Co-designing a Recommended Indicator Suite for Ireland

There is a growing database of information about climate change and hazards in Ireland that is available through the public-facing Climate Ireland website (https://www.climateireland.ie), which also supports national and local adaptation planning. Indicators can help to quantify the effectiveness of policies and actions when adaptation is integrated into existing decision making. Indicators need to be designed with sufficient sensitivity (i.e. the ability to capture significant environmental and socio-economic impacts and changes), robustness and longevity to be fit for purpose.

This chapter documents the outcome of the co-design of a suite of climate adaptation indicators to support the development of appropriate national-, sectoral- and local-level climate change indicators that will also meet international/EU reporting requirements, track progress on adaptation action indicators and aid awareness raising.

5.1 Outcomes of Stakeholder Engagement

The stakeholder engagement process detailed in Chapter 2 led to a total of 12 semi-structured interviews (with representatives from the CAROs, government departments and state agencies) and one written submission. Representatives from all four CAROs took part in the interviews, and their priorities and perspectives on climate change adaptation indicators were captured. It is important to note that the CAROs are currently tracking progress on the 2019 local authority climate change adaptation strategies, and this informs their consideration of adaptation action reporting (Climate Ireland, 2020). This is being done through the use of a key performance indicator (KPI) approach.

Although the KPI approach does not employ adaptation indicators per se, some complementarity can be found between this approach and one using adaptation indicators. The KPIs are used to track the implementation of actions in the local authority climate change adaptation plans and can dovetail with climate adaptation implementation indicators. For example, Figure 5.1 demonstrates the reporting considerations and issues as informed by the Climate Action Charters (Government of Ireland, 2019e). This figure captures issues of scale and the strategic concerns at each level of reporting, from local authority

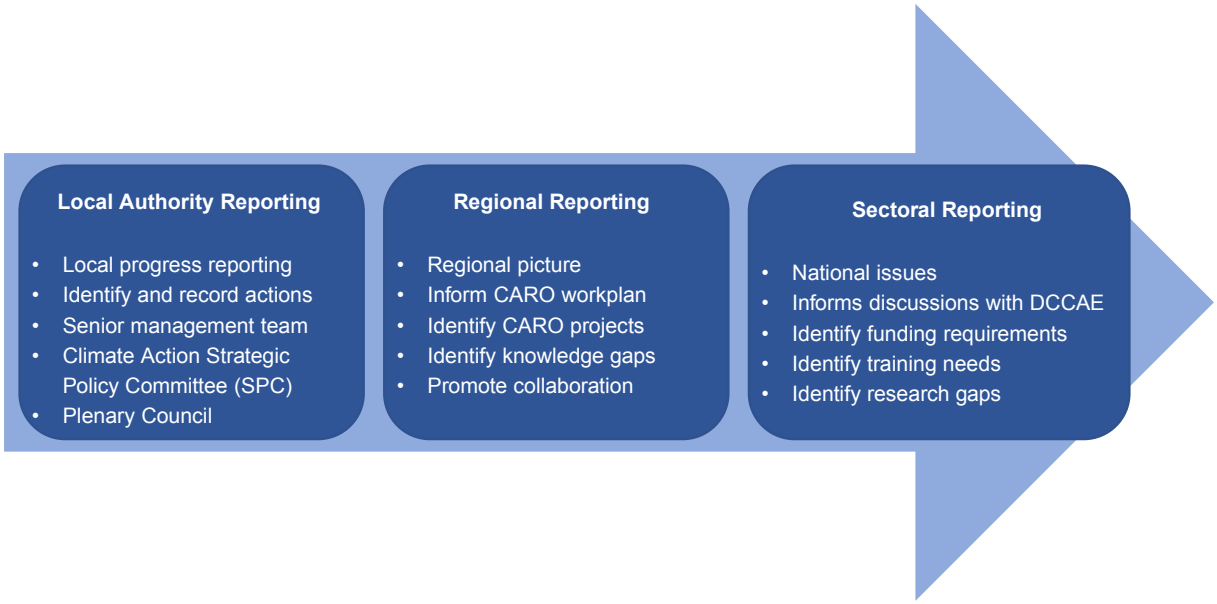

Figure 5.1. Climate adaptation action reporting. After Clarke and O'Donoghue, 2020.

to regional to national level. CAROs provide an important function as the interfaces between local authority climate adaptation progress and reporting and national-level sectoral adaptation planning. In their function as interface organisations they promote collaboration, identify knowledge gaps and provide a regional overview to inform local authority, as well as national-level priorities (CARO, 2021; Clarke and O'Donoghue-Hynes, 2020).

The outcomes from these interviews were compiled and presented at an online participative workshop involving a wider stakeholder community. Through the workshop additional inputs were gathered to contribute to the indicator selection process and inform implementation issues.

5.2 Recommended Indicator Suite for Ireland

The outcome from the stakeholder co-design process, followed by additional refinement, led to a total of 127 recommended indicators, of which 91 are seen as priority. Of these, 15 are climatological indicators, 23 are impact indicators, 32 are implementation indicators and 21 are outcome indicators. A full list of indicators is tabulated in Appendix 1, with a description of each indicator, its sectoral relevance, potential data source, data availability and priority. Here, a summary is provided of the indicator suite as designated under one of the three hazard areas with an indication of adaptation indicator type: climatological, impact, implementation and outcome. Furthermore, each indicator is tagged as "Priority" or "Watching brief". Indicators were tagged as priority if they were identified in the existing international indicator literature, were recognised by the stakeholders as being of high importance and were reflected in the Irish climate impact literature. "Watching brief" in this context means that the indicator is seen as potentially valuable and should be maintained on the list so that further action can be taken if and when necessary. The indicators in themselves are unlikely to have any influence or relevance unless they connect to the key opportunities and challenges that important sectors of the Irish economy are likely to face. These sectors have been identified by Climate Ireland (https://www.climateireland.ie/#!/tools/sectors), and the indicators are aligned to those sectors to which they are relevant in the following table (Table 5.1).

Table 5.1. Relevant Irish sectors and corresponding symbols

Sector	Symbol (key)
Agriculture	
Biodiversity	
Coastal areas	
Critical infrastructure (including transport and communication networks)	
Forestry	
Health	
Marine and fisheries	
Tourism and cultural heritage	
Water management (including water supply and quality, and flooding)	
Local authorities	

5.2.1 Pluvial and fluvial flooding

A total of six climatological indicators, of which five were identified as priority, are associated with pluvial and fluvial flooding hazards (Table 5.2).

All indicators are linked to precipitation amounts and duration, as well as ground saturation and river flows. Data availability is relatively good, with precipitation data available from the in situ synoptic, climatological and rainfall network of Met Éireann. River flow information is available for the national reference network of hydrometric gauges identified for tracking climate change (OPW, 2020). Six impact indicators, of which four are identified as priority, are associated with pluvial and fluvial hazards (Table 5.3).

These impact indicators are most closely aligned with the priorities of CAROs, the Department of Health, the Department of Transport, Tourism and Sport (DTTAS), the Department of Agriculture, Food and the Marine (DAFM), the Department of Housing, Local Government and Heritage and the Office of Public Works (OPW), and in this way they support existing sectors.

Issues pertaining to transport infrastructure and property damage, as captured in the indicators, were raised by the OPW. Pluvial and fluvial flood-related road damage was highlighted as a particular priority by the Atlantic Seaboard South and the Eastern and

Table 5.2. Climatological indicators associated with pluvial and fluvial flooding

Climatological indicator	Prioritisation	Sectors affected
Number of very wet days (days with rainfall > 30 mm)	Priority	
Total seasonal precipitation	Priority	
Maximum consecutive 5-day precipitation	Priority	
Occurrences of absolute drought	Priority	
River flood index (runoff)	Priority	
Total annual precipitation	Watching brief	

Table 5.3. Impact indicators associated with pluvial and fluvial flooding

Impact indicator	Prioritisation	Sectors affected
Extent (km^2) and grade of damage to roads as a result of flooding	Priority	
Extent (km^2) and grade of road and rail bridge damage due to flooding (damage to bridge floors and water intrusion into abutments)	Priority	
Number of properties flooded (residential and commercial)	Priority	
Extent (km^2), duration and frequency of protected habitats flooding	Priority	
Extent and duration of agricultural land flooded (km^2)	Watching brief	
Number of reported cases of water-borne diseases – verotoxigenic *Escherichia coli* (VTEC)	Watching brief	

Midlands CAROs, where significant damage was reported from previous flooding events and future vulnerabilities were identified. Property damage due to pluvial and fluvial flooding was of particular interest to all of the CAROs, as well as the built and archaeological heritage personnel in the then Department of Culture, Heritage and the Gaeltacht (DCHG). Habitat damage due to inland flooding hazards was identified as a significant impact by the biodiversity team in the DCHG. Although flood extent was an important factor, it was noted that flood duration and frequency were important contributing factors when considering the negative impacts on protected habitats and their flora and fauna.

Data on the condition of transport infrastructure are captured as part of existing monitoring programmes and would assist in generating the indicators. Information on properties and land affected by flooding is generally maintained by local authorities and in insurance claims. Some data on flooding of protected habitats are available under special areas of conservation (SACs) and special protection areas (SPAs) reporting.

Flooding of agricultural land is seen as significant and, as impacts are expected to increase over the medium to long term from both pluvial and fluvial sources, should be kept under a watching brief. Similarly, an increase in water-borne diseases was identified by the Department of Health as a significant potential future impact associated primarily with pluvial flooding. Verotoxigenic *E. coli* was identified as a particularly dangerous disease that should be monitored but would require additional resources for accurate testing, as documented by public health specialists Kelly and Fallon (2019). Fourteen implementation indicators, of which 11 are identified as priority, are associated with pluvial and fluvial flooding hazards (Table 5.4).

Similarly to impact indicators, these implementation indicators are most closely aligned with the priorities of CAROs, the Department of Health, DTTAS, DAFM, DCHG and the OPW. They mainly address transport

Table 5.4. Implementation indicators associated with pluvial and fluvial flooding

Implementation indicator	Prioritisation	Sectors affected
Is a proactive road drainage maintenance programme (to lessen or prevent flooding impact) in place?	Priority	LA
Number of protected/vulnerable areas	Priority	LA
Is there a proactive bridge maintenance programme (as captured under EIRSPAN Asset Management Programme) in place to lessen or prevent flooding impact?	Priority	LA
Area of land rezoned by local authorities to avoid building on floodplains	Priority	LA
Number of properties in river floodplains protected by existing flood protection measures	Priority	LA
Number/extent of native forestry projects on state-owned land to support flood water retention and biodiversity	Priority	
Number of vulnerable priority heritage sites located in river floodplains	Priority	
Vulnerability of protected habitats to flooding impacts	Priority	
Number of private wells with water quality monitoring (proxy – uptake of government-funded well improvement scheme)	Priority	
Number of SUDs in place	Priority	LA
Establishment of National Flood Forecasting and Flood Monitoring Service	Priority	LA
Investment in flood resilience (euros)	Watching brief	LA
Percentage of river embankments that include height to protect against future flood risk	Watching brief	LA
Number of properties located in river floodplains	Watching brief	LA

infrastructure, property and land issues, although some are cross-cutting.

Most of these indicators connect directly, through implementation responses, to the impact indicators in Table 5.3. For example, a proactive road drainage maintenance programme is an adaptation (implementation) response to road damage as a result of (pluvial and fluvial) flooding. Nonetheless, some implementation indicators do not map directly onto impact indicators. For example, the area of land rezoned to avoid building on floodplains is an implementation indicator responding to the impact of property flooding. A number of stakeholders recognised the important role that planning plays in reducing the impact of floods on properties, such as rezoning land located in floodplains from residential to agricultural use to dissuade development.

Monitoring the number of SUDs in place, a cross-cutting indicator, acknowledges the value of SUDs, particularly in reducing the impact of pluvial flooding (caused by heavy rain) in urban areas. SUDs consist of a collection of water management practices that aim to align modern drainage systems with natural water processes by making urban drainage systems more compatible with components of the natural water cycle (Hoang and Fenner, 2015). Increasing surface permeability to reduce runoff is a key component of their design. As well as being reflected in the international literature this indicator was suggested and supported by a number of stakeholders.

A National Flood Forecasting and Flood Monitoring Service is being developed by Met Éireann, in collaboration with the OPW. This is a cross-cutting indicator and will forecast fluvial and coastal floods through integrating hydrological models with real-time meteorological forecast data. Fifteen outcome indicators, of which nine are priority, are associated with pluvial and fluvial flooding hazards (Table 5.5).

All of the priority outcome indicators are associated with complementary implementation indicators and also (as with the implementation indicators) map onto impact indicators (Table 5.3). They include priority indicators focused on transport, planning (land

Table 5.5. Outcome indicators associated with pluvial and fluvial flooding

Outcome indicator	Prioritisation	Sectors affected
Percentage change in road flooding impacts	Priority	LA
Number of climate-adapted bridges	Priority	LA
Change in area of land rezoned to avoid building on floodplains	Priority	LA
Change in number/extent of native forestry projects on state-owned land to support flood water retention and biodiversity	Priority	
Change in number of vulnerable priority heritage sites located in river/coastal floodplains	Priority	
Change in vulnerability of protected habitats to flooding impacts	Priority	LA
Change in number of SUDs in place	Priority	LA
Operational National Flood Forecasting and Flood Monitoring Service	Priority	LA
Change in protected/vulnerable areas – prioritising assets such as roads, essential services	Priority	LA
Change in investment in flood resilience (euros)	Watching brief	LA
Percentage change in embankments that include height to protect against future flood risk	Watching brief	LA
Extent of roads maintained (to lessen or prevent settling impact)	Watching brief	LA
Percentage change in number of properties located in river floodplains	Watching brief	LA
Change in incidence of road settling impact as a result of proactive road maintenance programme	Watching brief	LA
Change in incidence of water-borne diseases as a result of drinking water improvement	Watching brief	

rezoning to reduce flood risk), forestry, built heritage and flood protection.

5.2.2 Extreme events

Indicators associated with extreme events (here defined as extreme heat, extreme wind, wildfires, drought, frost) are listed in Tables 5.6–5.9. Similarly to the pluvial and fluvial flooding indicators, they are listed under the heading of climatological, impact, implementation and outcome indicators. Seven climatological indicators, all of which are deemed priority, are associated with extreme event hazards (Table 5.6).

These indicators are linked to a number of climatological variables – primarily temperature-related ones, but also wind and precipitation. Data availability is relatively good, with the temperature-, wind- and precipitation-related data available from the in situ synoptic, climatological and rainfall network of Met Éireann. A total of 18 impact indicators, of which 13 are deemed to be priority, are associated with extreme hazards (Table 5.7).

Priority impact indicators associated with extreme heat are linked to rail network damage, as identified by DTTAS, and the number of people affected by heatwave events, as identified by representatives in the Department of Health and the Dublin Metropolitan CARO. Road melt damage due to extreme heat was raised as a significant potential future impact by DTTAS, and particularly the Eastern and Midlands CARO and the Atlantic Seaboard North CARO. The issue is most relevant for local roads in the medium to long term and, for this reason, it was classified as a watching brief rather than a priority (Moretti and Loprencipe, 2018).

Three priority indicators were associated with extreme wind events. DTTAS and the Dublin Metropolitan CARO raised the issue of extreme wind impacts on Luas and DART (Dublin tram/light rail system and electrified commuter railway network serving the

Table 5.6. Climatological indicators associated with extreme event hazards

Hazard	Climatological indicator	Prioritisation	Sectors affected
Extreme heat	Number of hot days (days with max. daily temperature above threshold)	Priority	
	Number of heatwave days (where heatwave is at least 3 consecutive days of daily max. temperature above 90th percentile)	Priority	LA
Extreme wind	Number of extreme wind speed days	Priority	LA
	Number of days with gale gusts	Priority	
Wildfire	Fire Weather Index	Priority	LA
Drought	Drought – frequency, duration, severity as measured by the mean soil moisture index and the standardised precipitation index	Priority	LA
Frost	Number of frost days	Priority	

Table 5.7. Impact indicators associated with extreme event hazards

Hazard	Impact indicator	Prioritisation	Sectors affected
Extreme heat	Rail network damage due to extreme heat (euros)	Priority	
	Number of people impacted by heatwave events (captured through hospital admissions)	Priority	LA
	Road melting damage due to extreme heat (euros)	Watching brief	LA
Extreme wind	Transport (Luas and DART) overhead power lines impacted by high winds (euros)	Priority	
	Overhead power lines impacted by high winds (cost impact)	Priority	
	Windthrow tree fall (m^3, euros)	Priority	
Wildfires	Other vegetation fires (km^2/economic cost)	Priority	LA
	Forest fires (km^2)	Watching brief	
Drought	Road settlement impact (cracking of local, smaller, roads on peatland due to drought conditions) (euros)	Priority	LA
	Agricultural losses reported as a result of drought (euros)	Priority	
	Additional fodder use as a result of drought conditions (volume, euros)	Priority	
	Water conservation orders (hosepipe bans) (number, duration)	Priority	LA
	Dry, cracked soil in agricultural land resulting in potential exposure of ground water to pesticides (ha)	Priority	
	Hectares lost to land degradation	Watching brief	
Frost	Agricultural losses reported as a result of frost (euros)	Watching brief	
	Forest damage reported as a result of frost (euros, km^2)	Watching brief	
Cross-cutting	Decline in fish habitats due to temperature change	Priority	
	Climate change impacts on natural habitats and species (species loss/habitat loss)	Priority	LA

coastline and city centre of Dublin, respectively) overhead power lines. Potential combined direct damage costs (of repair and replacement) and indirect costs of travel disruption were highlighted as significant. Extreme wind impacts on overhead electricity supply lines within the national grid were also recognised as a priority indicator. The priority indicator windthrow tree fall was also acknowledged to create spillover (or cascading) impacts on electricity supply lines, causing damage and power supply disruption due to trees falling during extreme wind events.

Wildfire-related indicators were highlighted by representatives from the National Parks and Wildlife Service, DCHG, DAFM and the CARO representatives. Burning of non-forest vegetation or scrub land was prioritised over forest fire impacts because of the magnitude of impact and challenges in managing non-forest vegetation fires, often on private land.

Five priority impact indicators associated with drought hazards were selected and one watching brief indicator was identified. The Eastern and Midlands CARO and the Atlantic Seaboard North CARO both recognised the significant impact of drought in damaging local roads as a result of the drying out and sinking of peatland. Three out of the four remaining drought-linked impact indicators are associated with agriculture. Two economic indicators are associated with (1) agricultural losses and (2) drought and the cost (and volume) of additional fodder needed to feed animals as a result of reduced levels of locally sourced feed because of poor grass growth. Local fodder availability can also be affected by cold and wet weather conditions, as well as drought conditions. The third agriculture-focused indicator, dry, cracked soil, has spillover (cascading) impacts on local water quality, which can in turn have impacts on human and animal health. Drought-induced dry, cracked soil can result in potential exposure of ground water to pesticides.

Frost impacts in agriculture and forestry were noted. However, the impacts were deemed not to be of sufficient magnitude to be considered a current priority. Finally, two priority cross-cutting impact indicators were recognised in natural systems – changing sea temperatures resulting in declining fish habitats, and climate change impacts on natural habitats and species. The DAFM, DCHG and the CAROs all noted the impact of climate change on natural habitats and species and pointed out the need for significant additional research, building on work carried out by Coll and Sweeney (2013) and Coll *et al*. (2013, 2014) and documented in the Biodiversity Sectoral Adaptation Plan, to gain greater insight into climate change impacts on protected habitats and species (DCHG, 2019). Twenty-two implementation indicators, of which 17 are identified as priority indicators, are associated with extreme event hazards (Table 5.8).

Two priority implementation indicators were selected for extreme heat. Mainstreaming climate change adaptation actions into rail network management plans was selected to mitigate against extreme heat risk on rail networks. Implementing the range of actions recommended in the Urb-ADAPT EPA research project (Paranunzio *et al*., 2020) was suggested to mitigate the present and future impacts of extreme heat on human populations, particularly in urban areas. These include identifying local and regional vulnerabilities and risks associated with key urban climate impacts, now and in the future, and implementing a suite of adaptation options (short, medium and long term).

Three priority indicators were identified for extreme wind. These include the implementation of the existing Luas Severe Weather Management Plan to account for high wind impacts on power lines and the implementation of mitigation actions against overhead power line damage on the national grid by high winds within the EirGrid Business Continuity Plan. Finally, the implementation of actions outlined within the National Council for Forest Research and Development (COFORD)-funded WINDRISK project was suggested to mitigate the present and future windthrow tree fall risk (Teagasc, 2020).

Priority drought indicators are associated with transport and agriculture. Implementing a proactive road maintenance programme was suggested to lessen or prevent the impact of road settling due to peatland and other underlying road supports drying out. Economic investment in irrigation schemes for agricultural land was selected as a priority indicator to reduce agricultural losses and impacts from drought. Increasing the use of heat-resistant (low water use) varieties of grass and crops was also suggested as a response to the drought impacts of climate change on agricultural systems.

Table 5.8. Implementation indicators associated with extreme event hazards

Hazard	Implementation indicator	Prioritisation	Sectors affected
Extreme heat	Mainstream mitigation against extreme heat risk on rail network in rail network management plans	Priority	
	Actions implemented as recommended in Urb-ADAPT research project to mitigate against present and future extreme heat	Priority	LA
	Use of stiffer binder in roads exposed to high temperatures (km^2)	Watching brief	LA
Extreme wind	Implementation of (existing) Luas Severe Weather Management Plan to account for present and increasing high wind impact on power lines	Priority	
	Mitigation actions against overhead power line damage by high winds in the EirGrid Business Continuity Plan	Priority	
	Actions implemented as recommended in WINDRISK research project to mitigate against present and future windthrow tree fall risk	Priority	
Wildfires	Number of forestry fire plans in place	Watching brief	
	Number of education/training programmes on fire prevention	Watching brief	
Drought	Proactive road maintenance programme (to lessen or prevent settling impact)	Priority	LA
	Investment (euros) in irrigation schemes for agricultural land	Priority	
	Number and area of heat-resistant varieties of grass and crops grown	Priority	
	Investment in agricultural education programmes to increase awareness of the value of maintaining soil organic carbon content above critical value (2%) in agricultural land	Watching brief	
Frost	Investment in frost management education for foresters (euros)	Watching brief	
Cross-cutting	Mainstreaming of climate change adaptation into local authority operations	Priority	LA
	Build internal capacity by engaging in knowledge sharing and information exchange to increase awareness of climate and adaptation issues across departments and agencies (number of capacity building initiatives, staff engaged)	Priority	LA
	Progress actions of Critical Infrastructure Working Group	Priority	LA
	Review of the effectiveness of current quantitative data collection procedures for the impacts of extreme weather events	Priority	LA
	Develop guidance for sectoral stakeholders to inform identification of critical transport assets, taking account of cross-sectoral interdependencies (action from Critical Infrastructure Working Group)	Priority	LA
	Progress on actions of climate working group within COFORD	Priority	
	Upskill farmers, foresters and fishermen to ensure that they have the knowledge and tools required to implement climate adaptation practices	Priority	
	Monitor and report ongoing activities of Climate Change Oversight Group (CCOG within the Department of Health)	Priority	
	Support national and regional initiatives to explore the consequences of climate change impacts on heritage, cultural and amenity sites and the potential for loss of tourism resources	Priority	LA

COFORD, National Council for Forest Research and Development.

Nine priority cross-cutting indicators were recommended to address a range of present and future impacts caused by extreme weather events. Many of these implementation indicators are focused on mainstreaming climate action into existing decision-making processes through building capacity and knowledge sharing on climate change impacts both within and across government departments and

agencies. This can be achieved, for example, through the actions of the critical infrastructure working group within DTTAS, or a number of formal climate working groups (within COFORD and the Department of Health). Outside formal working groups, educational initiatives, for example engaging and upskilling farmers, foresters and fishermen, can ensure that they have the knowledge and tools required to implement climate change adaptation practices. Supporting initiatives to explore the consequences of climate change impacts on heritage, cultural and amenity sites and the potential for loss of tourism resources is another suggested priority.

A total of 12 outcome indicators, of which seven are identified as priority, are associated with extreme event hazards (Table 5.9).

These seven priority outcome indicators all map onto the implementation indicators in Table 5.8. They cover issues linked with transport, human health, infrastructure, agriculture and land management/ forestry.

5.2.3 Coastal flooding and erosion

A total of three climatological indicators, all of which were identified as priority, are associated with coastal flooding (Table 5.10).

Meteorological data related to precipitation and storms are available from the in situ synoptic, climatological and rainfall network of Met Éireann. The tide gauge network, operated by the Marine Institute, OPW and port authorities, could support the derivation of

Table 5.9. Outcome indicators associated with extreme event hazards

Hazard	Outcome indicator	Prioritisation	Sectors affected
Extreme heat	Change in rail network damage (euros) due to extreme heat as a result of climate mainstreaming in rail network management plans	Priority	
	Change in number of people impacted by heatwave events as a result of the Heatwave Response Plan's implementation	Priority	LA
	Change in road surface melting impact due to use of stiffer binder in road surfacing (euros)	Watching brief	LA
Extreme wind	Change in impact on power lines as a result of implementation of Luas Severe Weather Management Plan	Priority	
	Change in overhead power line damage by high winds as a result of mitigation actions within EirGrid Business Continuity Plan	Priority	
	Change in windthrow tree fall due to implemented mitigation actions	Watching brief	
Wildfires	Change in incidence of other vegetation fires (km^2)	Priority	LA
	Change in forest fire impacts (km^2, euros) due to fire plans	Watching brief	
Drought	Change in road settling impact as a result of proactive road maintenance programme	Priority	LA
	Change in agricultural losses reported as a result of drought (euros)	Priority	
	Change in soil organic carbon content (%) in agricultural land	Watching brief	
Frost	Change in economic impact of frost on forestry (euros)	Watching brief	

Table 5.10. Climatological indicators associated with coastal flooding and erosion

Climatological indicator	Prioritisation	Sectors affected
Number of very wet spell days (days with rainfall >30 mm)	Priority	LA
Sea level anomaly (height of water over mean sea level over a 30-year reference period)	Priority	LA
Coastal storm events (linked with coastal surge) (number, height)	Priority	LA

sea level anomaly information. A total of 11 impact indicators, of which six are identified as priority, are associated with coastal flooding and erosion (Table 5.11).

Priority impact indicators are associated with transport: road damage as a result of coastal flooding and damage to rail as a result of coastal erosion. The CAROs and DTTAS noted that coastal erosion was more of an issue for rail than coastal flooding owing to the impacts of erosion on the rail line from Wexford to Belfast. Coastal flooding impacts to properties were also raised as a priority issue, as well as coastal erosion impacts on built heritage. Data on coastal erosion rates are captured by local authorities and other agencies including the OPW. Currently, an up-to-date comprehensive national-level dataset on coastal erosion rates is not available. Erosion was noted as a more significant issue than flooding for built heritage, as many valuable heritage sites are located in close proximity to coastlines that have historically been vulnerable to erosion. An inter-departmental group on managing coastal change is currently developing processes to measure coastal erosion in a coordinated way. Finally, coastal erosion was recognised as a significant issue in relation to the protection of coastal habitats and species.

A total of four implementation indicators, all of which were identified as priority, are associated with coastal flooding and erosion (Table 5.12).

A priority implementation indicator with strong endorsement is investment in programmes to monitor and forecast coastal erosion (and associated

Table 5.11. Impact indicators associated with coastal flooding and erosion

Impact indicator	Prioritisation	Sectors affected
Coastal erosion rates	Priority	LA
Extent (km^2) and grade (euros) of damage to roads as a result of coastal flooding	Priority	LA
Damage costs (euros) incurred by rail as a result of coastal erosion	Priority	LA
Coastal flooding damage to property (euros)	Priority	LA
Coastal erosion impacts on built heritage (euros)	Priority	
Coastal erosion impacts on protected habitats and species (habitat condition and species impacts)	Priority	LA
Coastal flooding impacts on built heritage (euros)	Watching brief	
Coastal erosion damage (euros) to property	Watching brief	LA
Damage costs (euros) incurred by rail as a result of coastal flooding	Watching brief	
Extent (km^2) of damage to roads as a result of coastal erosion	Watching brief	LA
Damage (euros) to ports/marinas as a result of coastal storms	Watching brief	LA

Table 5.12. Implementation indicators associated with coastal flooding and erosion

Implementation indicator	Prioritisation	Sectors affected
Investment (euros) in programmes to monitor and forecast coastal erosion	Priority	LA
Proactive road drainage maintenance programme (to lessen or prevent coastal flooding impact)	Priority	LA
Investment (euros) in coastal protection/management measures to mitigate the impact of coastal erosion	Priority	LA
Investment (euros) in coastal protection/management measures to mitigate coastal flooding	Priority	LA

accretion). Road drainage maintenance programmes were also cited as critical in reducing the impacts (duration and extent) of coastal flooding. Investment in coastal protection/management measures were differentiated between coastal erosion and flooding impacts, as, although interrelated, stakeholders contested that each requires tailored responses. For example, flood protection (through building seawalls or groynes) may increase flood defence along coasts but not necessarily reduce erosion, depending on how the flood protection is constructed and located. A total of nine outcome indicators, of which five are identified as priority, are associated with coastal flooding and erosion (Table 5.13).

The five priority outcome indicators for coastal flooding and erosion track back to the priority implementation and impact indicators presented above. The outcome indicators are linked to transport infrastructure, property, coastal habitats and built heritage.

5.3 From Selection to Implementation

The tables presented in section 5.2 represent the final recommended indicator suite derived from a co-design process that involved experts with an institutional interest and involvement in pursuing climate change adaptation in Ireland. Although many of the indicators selected have a foundation in available data, some are based on what should be available ideally, but may currently have an incomplete or absent data foundation. A vital corollary to the selection of an indicator suite is its implementation. This section focuses on the indicator implementation framework, examining the issues that need to be considered and addressed to improve uptake and implementation of the recommended indicator suite. There are a number of factors that need to be in place to increase the likelihood of successful implementation; these include issues relating to governance, resource availability, technical considerations of data and data availability, and reporting obligations.

At the outset is it important that the proposed indicator suite meets the needs and demands set out within existing policy frameworks. In its 2019 end-of-year review the CCAC recommended that an agreed set of climate change adaptation indicators should be developed and implemented as soon as possible and reported on through the Annual Transition Statement process (CCAC, 2019). With the publication of the Climate Action and Low Carbon Development (Amendment) Bill (DECC, 2021)[14] the Annual Transition Statement process is replaced by annual

Table 5.13. Outcome indicators associated with coastal flooding and erosion

Outcome indicator	Prioritisation	Sectors affected
Change in extent (km²) and grade of damage to roads due to coastal flooding as a result of proactive road drainage maintenance programme	Priority	LA
Change in damage costs (euros) incurred by rail due to coastal erosion as a result of coastal protection/management measures	Priority	
Change in number of properties at flood risk as a result of construction of new or enhanced coastal defences	Priority	LA
Change in coastal erosion impacts on built heritage (euros) as a result of investment in coastal protection/management measures to mitigate impact of coastal erosion	Priority	
Change in coastal erosion impacts on protected habitats and species (habitat condition and species impacts) as a result of investment in coastal protection/management measures to mitigate impact of coastal erosion	Priority	LA
Change in coastal flooding impacts on built heritage (euros) as a result of construction of new or enhanced coastal defences	Watching brief	
Change in coastal erosion damage (euros) to property as a result of coastal protection/ management measures	Watching brief	LA
Change in damage costs (euros) incurred by rail due to coastal flooding as a result of investment in coastal protection/management measures	Watching brief	
Change in extent (km²) of damage to roads due to coastal erosion as a result of coastal protection/management measures	Watching brief	LA

14 Note: this research considered the Draft Climate Action and Low Carbon Development (Amendment) Bill 2020, which has since been amended and re-published. Please refer to the Climate Action and Low Carbon Development (Amendment) Bill 2021 (https://www.gov.ie/en/publication/984d2-climate-action-and-low-carbon-development-amendment-bill-2020/).

reporting on the most recent approved climate action plan in person by sectoral Ministers to the Oireachtas.

Positioning adaptation indicator *reporting* within the revised reporting process would provide a robust means of regular reporting and give adaptation action status, visibility, recognition and accountability at an appropriate governance level. It is important that progress on adaptation indicators be given an equal footing with climate actions, as outlined in the Climate Action Plan, and is coordinated with priority actions set out in local authority climate change adaptation strategies and sectoral climate change adaptation plans. For example, as actions in the local authority strategies often have long timeframes for completion, local authorities could start reporting on actions due in 5 years from, for example, 2021 according to relevant indicators. Actions with short timeframes set out in the sectoral plans will not need to be associated with an indicator that will impose an additional reporting burden.

Striking a balance between highly *quantitative climate adaptation* indicators, such as investment (euros) in coastal protection/management measures to mitigate the impact of coastal erosion, and more *qualitative indicators*, such as tracking commitment of climate change adaptation activities in local authorities (e.g. reporting on levels of awareness of staff to climate change adaptation), will also be important in realising implementation. Giving voice to more qualitative indirect or process-based indicators (such as establishment of cross-sectoral working groups and committees) is important in building and developing adaptative capacity within relevant institutions and society at large.

Providing adequate *resources*, in the form of personnel and expertise and financial investment and support, will be another important spoke in the wheel of adaptation indicator implementation. The vital €10 million allocated to set up and fund the CAROs over a 5-year period will need to be matched by significant investments in staffing local authorities and government departments with dedicated personnel to carry out the task of implementing climate change adaptation actions. Moreover, significant additional investment will be needed for data collection, curation, analysis and archiving for indicator development. The 2019 Climate Action Plan documents conservative economic damage costs associated with 2017's Storm Ophelia at €45 million and insurance claim costs resulting from 2018's Storm Emma at €39 million (DCCAE, 2019). With these type of damage costs set to increase in line with current and projected climate impacts, a strong business case can be made for allocating adequate resources to fund adaptation action. Creating transparent and transferable cost estimates for climate impacts linked with climate hazards will be of vital importance in making an ongoing business case to the Department of the Taoiseach and the Department of Finance to secure funds.

Closely aligned with resource availability are *data availability and constraints*. Outside climatological indicators, the majority of climate impact, implementation and outcome indicators have significant limitations in relation to current data availability. There can be multiple reasons for these limitations: data may be available only at a case study level, data may not be available at an appropriate scale, data may be commercially sensitive, data may be available across a range of publicly available locations but need future collation and aggregation to be useful, data may be publicly available but only presented in aggregate forms when disaggregated data sources are needed to derive an indicator, and collected data may not be comparable across counties and regions. For this reason a framework for data availability, collection and calculation would be an initial step in implementing many of the adaptation indicators presented in the recommended indicator suite. A framework for data availability, collection and calculation may fit within an NFCS. Such a framework would sit under the Global Framework for Climate Services (GFCS) proposed at the World Climate Conference-3 held in Geneva in 2009 (WMO, 2009). As Ireland's climate adaptation information portal, Climate Ireland can take an important role in providing climate service functions. This aligns with Action 183 from Ireland's 2019 Climate Action Plan.

When striving to achieve implementation of climate change adaptation indicators, a potential approach is to set out an *implementation pathway* to pilot and test a subset of the recommended co-selected indicator suite before rolling it out to all sectors and CAROs. This pilot could be reported in the annual reporting process [revised under the Climate Action and Low Carbon Development (Amendment) Bill 2020] to ensure that it becomes embedded within reporting

structures and has the opportunity to develop and expand as additional resources become available. Given the number of local authorities, departments, agencies and bodies that have a stake in climate change adaptation, it is vital that alignment is achieved between them to ensure that uptake and implementation of any indicator framework is coherent and efficient. This will require dialogue between the bodies, agreement on priorities and approaches, sharing of data and methodologies, and adoption of an agreed timetable.

Sustainability and longevity of indicators is another prerequisite for implementation. Indicators will need to be in place and progress reported for decades to come; hence, it is vital that the underlying data and resources for their implementation are guaranteed for the long term. Provision of many of the climatological variables is assured by the mandate of the relevant observing bodies: Met Éireann, the Marine Institute and the OPW. However, a comprehensive analysis of the impact, implementation and outcomes indicators would be required to determine their availability over the long term. Nonetheless, the indicator suite should be revised on a regular basis, with some indicators leaving the list and new indicators being adopted in response to changing policy and implementation requirements.

Awareness raising and capacity building on adaptation indicators are also required. Heretofore, they have not been used in an Irish context, and their implementation within the EU and further afield is relatively recent. Information on the usefulness of indicators and how they complement existing adaptation planning, international success stories and training on the practicalities of adopting such a framework need to be provided. This needs to involve a wide range of stakeholders, not just those involved in implementation. For example, the results of indicator reporting will be of particular interest to wider society, including not-for-profit organisations, civil society and business interests. Climate Ireland offers a framework within which such capacity building could take place.

6 Discussion

The Climate Action and Low Carbon Development Act 2015,[15] Ireland's climate policy framework, includes an aim to transition to a climate-resilient society and economy by 2050 (Government of Ireland, 2015). As a contribution to this aim the NAF provides a strategic policy focus to ensure that adaptation measures are taken across all sectors and levels of governance to increase Ireland's preparedness for, and decrease vulnerability to, the impacts of climate change through adaptation planning. Although indicators that monitor the causes and effects of climate change are relatively well developed, indicators that monitor resilience to climate change are less developed. The PCAS project sought to identify a framework for indicator selection and, on that basis, a suite of indicators that provides metrics that monitor the connectivity between climate change and development.

Such an indicator suite should not only adhere to the recognised SMART criteria (Maxwell *et al*., 2015; Kopke *et al*., 2018), but be tailored to Ireland-specific circumstances and information needs, and enriched by nationally available data before being applied. A key consideration while identifying relevant climate resilience indicators for Ireland is cohesion between climate activities. Having multiple indicator sets that are potentially conflicting and add to the burden of government departments, national agencies and local authorities will hinder efforts rather than support them. This highlights the importance of a process of targeted, effective co-design that has shaped the implementation of the PCAS project through stakeholders' participation in selecting indicators that best fit to Ireland's observed and projected climatic risks and impacts, as well as its adaptation and development priorities. As sectors and local authorities develop adaptation plans, as mandated by the NAF (DCCAE, 2018a), the PCAS project sought to co-design a coherent suite of recommended indicators to monitor progress and pathways towards climate resilience for Ireland.

Information gathering on climate change impacts in Ireland is ongoing and made available through the Climate Ireland platform; however, although much of this information is comprehensive with regard to certain sectors, different levels of analysis and understanding exist across sectors, and a means of comparing impacts across and between sectors is not in place. The resilience-focused indicator suite co-designed during the PCAS project affords capacity for measuring trends, benchmarking and sector comparisons, but will also build measures for monitoring the effectiveness of adaptation responses, as well as provide a measure of accountability and legitimacy of actions through reporting. A common cross-sectoral indicator suite can overcome potential mistrust of indicators as distorting perspectives and priorities and focusing on particular issues, and can demonstrate the utility of an indicator suite that has been co-designed by agencies and end users.

This chapter provides an overview of the process of indicator selection and reflects on the challenges of this process and the steps taken along the way to successfully navigate it. The challenges of ensuring effective stakeholder uptake and indicator implementation are considered and a pathway towards implementation is proposed.

6.1 Challenges in the Indicator Selection Process

A review of other countries experiences, particularly those in the EU, suggested key elements in the development of an indicator suite:

- Although an important characteristic of adaptation indicators is their consistency and longevity because this allows for comparability tracking from a baseline, any indicator suite should permit revision and evolution and be embedded within an MRE framework.

15 Note: this research considered the Draft Climate Action and Low Carbon Development (Amendment) Bill 2020, which has since been amended and re-published. Please refer to the Climate Action and Low Carbon Development (Amendment) Bill 2021 (https://www.gov.ie/en/publication/984d2-climate-action-and-low-carbon-development-amendment-bill-2020/).

- Basing an indicator suite on a typology that captures vulnerability in socio-economic, built and natural environment systems is necessary.
- Qualitative indicators should be used to complete the stories in relation to climate adaptation needs and effects, and help inform us in the absence of suitable information to construct quantitative indicators.
- Indicator development and implementation processes should foster complementarity and build links between sectors in terms of sharing information and understanding of common climate hazards and impacts that cascade across a range of sectors.

In the PCAS project an important decision in the indicator selection process was deciding on the most useful adaptation indicator typology to classify the indicators. The aim was to create a typology that would comprehensively address a wide range of purposes but not be overly complicated and challenging to communicate. Drawing on the work of the Organisation for Economic Co-operation and Development, which provided insight on national adaptation monitoring and evaluation systems (Vallejo, 2017), it was deemed essential that any indicator typology cover climate risks (through hazards and impacts), adaptation processes and adaptation outcomes. The selected indicator typology – climatological, impact, implementation and outcome – framed under three major sets of climate hazards, sought to illustrate these important components of adaptation monitoring and evaluation in a straightforward manner. The strengths of the approach taken are the limited number (four) of indicator type headings, which simplifies understanding. The suite also clearly sets out a vision to increase the resilience of society to the impacts of climate change through the selection of indicators that outline a pathway to measure and quantify status and progress from hazard to climate impacts, to adaptation actions and then to adaptation outcomes.

The typology also offers room for development and further refinement. Three of the indicator types (impact, implementation and outcome) could be expanded to increase the level of detail. For example, adaptation impact indicators could be further refined by adding specific indicators for exposure and vulnerability. While this could increase the completeness of the indicator typology, it was decided to start simple, in line with international best practice. However, when adaptation indicator uptake occurs this could present an opportunity to revisit the typology and include additional indicators for a number of indicator types if that is considered to be of value.

With the adaptation indicator typology established and an initial suite of potentially relevant climate change adaptation indicators selected, the next step was consideration of capturing the cross-sectoral complementarity of the indicator suite, i.e. the relevance of a particular indicator to multiple sectors and the potential need to collaborate to share data or pool resources to generate a specific indicator that, when implemented, provides benefits/valuable knowledge to a range of sectors. For example, the collation of a coastal erosion impact indicator will require collaboration between several agencies, government departments and local authorities. Complementarity was explored through the co-creation process by inviting interviewees to comment on relevance but also to address where they saw potential for cross-sectoral collaboration. The more sectors an indicator is relevant to, the greater the possibilities of it being adopted and implemented. As it garners wide approval and support, however, it may increase in complexity in terms of its development and implementation. Therefore, although some indicators may be sectorally specific in their measurement, the information is relevant across multiple sectors (e.g. vegetation fires, built heritage) and it is important to determine who is responsible for indicator measurement versus indicator utility in the selection process.

An additional challenge is the incorporation of softer/non-quantitative indicators within the indicator suite. As quantitative indicators alone cannot capture the full range of adaptation impacts and actions, it is necessary to include qualitative (or softer) adaptation indicators to tell the full story. For example, it has been documented that so-called softer indicators covering areas such as social cohesion, community health, deprivation and well-being can be important for measuring the adaptive capacity of a community or group (Ford and Pearce, 2010; Pobal, 2020).

When co-selecting a suite of adaptation indicators it is necessary to ensure the comprehensiveness of the indicators selected to address all aspects of as many relevant hazards and risks as possible. Gaps may occur related to particular sectoral impacts that may be important but were uncaptured or

overlooked, or missed opportunities for cross-sectoral complementarity. There are several reasons why an indicator suite may not be fully comprehensive. Three principal reasons relate to levels of stakeholder engagement, data availability and the cross-cutting nature of the indicator. For example, when developing and co-selecting the indicator suite a number of suggested health-related indicators were not adopted by stakeholders, as they were deemed too ambitious, too "soft", or not positioned closely enough to climate change adaptation. The mental health impact on those affected by property flooding was one such example in gauging the adaptive capacity of a community. However, it would demand the collection of health data to be cross-referenced with victims of property flooding. Although the indicator may also be challenging to develop, as affected individuals may not present with their mental health issues to health services, a clear link between climate change and health has been demonstrated as a vital component of any adaptive society (IPCC, 2014; UNDP, 2018; Doubleday *et al*., 2020).

A vital consideration in the process of indicator selection is ensuring that any recommended indicators can provide sustainability and longevity, i.e. it is important that any indicators adopted will be measured and available for many decades to come and that all approaches are taken to ensure this. For example, embedding an indicator within an existing process tied to a long-term vision or goal, and identifying pitfalls, such as the use of project-related data tied to the lifetime of a specific project, will help to determine the longevity or otherwise of indicator measurement. Within an Irish context, while some indicators are measured as a matter of course, for some indicators sustainability or longevity would require ongoing investment to support data acquisition and processing, and would ideally be captured within a framework for data availability, collection and calculation. Furthermore, once the indicator in question is included in ongoing reporting structures, this increases the likelihood that its compilation will be maintained over the longer term.

6.2 Ensuring Stakeholder Uptake and Use

The PCAS project's stakeholder participation process begins a process for ensuring strong stakeholder uptake and use. The recommended indicator suite needs to be further validated within government structures so that it can be implemented within the existing Irish policy context. There will be challenges associated with implementing it in reality. This would require support from the CCAC and its adaptation sub-committee in the first instance. Buy-in from government departments and agencies would also be needed. Adequate financial and human resources would need to be made available to underpin the task. In addition, effective and impactful communication of key messages in a digestible format will be of significant importance in achieving stakeholder interest, uptake and buy-in.

Furthermore, to achieve uptake care needs to be taken to minimise duplication of efforts and potential administrative burden. The CCAC could also play a role in providing policy evaluation advice to help streamline the process and by holding government departments accountable to their adaptation actions. This effort can also be facilitated through leveraging existing groups and networks. An example of the type of collaboration necessary is the work of the National Coastal Change Management Strategy Steering Group, which met for the first time on 3 September 2020. This group is tasked with examining how Ireland can best manage its coastline and mitigate against risks from rising sea levels, including coastal erosion and more frequent extreme coastal storm events. Other relevant groups include the Global Climate Observing System (GCOS-Ireland) group, which could take on a role in relation to the climatological indicators; the Critical Infrastructure Working Group, chaired by the Department of Transport; the Climate Change Oversight Group (CCOG) within the Department of Health; and the Climate Working Group within COFORD. Such groups are important for incentivising and promoting indicator ownership through representation and acknowledgment of interests. However, although groups facilitate information sharing and coordination, it will be important not to have an overabundance of them, or coordination and unity of purpose will become challenging. The National Adaptation Steering Committee, chaired by the DECC, would be well positioned to act as coordinator to help avoid potential duplication of efforts. The DCCAE published guidelines on the development of sectoral adaptation plans (DCCAE, 2020b). Any planned revision of these

guidelines could be an opportunity to deal with the issue of indicators and offer more specific guidance to sectors on the use and selection of indicators during the sectoral plan development process.

To coordinate the actions at the local authority level, the CAROs will take on an important role in coordinating between climate action strategic policy committees (SPCs) in local authorities and the national-level reporting. For example, KPIs associated with actions within local authority climate change adaptation strategies (DCCAE, 2018c) can be aligned, where relevant, with adaptation indicators. Adaptation indicators are used for tracking progress in the short term (and particularly if associated with particular actions), as well as over the long term, whereas KPIs often have short-term reporting requirements but may be valuable in indicating progress towards longer-term goals. KPIs may also inform the softer, qualitative and process-based adaptation indicators, for example adaptive capacity building through mainstreaming adaptation actions across local government. This can be captured by tracking the roll-out of training programmes to build knowledge of climate adaptation issues among council staff or capturing the number of full-time equivalent staff in place with climate change adaptation roles.

Another important element for user uptake will be the standardisation of information/data used in generating indicators. Currently, there are numerous gaps in relevant data, or data are not available at all, available on a project basis only, may not be aligned in terms of collection methodology, or may be collected for purposes not related to climate. More detail on data availability is summarised in the tabulated reports in Appendix 1. The process could be guided by a fit-for-purpose framework for data availability, collection and calculation that could be best positioned within an NFCS. Furthermore, Climate Ireland, as Ireland's climate adaptation information portal, may be best placed to provide climate service functions – as aligned with Action 183 from Ireland's 2019 Climate Action Plan, which recommends that Climate Ireland be developed to its full potential as an operational support for climate adaptation and climate action in Ireland. Met Éireann should play an important role in supporting the development of an NFCS. In addition, that agency is currently supporting the development of climate services to meet the needs of adaptation actions through its TRANSLATE climate services research call (Met Éireann, 2020b).

Lastly, encouraging uptake, by both demonstrating the value of adaptation indicator adoption through training and information sharing and providing the human and financial resources needed to achieve indicator development and implementation, will be vital. Compiling and reporting on adaptation indicators, even if managed and reported as efficiently as possible, will require additional time and person-hours. Resources will need to be provided to facilitate the process.

6.3 Implementation Challenges

Implementation challenges relate to many of the issues discussed above. The focus here will be on considering an implementation framework to be used to achieve indicator uptake and use while achieving coherency and alignment. An indicator implementation framework is an iterative process that moves through a number of steps. It begins with the initial exploration and selection of indicators. This report represents such a first step for Ireland. This is followed by embedding indicators within the existing policy and reporting environment. Public bodies in Ireland have historically not been used to working with indicators; therefore, capacity building on the issue is important and a step-wise approach to implementation should be considered. Initial implementation should consist of reporting on a subset of adaptation indicators, within the selected reporting framework, to initiate the process of uptake and use. For this to happen there will need to be selection and agreement of an appropriate subset of the indicators proposed. Selection criteria would be used to generate the subset. Indicators could be ranked under potential impacts, potential data availability and the ability to generate data needed, and coverage across sectors. For example, currently 16 priority indicators have data availability classified as good, 71 have data availability classified as fair, and four have data availability classified as poor. Reporting could commence with priority indicators that have good data availability and could also initially focus on climatological and impact indicators before moving into implementation and outcome indicators. Once a subset has been trialled the indicator set can be expanded or scaled up to include a more comprehensive suite of adaptation indicators.

Once established, an important element of implementation is measuring progress towards strategic objectives. As mentioned previously, an indicator implementation framework can help to achieve coordination, ownership and consensus by providing the opportunity for those tasked with implementing the indicator suite to work with key stakeholders to agree on the coordination and implementation approach (Klostermann *et al*., 2015). Regular reporting on indicators is an opportunity to review progress; however, determining the most appropriate way to ascertain whether strategic objectives are being met needs to be defined.

Challenges to the implementation process include the initial or up-front investment of time and resources. For example, sectors adopting adaptation plans must consider the need for appropriate monitoring and implementation measures and any resource implications arising. Tracking adaptation outcomes can be challenging because of the complexity of determining an initial baseline. Data may need to be collected and disaggregated to, for example, identify an initial baseline or measure of climate impacts to track over time.

7 Conclusions and Recommendations

The conception and use of climate change adaptation indicators is a relatively recent development; however, they are being adopted by an increasing number of countries, are mandated by the EU in its legislation and are required for international reporting, such as the global stocktake under the Paris Agreement. Moreover, they can align with other indicator frameworks and reporting obligations, such as those used in DRM and biodiversity reporting. Beyond reporting obligations, well-designed indicators provide a comprehensive and rigorous approach to track, monitor and evaluate adaptation actions.

The establishment of the CCAC, the Climate National Adaptation Steering Committee and CAROs, the development of local adaptation strategies and the preparation of sectoral adaptation plans by government departments all provide key governance institutions and policy structures to support the implementation, monitoring and evaluation of climate adaptation objectives as set out in the NAF and supported by the 2015 Climate Act. The development and use of climate change adaptation indicators is a clear opportunity to enhance this MRE framework and will provide an important component of this climate policy and governance structure.

The NAF states that adaptation actions must be risk based and informed by existing vulnerabilities and an understanding of projected climate change. Therefore, the indicator typology developed to generate the indicator suite was grounded in a risk-based perspective to be in line with the current Framework. Furthermore, the national risk assessment (Flood *et al*., 2020) underpins a risk management approach by providing a national-scale overview of priority climate change risks in accordance with existing and strategic policy directions. Priority climate hazards were identified, through a process of review and stakeholder consultation, as relating to sea level rise, coastal storms and pluvial and fluvial flooding, and extreme events (extreme heat, extreme wind, wildfires, drought and frost).

The draft indicator suite of climatological, impact, implementation and outcome indicators was refined through informal consultation with stakeholders and researchers and presenting and receiving feedback from the climate change adaptation committee of the CCAC, semi-structured interviews, and a follow-up online workshop with CAROs, state agencies and sectoral representatives. This comprehensive co-creation approach ensures that key stakeholders see the value of indicators, and that they should be in a position to support their adoption and implementation. The outcome of this process resulted in a total of 127 recommended indicators, of which 91 are seen as priority. Of these 91 priority indicators, 15 are climatological indicators, 23 are impact indicators, 32 are implementation indicators and 21 are outcome indicators.

Reliable, good-quality and appropriate data in terms of scale and relevance underpin the generation of quantitative indicators. Insofar as is possible, data holders and sources have been identified for each indicator, although in some cases there are limitations of the data that can affect their fitness for purpose. Qualitative indicators are also important, as they help to increase the comprehensiveness and coverage of the indicator suite. The use of qualitative indicators helps to form a more detailed and nuanced picture of climate adaptation needs and can help inform us in the absence of suitable information to construct quantitative indicators. The proposed establishment of an NFCS offers a mechanism within which data issues can be addressed.

In terms of implementation it is paramount that the adoption of an indicator set does not significantly increase reporting burdens. Therefore, it is important to streamline indicators into existing reporting structures where possible. As a first step towards the adoption of this indicator set, and following experience in other countries that suggests keeping it simple, it would be useful to implement a subset of adaptation indicators, within the selected reporting framework, to initiate the process of uptake and use. For this to happen there will need to be selection and agreement of an appropriate subset of the indicators proposed.

The priority indicators identified provide the basis for this. Indicators need to be reviewed and updated on a regular basis. During these reviews, certain

indicators may be dropped, others refined and new ones adopted. Such a review procedure needs to be integrated into the MRE process. Moreover, there is a need for capacity building and for communication on the role of adaptation indicators to all relevant stakeholders to ensure maximum transparency and understanding and to minimise resistance to their adoption and implementation.

Therefore, the following recommendations are made as a result of this study:

- The co-created recommended indicator set should form the basis for monitoring, reporting and evaluating climate change adaptation actions for Ireland. An agreed subset of these indicators should be implemented in a pilot study.
- A full scoping exercise on the dataset characteristics[16] is beyond the scope of this project, but it would need to be carried out prior to implementation of the indicator set.
- The most appropriate existing state body should be identified to oversee the detailed development and implementation of the indicator framework.
- An NFCS should be established and have as part of its remit the authority to identify, evaluate and recommend appropriate data for indicator calculation. Qualitative data should also be incorporated to ensure the comprehensiveness of the indicator framework.
- Collecting data demands significant resources. Therefore, the selection of indicators should be driven by pragmatic decisions related to data availability.
- Implementation and reporting on indicators should be aligned with existing reporting requirements to streamline reporting burdens and avoid duplication of reporting obligations. Moreover, synergies with DRM, sustainable planning and the green infrastructure agenda should be identified.
- Appropriate financial and human resources should be allocated to ensure uptake and adoption of the indicator framework.
- A comprehensive capacity building and communications programme should be implemented in relation to climate adaptation indicators to engage with all relevant stakeholders, especially those in local authorities and government departments that will be responsible for implementing adaptation actions. Climate Ireland would be well placed to support this activity in its role as a research service that connects and integrates scientific research, policymaking and adaptation practice for the purposes of enhancing adaptation decision making in Ireland.

16 Dataset characteristics include accuracy (correctness in detail), completeness (comprehensiveness) and reliability (does the information contradict other trusted sources).

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Abbreviations

CARO	Climate action regional office
CCAC	Climate Change Advisory Council
CCOG	Climate Change Oversight Group
CFRAM	Catchment flood risk assessment and management
COFORD	National Council for Forest Research and Development
DAFM	Department of Agriculture, Food and the Marine
DCCAE	Department of Communications, Climate Action and Environment
DCHG	Department of Culture, Heritage and the Gaeltacht
DECC	Department of the Environment, Climate and Communications
DECLG	Department of the Environment, Community and Local Government
DTTAS	Department of Transport, Tourism and Sport
DRM	Disaster risk management
EPA	Environmental Protection Agency
EU	European Union
IPCC	Intergovernmental Panel on Climate Change
KPI	Key performance indicator
MRE	Monitoring, reporting and evaluation
NAF	National Adaptation Framework
NAP	National Adaptation Plan
NAS	National Adaptation Strategy
NFCS	National Framework for Climate Services
NECP	National Energy and Climate Plan
OPW	Office of Public Works
PCAS	Policy Coherence in Adaptation Studies
PDMS	Personal development management system
SAC	Special area of conservation
SDG	Sustainable Development Goal
SPA	Special protection area
SPC	Strategic Policy Committee
TII	Transport Infrastructure Ireland
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

Appendix 1 Recommended Suite of Indicators

Key for Data Availability

Good	Standardised, multi-year, quality assured, with national coverage, future collection assured
Fair	Not standardised, temporal and spatial data gaps, with regional or local coverage, future collection not assured
Poor	Often project- or case study-based, short temporal data series, very limited spatial coverage

Note: DCHG is now the Department of Tourism, Culture, Arts, Gaeltacht, Sport and Media.

Climatological Indicators

Indicator name/reference number	**Coastal storm events/Climate 1**
Description	Intense storm events characterised by strong winds, large waves and storm surge
Measurement unit	Number of events, height of storm surge
Indicator type	Climatological
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Marine Institute/Met Éireann/OPW
Data availability	Good: available from Met Éireann Major Weather Events, Irish Marine Data Buoy Observation Network stations and tide gauge network
Priority status	Priority

Indicator name/reference number	**Drought/Climate 2**
Description	Drought frequency, duration, severity as measured by soil moisture deficit and standardised precipitation index
Measurement unit	Soil moisture deficit (mm) – the amount of rain needed to bring the soil moisture content back to field capacity Standardised precipitation index (mm) – defined as the number of standard deviations that observed cumulative precipitation deviates from the climatological average
Indicator type	Climatological
Relevant hazards	Drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Met Éireann
Data availability	Good: available from Met Éireann's agri-meteorological data service and rainfall observation network
Priority status	Priority

Indicator name/reference number	**Extreme windspeed days/Climate 3**
Description	Number of days with daily maximum wind speed above the 98th percentile computed over a 30-year reference period
Measurement unit	Days
Indicator type	Climatological
Relevant hazards	Extreme wind
Relevance (to sectors and CAROs)	
Potential data source/provider	Met Éireann/Marine Institute
Data availability	Good: available from Met Éireann and Irish Marine Data Buoy Observation Network stations
Priority status	Priority

Indicator name/reference number	**Fire Weather Index/Climate 4**
Description	Rates forest fire risk under four categories, including corresponding increase in fuel ignition potential and consequent fire behaviour, intensity and spread rates
Measurement unit	Fine fuel moisture code from 0 to > 80 (condition green 0 < 50, condition yellow 50 < 70, condition orange 70 < 80, condition red > 80)
Indicator type	Climatological
Relevant hazards	Wildfire
Relevance (to sectors and CAROs)	
Potential data source/provider	Met Éireann
Data availability	Good: available from Forest Fire Risk Warning System by Met Éireann and the European Forest Fire Information System
Priority status	Priority

Indicator name/reference number	**Heatwave days/Climate 5**
Description	Heatwave days (where heatwave is at least 3 consecutive days of daily max. temp above 90th percentile)
Measurement unit	Days
Indicator type	Climatological
Relevant hazards	Extreme heat
Relevance (to sectors and CAROs)	
Potential data source/provider	Met Éireann
Data availability	Good: available from Met Éireann, catalogued on data.gov.ie portal
Priority status	Priority

Indicator name/reference number	**Maximum consecutive 5-day precipitation/Climate 6**
Description	Trends in maximum annual 5-day consecutive precipitation in winter and summer
Measurement unit	Trend in 5-day precipitation events
Indicator type	Climatological
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Met Éireann
Data availability	Good: available from Met Éireann, catalogued on data.gov.ie portal
Priority status	Priority

Indicator name/reference number	**Number of days with gale gusts/Climate 7**
Description	Measured in number of days with gale gusts [a wind speed of greater than 17.5 metres per second (m/s) or 34 knots (kt)]
Measurement unit	Days
Indicator type	Climatological
Relevant hazards	Extreme wind
Relevance (to sectors and CAROs)	
Potential data source/provider	Met Éireann
Data availability	Good: available from Met Éireann, catalogued on data.gov.ie portal and Irish Marine Data Buoy Observation Network stations
Priority status	Priority

Indicator name/reference number	**Number of frost days/Climate 8**
Description	A day on which the minimum temperature at the level of the ground or on the tops of low, close-growing vegetation falls to <–0.9°C
Measurement unit	Days
Indicator type	Climatological
Relevant hazards	Frost
Relevance (to sectors and CAROs)	
Potential data source/provider	Met Éireann
Data availability	Good: available from Met Éireann's agri-meteorological data service
Priority status	Priority

Indicator name/reference number	**Number of extreme heat days/heatwave/Climate 9**
Description	Number of days in a year with maximum daily temperature above a given threshold
Measurement unit	Days
Indicator type	Climatological
Relevant hazards	Extreme heat/heatwaves
Relevance (to sectors and CAROs)	
Potential data source/provider	Met Éireann
Data availability	Good: available for ground network of synoptic and climatological weather stations
Priority status	Priority

Indicator name/reference number	**Number of very wet days/Climate 10**
Description	Number of very wet days (days with rainfall greater than 30 mm)
Measurement unit	Days
Indicator type	Climatological
Relevant hazards	Pluvial and fluvial flooding/coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Met Éireann
Data availability	Good: available from Met Éireann, catalogued on data.gov.ie portal
Priority status	Priority

Indicator name/reference number	**River Flood Index/Climate 11**
Description	River Flood Index (runoff). The Irish Reference Network of River Flow Stations provides the basis for calculating this indicator. See EPA HydroDetect project for details (http://www.epa.ie/pubs/reports/research/climate/CCRP_27.pdf)
Measurement unit	100-year return value of river discharge
Indicator type	Climatological
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	OPW/EPA
Data availability	Good: available from Irish river flow monitoring stations reference network
Priority status	Priority

Indicator name/reference number	**Sea level anomaly/Climate 12**
Description	Sea level anomaly (height of water over mean sea level over a 30-year reference period)
Measurement unit	mm
Indicator type	Climatological
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Marine Institute/OPW
Data availability	Fair: data available from Irish National Tide Gauge Network. However, changes in measurement systems, location of the sensors, data quality, etc., have made it difficult to analyse the historical datasets and extract a reliable trend
Priority status	Priority

Indicator name/reference number	**Occurrences of absolute drought/Climate 13**
Description	Absolute drought defined by Met Éireann as 15 consecutive days with precipitation < 0.2 mm on each day.
Measurement unit	mm
Indicator type	Climatological
Relevant hazards	Pluvial and fluvial
Relevance (to sectors and CAROs)	
Potential data source/provider	Met Éireann
Data availability	Good: available from Met Éireann's agri-meteorological data service
Priority status	Priority

Indicator name/reference number	**Total seasonal precipitation/Climate 14**
Description	Total precipitation over a given season. This indicator is reported for each of the four seasons
Measurement unit	mm
Indicator type	Climatological
Relevant hazards	Pluvial and fluvial flooding/drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Met Éireann
Data availability	Good: data available from the Rainfall Observational Network and documented in the Island of Ireland Precipitation series
Priority status	Priority

Indicator name/reference number	**Total annual precipitation/Climate 15**
Description	Total precipitation over a given year
Measurement unit	mm
Indicator type	Climatological
Relevant hazards	Pluvial and fluvial flooding/drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Met Éireann
Data availability	Good: data available from the Rainfall Observational Network and documented in the Island of Ireland Precipitation series
Priority status	Watching brief

Impact Indicators

Indicator name/reference number	**Additional fodder use as a result of drought conditions/Impact 1**
Description	Additional fodder needed to feed livestock as a result of cold, wet weather and drought conditions
Measurement unit	Volume, euros
Indicator type	Impact
Relevant hazards	Drought/extreme rainfall
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc/DAFM
Data availability	Fair: captured in Teagasc Situation and Outlook reporting/DAFM reporting
Priority status	Priority

Indicator name/reference number	**Agricultural losses reported as a result of drought/Impact 2**
Description	Loss in agricultural income as a result of drought conditions
Measurement unit	Euros
Indicator type	Impact
Relevant hazards	Drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc/DAFM
Data availability	Fair: captured in Teagasc Situation and Outlook reporting/DAFM reporting
Priority status	Priority

Indicator name/reference number	**Climate change impacts on natural habitats and species/Impact 3**
Description	Climate change is altering habitat conditions, resulting in impacts on flora and fauna
Measurement unit	Habitat condition and species impact
Indicator type	Impact
Relevant hazards	Cross-cutting
Relevance (to sectors and CAROs)	
Potential data source/provider	National Biodiversity Data Centre
Data availability	Poor: significant research needed to address the status of EU-listed habitats in Ireland combined with climate (phenology) impact research
Priority status	Priority

Indicator name/reference number	**Coastal erosion impacts on built heritage/Impact 4**
Description	Calculating the economic costs of coastal erosion impacts on built heritage, including architectural and archaeological heritage
Measurement unit	Euros
Indicator type	Impact
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Geological Survey of Ireland/Climate Ireland/DCHG
Data availability	Fair: case study research in the Dublin area by the Geological Survey of Ireland
Priority status	Priority

Indicator name/reference number	**Coastal erosion impacts on protected habitats and species/Impact 5**
Description	Coastal erosion impacts on protected habitats and species (habitat condition and species impacts)
Measurement unit	m^2
Indicator type	Impact
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	OPW
Data availability	Fair: coastal protected habitats and species data available under Article 17 Habitats Directive reporting/OPW
Priority status	Priority

Indicator name/reference number	**Coastal erosion rates/Impact 6**
Description	The rate of loss or displacement of sediment and rocks along the coastline due to the action of waves, currents, tides and storm events
Measurement unit	m^2
Indicator type	Impact
Relevant hazards	Coastal erosion and flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: data at local authority level – coordination needed
Priority status	Priority

Indicator name/reference number	**Coastal flooding damage to property/Impact 7**
Description	Economic costs of coastal flooding damage to private and public property
Measurement unit	Euros
Indicator type	Impact
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: captured by local authorities/insurance claim data/OPW and other relevant agencies
Priority status	Priority

Indicator name/reference number	**Damage incurred by rail as a result of coastal erosion/Impact 8**
Description	Damage costs to rail lines incurred by Irish Rail and the DART service as a result of coastal erosion
Measurement unit	Euros
Indicator type	Impact
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Department of Transport/Irish Rail/Transdev (DART services)
Data availability	Fair: captured by Irish Rail/Transdev
Priority status	Priority

Indicator name/reference number	**Decline in fish habitats due to temperature change/Impact 9**
Description	Shifts in fish habitat locations, range and food sources as a result of changing water temperatures
Measurement unit	Habitat change area (km^2)
Indicator type	Impact
Relevant hazards	Cross-cutting
Relevance (to sectors and CAROs)	
Potential data source/provider	DAFM/Marine Institute
Data availability	Poor: research/data gaps for marine species habitat loss and distribution changes as result of climate change
Priority status	Priority

Indicator name/reference number	**Dry cracked soil in agricultural land resulting in potential exposure of ground water to pesticides/Impact 10**
Description	Drought conditions leading to dry, cracked soil in agricultural land resulting in potential exposure of ground water to pesticides, including nutrient runoff, increase in crop and animal diseases
Measurement unit	Water quality, change in incidence of diseases, soil moisture deficit
Indicator type	Impact
Relevant hazards	Drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc
Data availability	Fair: captured in Teagasc Situation and Outlook reporting
Priority status	Priority

Indicator name/reference number	**Extent, duration and frequency of protected habitat flooding/Impact 11**
Description	Captures the extent (km^2), duration and frequency of protected habitat flooding that can result in habitat damage and species loss
Measurement unit	km^2, days, instances/year
Indicator type	Impact
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW/DCHG
Data availability	Fair: captured by local authorities/local landowners reporting to local authorities/documented under SAC and SPA reporting
Priority status	Priority

Indicator name/reference number	**Extent and type of damage to roads as a result of coastal flooding/Impact 12**
Description	Captures the extent and cost of damage to roads as a result of coastal flooding, including dumping sediment and washing away surfaces
Measurement unit	km^2, euros
Indicator type	Impact
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/TII/Department of Transport
Data availability	Fair: road condition captured under Pavement Surface Condition Index rating system
Priority status	Priority

Indicator name/reference number	**Extent and grade of damage to roads as a result of flooding/Impact 13**
Description	Measurement of the extent (km^2) and grade of damage to roads as a result of pluvial and fluvial flooding events
Measurement unit	km^2
Indicator type	Impact
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	LA
Potential data source/provider	Local authorities/TII/Department of Transport
Data availability	Fair: road condition captured under Pavement Surface Condition Index rating system
Priority status	Priority

Indicator name/reference number	**Extent and grade of road and rail bridge damage due to flooding/Impact 14**
Description	Captures the extent and grade of road and rail bridge damage due to flooding, such as damage to bridge floors and water intrusion into abutments
Measurement unit	Euros
Indicator type	Impact
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	LA
Potential data source/provider	Local authorities/TII/Irish Rail/Department of Transport
Data availability	Fair: captured under bridge maintenance programme (under EIRSPAN Asset Management Programme: https://www.tiipublications.ie/library/AM-STR-06054-01.pdf)
Priority status	Priority

Indicator name/reference number	**Number of people impacted by heatwave events/Impact 15**
Description	Number of people impacted by heatwave events resulting in health impacts such as heat stroke, dehydration, hyperthermia. Especially impactful in vulnerable older populations. Captured by hospital admissions
Measurement unit	Number of people
Indicator type	Impact
Relevant hazards	Extreme heat
Relevance (to sectors and CAROs)	LA
Potential data source/provider	Health Service Executive
Data availability	Fair: Health Service Executive data
Priority status	Priority

Indicator name/reference number	**Number of properties flooded/Impact 16**
Description	Total number of properties flooded (residential and commercial) over a given period (annual basis or reporting period)
Measurement unit	Number, km^2
Indicator type	Impact
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	LA
Potential data source/provider	Local authorities/insurance companies/OPW
Data availability	Fair: recorded by local authorities/captured in insurance claim costs
Priority status	Priority

Indicator name/reference number	**Other vegetation fires/Impact 17**
Description	Captures the extent and economic costs associated with other vegetation fires; normally fires on scrub, farm or marginal land
Measurement unit	km^2, euros
Indicator type	Impact
Relevant hazards	Wildfires
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/DAFM
Data availability	Fair: limited data kept by landowners, local authorities and DAFM
Priority status	Priority

Indicator name/reference number	**Overhead power lines impacted by high winds/Impact 18**
Description	Economic costs of damage to overhead power lines impacted by high winds
Measurement unit	Euros
Indicator type	Impact
Relevant hazards	Extreme wind
Relevance (to sectors and CAROs)	
Potential data source/provider	ESB networks/EirGrid/media and press releases
Data availability	Fair: some information of outages available from ESB networks/media reports documenting power outages and storm impacts, including economic impacts. Case study information also available from published paper from EPA CIVIC report (Hawchar *et al*., 2020)
Priority status	Priority

Indicator name/reference number	**Rail network damage due to extreme heat/Impact 19**
Description	Extent of damage and economic costs to the rail network as a result of damage due to extreme heat such as buckling of tracks
Measurement unit	m, euros
Indicator type	Impact
Relevant hazards	Extreme heat
Relevance (to sectors and CAROs)	
Potential data source/provider	Irish Rail/Transdev (Luas and DART Services)/Department of Transport
Data availability	Fair: data held Irish Rail and Transdev
Priority status	Priority

Indicator name/reference number	**Road settlement impact/Impact 20**
Description	Road settlement impact, such as cracking of local roads on peatland due to drought conditions
Measurement unit	m, euros
Indicator type	Impact
Relevant hazards	Drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities
Data availability	Fair: data available at local authority level for settlement of local roads
Priority status	Priority

Indicator name/reference number	**Transport (Luas and DART) overhead power lines impacted by high winds/Impact 21**
Description	Transport (Luas and DART) overhead power lines impacted by high winds (extent and cost)
Measurement unit	m, euros
Indicator type	Impact
Relevant hazards	Extreme wind
Relevance (to sectors and CAROs)	
Potential data source/provider	Transdev
Data availability	Fair: data held by Transdev
Priority status	Priority

Indicator name/reference number	**Water conservation orders/Impact 22**
Description	Captures the number and duration of water conservation orders such as hosepipe bans
Measurement unit	Number and duration
Indicator type	Impact
Relevant hazards	Drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/Irish Water/media records
Data availability	Fair: data available from local authorities, Irish Water and media records
Priority status	Priority

Indicator name/reference number	**Windthrow tree fall/Impact 23**
Description	Measures the volume and economic cost of windthrow tree fall as a result of extreme wind events
Measurement unit	m^3, euros
Indicator type	Impact
Relevant hazards	Extreme wind
Relevance (to sectors and CAROs)	
Potential data source/provider	DAFM
Data availability	Fair: captured for forestry sector in National Forest Inventory every 4 years
Priority status	Priority

Indicator name/reference number	**Agricultural losses reported as a result of frost/Impact 24**
Description	Captures reported agricultural economic losses associated with frost events
Measurement unit	Euros
Indicator type	Impact
Relevant hazards	Frost
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc/DAFM
Data availability	Fair: captured in Teagasc Situation and Outlook reporting/DAFM reporting
Priority status	Watching brief

Indicator name/reference number	**Coastal erosion damage to property/Impact 25**
Description	Measures the economic impact of coastal erosion damage to private and public property
Measurement unit	Number of properties affected, euros
Indicator type	Impact
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/insurance companies/OPW
Data availability	Fair: captured by local authorities/insurance claim data/OPW
Priority status	Watching brief

Indicator name/reference number	**Coastal flooding impacts on built heritage/Impact 26**
Description	Measures the economic costs of coastal flooding impacts on built heritage, including archaeological and architectural structures and sites
Measurement unit	Number of sites affected, euros
Indicator type	Impact
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Geological Survey of Ireland/DCHG
Data availability	Fair: case study research underway in the Dublin area by the Geological Survey of Ireland
Priority status	Watching brief

Indicator name/reference number	**Damage costs incurred by rail as a result of coastal flooding/Impact 27**
Description	Measures the economic costs incurred by rail as a result of coastal flooding events
Measurement unit	Euros
Indicator type	Impact
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Irish Rail/Transdev (for DART service)
Data availability	Fair: data held by Irish Rail/Transdev
Priority status	Watching brief

Indicator name/reference number	**Damage to ports/marinas as a result of coastal storms/Impact 28**
Description	Economic losses and damage costs to ports/marinas as a result of coastal storm events
Measurement unit	Number of ports or marinas affected, euros
Indicator type	Impact
Relevant hazards	Coastal erosion and flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/DAFM/port authorities/insurance companies/media
Data availability	Fair: captured by port authorities/insurance claims costs/documented in media reports
Priority status	Watching brief

Indicator name/reference number	**Extent and duration of agricultural land flooded/Impact 29**
Description	Extent and duration of agricultural land flooded as a result of pluvial and or fluvial flooding events
Measurement unit	km^2, days
Indicator type	Impact
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	European Space Agency
Data availability	Fair: potential use of (free) European Space Agency Copernicus programme satellite data to map the extent and impact of flooding in rural areas
Priority status	Watching brief

Indicator name/reference number	**Extent of damage to roads as a result of coastal erosion/Impact 30**
Description	Captures the area impacted and economic costs incurred to roads as a result of coastal erosion
Measurement unit	km^2, euros
Indicator type	Impact
Relevant hazards	Coastal erosion and flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/TII/Department of Transport
Data availability	Fair: road condition captured under Pavement Surface Condition rating system
Priority status	Watching brief

Indicator name/reference number	**Forest damage reported as a result of frost/Impact 31**
Description	Measures the economic cost and extent of forest damage reported as a result of frost
Measurement unit	Euros, km^2
Indicator type	Impact
Relevant hazards	Frost
Relevance (to sectors and CAROs)	
Potential data source/provider	DAFM
Data availability	Good: captured for forestry sector in National Forest Inventory every 4 years
Priority status	Watching brief

Indicator name/reference number	**Forest fires/Impact 32**
Description	Extent of forest fires due to wildfire events
Measurement unit	km^2
Indicator type	Impact
Relevant hazards	Wildfires
Relevance (to sectors and CAROs)	
Potential data source/provider	DAFM
Data availability	Fair: captured for forestry sector in National Forest Inventory every 4 years
Priority status	Watching brief

Indicator name/reference number	**Hectares lost to land degradation/Impact 33**
Description	Number of hectares lost to land degradation that includes soil erosion and nutrient loss
Measurement unit	ha
Indicator type	Impact
Relevant hazards	Drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc
Data availability	Fair: captured under Teagasc soil quality assessment work – threshold level important
Priority status	Watching brief

Indicator name/reference number	**Number of reported cases of water-borne diseases/Impact 34**
Description	Number of reported cases of water-borne diseases such as Verotoxigenic *E. coli* (VTEC)
Measurement unit	Case numbers
Indicator type	Impact
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	EPA/Health Service Executive
Data availability	Poor: current sampling methods not fit for purpose to test for VTEC. Health Service Executive special report (Kelly and Fallon, 2019) documents the issue of concern and makes recommendations
Priority status	Watching brief

Indicator name/reference number	**Road damage due to extreme heat/Impact 35**
Description	Road damage due to extreme heat – e.g. rutting (euro costs)
Measurement unit	m, euros
Indicator type	Impact
Relevant hazards	Extreme heat
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities and TII
Data availability	Fair: captured by local authority budget spends
Priority status	Watching brief

Implementation Indicators

Indicator name/reference number	**Actions implemented as recommended in Urb-ADAPT research project to mitigate against present and future extreme heat/Implementation 1**
Description	Building on research carried out for local and regional vulnerabilities and risks associated with key urban climate impacts in the Dublin area for other urban areas in Ireland
Measurement unit	Identifying local and regional vulnerabilities and risks associated with key urban climate impacts, now and in the future, and implementing a suite of adaptation options (short, medium and long term)
Indicator type	Implementation
Relevant hazards	Extreme heat
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/EPA research report
Data availability	Fair: Urb-ADAPT research project findings
Priority status	Priority

Indicator name/reference number	**Actions implemented as recommended in WINDRISK research project to mitigate against present and future windthrow tree fall risk/Implementation 2**
Description	Implement best practice findings from research carried out to mitigate against present and future windthrow tree fall risk
Measurement unit	Recommended actions
Indicator type	Implementation
Relevant hazards	Extreme wind
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc
Data availability	Fair: WINDRISK research project findings
Priority status	Priority

Indicator name/reference number	**Area of land rezoned by local authorities to avoid building on floodplains/ Implementation 3**
Description	Area of land rezoned to avoid building on floodplains
Measurement unit	km^2
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: captured by planning departments and under catchment flood risk assessment and management (CFRAM) schemes
Priority status	Priority

Indicator name/reference number	**Build internal adaptive capacity/Implementation 4**
Description	Build internal capacity by engaging in knowledge sharing and information exchange to increase awareness of climate and adaptation issues across departments and agencies
Measurement unit	Number of capacity building initiatives, staff engaged
Indicator type	Implementation
Relevant hazards	Cross-cutting
Relevance (to sectors and CAROs)	
Potential data source/provider	All local authorities, government departments and agencies
Data availability	Fair: data captured by human resource departments/PDMS (personal development management system)
Priority status	Priority

Indicator name/reference number	**Develop guidance for sectoral stakeholders to inform identification of critical transport assets, taking account of cross-sectoral interdependencies/Implementation 5**
Description	Develop guidance for sectoral stakeholders to inform identification of critical transport assets, taking account of cross-sectoral interdependencies – action from Critical Infrastructure Working Group
Measurement unit	Guidance developed/guidance in use
Indicator type	Implementation
Relevant hazards	Cross-cutting
Relevance (to sectors and CAROs)	
Potential data source/provider	Department of Transport
Data availability	Fair: guidance developed through co-development process
Priority status	Priority

Indicator name/reference number	**Establishment of National Flood Forecasting and Flood Monitoring Service/ Implementation 6**
Description	Establishment of National Flood Forecasting and Flood Monitoring Service – https://www.met.ie/review-of-hydrological-models
Measurement unit	Establishment of service
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	OPW/Met Éireann
Data availability	Good: available from OPW and Met Éireann
Priority status	Priority

Indicator name/reference number	**Implementation of (existing) Luas Severe Weather Management Plan to account for present and increasing high wind impact on power lines/Implementation 7**
Description	Implementation of (existing) Luas Severe Weather Management Plan to account for present and increasing high wind impacts on power lines – https://bit.ly/3jkPlgE
Measurement unit	Number of activations
Indicator type	Implementation
Relevant hazards	Extreme wind
Relevance (to sectors and CAROs)	
Potential data source/provider	Transdev (Luas Operator)
Data availability	Fair: captured by reporting by Transdev
Priority status	Priority

Indicator name/reference number	**Investment in coastal protection/management measures to mitigate impact of coastal erosion/Implementation 8**
Description	Extent of areas protected by and economic investment in coastal protection/management measures to mitigate the impacts of coastal erosion
Measurement unit	km^2, euros
Indicator type	Implementation
Relevant hazards	Coastal erosion and flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW/Department of Housing, Local Government and Heritage
Data availability	Fair: data available from providers above but consolidation needed
Priority status	Priority

Indicator name/reference number	**Investment in coastal protection/management measures to mitigate against coastal flooding/Implementation 9**
Description	Extent of areas protected by and economic investment in coastal protection/management measures to mitigate the impacts of coastal flooding
Measurement unit	km^2, euros
Indicator type	Implementation
Relevant hazards	Coastal erosion and flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW/Department of Housing, Local Government and Heritage
Data availability	Fair: data available from providers above but consolidation needed
Priority status	Priority

Indicator name/reference number	**Investment in irrigation schemes for agricultural land/Implementation 10**
Description	Economic investment in irrigation schemes for agricultural land, such as “dripper pipes”
Measurement unit	Euros
Indicator type	Implementation
Relevant hazards	Drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc/DAFM
Data availability	Fair: data available from DAFM and Teagasc
Priority status	Priority

Indicator name/reference number	**Investment in programmes to monitor and forecast coastal erosion/Implementation 11**
Description	Economic investment in programmes to monitor and forecast coastal erosion
Measurement unit	Euros
Indicator type	Implementation
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW/Department of Housing, Local Government and Heritage
Data availability	Fair: data available from providers above but consolidation needed
Priority status	Priority

Indicator name/reference number	**Mainstreaming of climate change adaptation into local authority operations/ Implementation 12**
Description	Mainstreaming of climate change adaptation into local authority operations through a series of incremental measures
Measurement unit	Captured through percentage full-time equivalent/climate action team established/climate action SPC/incorporation into training framework in PDMS
Indicator type	Implementation
Relevant hazards	Cross-cutting
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities
Data availability	Fair: data available from human resources and local authority reporting
Priority status	Priority

Indicator name/reference number	**Mainstream adaptation against extreme heat risk on rail network/Implementation 13**
Description	Mainstream adaptation against extreme heat risk on rail network in rail network management plans
Measurement unit	Incorporation of actions in management plans
Indicator type	Implementation
Relevant hazards	Extreme heat
Relevance (to sectors and CAROs)	
Potential data source/provider	Irish Rail and Transdev
Data availability	Fair: data available in rail network management plan reporting
Priority status	Priority

Indicator name/reference number	**Adaptation actions against overhead power line damage by high winds/ Implementation 14**
Description	Adaptation actions against overhead power line damage by high winds within EirGrid Business Continuity Plan
Measurement unit	Incorporation of actions in management plans
Indicator type	Implementation
Relevant hazards	Extreme wind
Relevance (to sectors and CAROs)	
Potential data source/provider	EirGrid
Data availability	Fair: data available within EirGrid Business Continuity Plan reporting. Case study information also available from published paper from EPA CIVIC report (Hawchar *et al*., 2020)
Priority status	Priority

Indicator name/reference number	**Monitor and report ongoing activities of Climate Change Oversight Group (CCOG) within the Department of Health/Implementation 15**
Description	Mainstreaming indicator to monitor and track actions by CCOG within Department of Health
Measurement unit	Documentation of activities and actions by the group
Indicator type	Implementation
Relevant hazards	Cross-cutting
Relevance (to sectors and CAROs)	
Potential data source/provider	Department of Health
Data availability	Fair: data available from Department of Health
Priority status	Priority

Indicator name/reference number	**Number and area of heat-resistant varieties of grass and crops grown/Implementation 16**
Description	Number and area of heat-resistant varieties of grass and crops grown. Heat-resistant varieties grown to help adapt agricultural practices to a warming climate
Measurement unit	Number and variety of grasses and crops
Indicator type	Implementation
Relevant hazards	Drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc
Data availability	Fair: data available from Teagasc research and development
Priority status	Priority

Indicator name/reference number	**Number/extent of native forestry projects on state-owned land to support flood water retention and biodiversity/Implementation 17**
Description	Number/extent of native forestry projects on state-owned land to support flood water retention and biodiversity
Measurement unit	km^2, number of schemes
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	DAFM
Data availability	Fair: data will be available from DAFM
Priority status	Priority

Indicator name/reference number	**Number of properties in river floodplains protected by existing measures/ Implementation 18**
Description	Number of properties in river floodplains protected by existing measures, hard and soft defences
Measurement unit	Number
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: local authority records and CFRAM schemes
Priority status	Priority

Indicator name/reference number	**Number of protected/vulnerable areas/Implementation 19**
Description	Number of protected/vulnerable areas to pluvial and fluvial flooding
Measurement unit	Number
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	OPW/local authorities
Data availability	Fair: local authority records and CFRAM schemes
Priority status	Priority

Indicator name/reference number	**Number of sustainable (urban) drainage systems (SUDs) in place/Implementation 20**
Description	Number of SUDs in place, where SUDs consist of a collection of water management practices that aim to align modern drainage systems with natural water processes by making urban drainage systems more compatible with components of the natural water cycle
Measurement unit	Number
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities
Data availability	Fair: detailed inventory of SUDs for Dublin case study region available through Smart Dublin/ Dublinked Open Data Store. Other local authorities also hold records of their SUDs schemes
Priority status	Priority

Indicator name/reference number	**Number of vulnerable priority heritage sites located in river floodplains/Implementation 21**
Description	Number of vulnerable heritage sites, including architectural and archaeological heritage, located in river floodplains. Note that some case study vulnerable sites are documented in the Built & Archaeological Heritage Climate Change Sectoral Adaptation Plan (https://assets.gov.ie/75639/a0ad0e1d-339c-4e11-bc48-07b4f082b58f.pdf)
Measurement unit	Number of sites
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: OPW and local authorities with CRFAM scheme flood map data have potential to map sites
Priority status	Priority

Indicator name/reference number	**Is proactive bridge maintenance in place to lessen or prevent flooding impact?/ Implementation 22**
Description	Proactive bridge maintenance as captured under EIRSPAN Asset Management Programme to lessen or prevent flooding impact
Measurement unit	Documented measures from management programme
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/Irish Rail/TII/National Roads Authority
Data availability	Fair: captured under EIRSPAN Asset Management Programme (https://www.tiipublications.ie/library/AM-STR-06054-01.pdf)
Priority status	Priority

Indicator name/reference number	**Is a proactive road drainage maintenance programme in place (to lessen or prevent flooding impact)?/Implementation 23**
Description	Proactive road drainage maintenance programme to lessen or prevent flooding impact through runoff and dewatering management actions. “Runoff” covers water flowing from the surface of the pavement via road shoulders and inner slopes to the ditches. “Dewatering” covers the collection and transport of water from the surface and structure of the road so that there will be no ponds on the road or in the ditches
Measurement unit	Documented measures from maintenance programme
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: coordination with OPW national arterial drainage maintenance activities
Priority status	Priority

Indicator name/reference number	**Proactive road drainage maintenance programme (to lessen or prevent coastal flooding impact)/Implementation 24**
Description	Proactive road drainage maintenance programme to lessen or prevent coastal flooding impact through runoff and dewatering management actions. “Runoff” covers water flowing from the surface of the pavement via road shoulders and inner slopes to the ditches. “Dewatering” covers the collection and transport of water from the surface and structure of the road so that there will be no ponds on the road or in the ditches
Measurement unit	Documented measures from maintenance programme
Indicator type	Implementation
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: coordination with OPW national arterial drainage maintenance activities
Priority status	Priority

Indicator name/reference number	**Proactive road maintenance programme (to lessen or prevent settling impact)/ Implementation 25**
Description	Proactive road maintenance programme to lessen or prevent settling impact, where settling impact is the sinking/deterioration of road surfaces as a result of being built on soft/limited foundations, such as roads constructed across bogland/wetlands
Measurement unit	Documented measures from maintenance programme
Indicator type	Implementation
Relevant hazards	Drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/TII/Department of Transport
Data availability	Fair: road condition captured under Pavement Surface Condition Index rating system
Priority status	Priority

Indicator name/reference number	**Progress actions of climate working group within COFORD/Implementation 26**
Description	Progress actions of climate working group within COFORD
Measurement unit	Documentation of activities and actions by the group
Indicator type	Implementation
Relevant hazards	Cross-cutting
Relevance (to sectors and CAROs)	
Potential data source/provider	COFORD
Data availability	Fair: managed by COFORD
Priority status	Priority

Indicator name/reference number	**Progress actions of Critical Infrastructure Working Group/Implementation 27**
Description	Progress actions of Critical Infrastructure Working Group coordinated by Department of Transport
Measurement unit	Documentation of activities and actions by the group
Indicator type	Implementation of actions
Relevant hazards	Cross-cutting
Relevance (to sectors and CAROs)	
Potential data source/provider	Department of Transport
Data availability	Fair: coordinated by Department of Transport
Priority status	Priority

Indicator name/reference number	**Review of the effectiveness of current quantitative data collection procedures for the impacts of extreme weather events/Implementation 28**
Description	Review of the effectiveness of current quantitative data collection procedures for the impacts of extreme weather events – to reach a set of standardised data collection procedures
Measurement unit	Co-creating a standardised set of agreed data collection procedures
Indicator type	Implementation
Relevant hazards	Cross-cutting
Relevance (to sectors and CAROs)	
Potential data source/provider	Department of Transport/CAROs/Local authorities
Data availability	Fair: coordinated by Department of Transport
Priority status	Priority

Indicator name/reference number	**Support national and regional initiatives to explore the consequences of climate change impacts on heritage, cultural and amenity sites and the potential for loss of tourism resources/Implementation 29**
Description	Support national and regional initiatives to explore the consequences of climate change impacts on heritage, cultural and amenity sites, and the potential for loss of tourism resources – as identified in the Cultural Heritage Climate Change Adaptation Plan
Measurement unit	Initiatives tracked and documented
Indicator type	Implementation
Relevant hazards	Cross-cutting
Relevance (to sectors and CAROs)	
Potential data source/provider	International Climate Heritage Network
Data availability	Fair: linking with the (international) Climate Heritage Network – on how heritage can help to engage stakeholders with climate action
Priority status	Priority

Indicator name/reference number	**Upskill farmers, foresters and fishermen to ensure they have the knowledge and tools required to implement climate adaptation practices/Implementation 30**
Description	Upskill farmers, foresters and fishermen to ensure they have the knowledge and tools required to implement climate adaptation practices as a climate change adaptation capacity building indicator
Measurement unit	Documented actions/programmes to upskill farmers, foresters or fishermen carried out in forestry and agriculture knowledge transfer groups
Indicator type	Implementation
Relevant hazards	Cross-cutting
Relevance (to sectors and CAROs)	
Potential data source/provider	COFORD/Teagasc/Irish Farmers' Association
Data availability	Fair: forestry and agriculture knowledge transfer groups – COFORD/Teagasc/Irish Farmers' Association
Priority status	Priority

Indicator name/reference number	**Vulnerability of protected habitats to flooding impacts/Implementation 31**
Description	Vulnerability of protected habitats to flooding impacts calculated through a vulnerability assessment exercise
Measurement unit	Habitat vulnerability rating
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	DCHG
Data availability	Fair: data available for area of restored peatlands – under the National Peatlands Strategy (NPWS, 2015)
Priority status	Priority

Indicator name/reference number	Number of private wells with water quality monitoring/Implementation 32
Description	Water quality monitoring for private wells (proxy – uptake of government-funded well improvement scheme)
Measurement unit	Number of improvement schemes funded
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Department of Housing, Local Government and Heritage
Data availability	Fair: data available from Rural Water Programme grants scheme
Priority status	Priority

Indicator name/reference number	Investment in agricultural education programmes to increase awareness of the value of maintaining soil organic carbon content above critical value/Implementation 33
Description	Investment in agricultural education programmes to increase awareness of value of maintaining soil organic carbon content above a critical value (2%) in agricultural land – based on Teagasc in-house soil organic carbon research
Measurement unit	Euros
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc
Data availability	Fair: Teagasc in-house soil organic carbon research
Priority status	Watching brief

Indicator name/reference number	Investment in the area of flood resilience/Implementation 34
Description	Economic investment in the area of flood resilience, where resilience is defined as the ability of communities to minimise damage and rapidly recover from the impacts of flooding. Note that investment in flood resilience will reduce flood damage; however, returns on investment will decline as flood resilience is established
Measurement unit	Number of communities, euros
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	OPW
Data availability	Fair: data available from OPW CFRAM schemes
Priority status	Watching brief

Indicator name/reference number	Investment in frost management education for foresters/Implementation 35
Description	Economic investment in frost management education programmes for foresters
Measurement unit	Number of programmes and participants
Indicator type	Implementation
Relevant hazards	Frost
Relevance (to sectors and CAROs)	
Potential data source/provider	COFORD
Data availability	Fair: data available from COFORD reporting
Priority status	Watching brief

Indicator name/reference number	**Number of education/training programmes on fire prevention/Implementation 36**
Description	Number of education/training programmes on fire prevention as measure of adaptive capacity
Measurement unit	Number of programmes and participants
Indicator type	Implementation
Relevant hazards	Wildfires
Relevance (to sectors and CAROs)	
Potential data source/provider	DAFM/Irish Farmers' Association
Data availability	Fair: available from DAFM/Irish Farmers' Association reporting
Priority status	Watching brief

Indicator name/reference number	**Number of forestry fire plans in place/Implementation 37**
Description	Number of forestry fire plans in place as a measure of adaptive capacity
Measurement unit	Number of plans
Indicator type	Implementation
Relevant hazards	Wildfires
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc and COFORD
Data availability	Fair: Teagasc and COFORD reporting
Priority status	Watching brief

Indicator name/reference number	**Number of properties located in river floodplains/Implementation 38**
Description	Number of private and commercial properties located in river floodplains
Measurement unit	Number of properties
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: local authority records and CFRAM schemes
Priority status	Watching brief

Indicator name/reference number	**Percentage of river embankments that include height to protect against future flood risk/Implementation 39**
Description	Percentage of river embankments that include height to protect against future flood risk, where an embankment is an artificial bank raised above the immediately surrounding land to redirect or prevent flooding by a river
Measurement unit	Percentage
Indicator type	Implementation
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: data available from local authorities and OPW
Priority status	Watching brief

Indicator name/reference number	**Use of stiffer binder in roads exposed to high temperatures/Implementation 40**
Description	Area of use of stiffer binder in roads exposed to high temperatures to increase the ability of roads to withstand extreme heat and avoid melting
Measurement unit	km^2
Indicator type	Implementation
Relevant hazards	Extreme heat
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/TII
Data availability	Fair: local authority and TII budget records
Priority status	Watching brief

Outcome Indicators

Indicator name/reference number	**Change in area of land rezoned by local authorities to avoid building on floodplains/ Outcome 1**
Description	Change in area of land rezoned by local authorities to avoid building on floodplains, where land is rezoned from residential or commercial use to other land uses
Measurement unit	km^2
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities
Data availability	Fair: captured by local authority planning departments
Priority status	Priority

Indicator name/reference number	**Change in coastal erosion impacts on built heritage as a result of investment in coastal protection/management measures to mitigate impact of coastal erosion/Outcome 2**
Description	Capturing the change in damage costs of coastal erosion impacts on built heritage as a result of economic investment in coastal protection/management measures to mitigate impact of coastal erosion
Measurement unit	Euros
Indicator type	Outcome
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: case study research under way in the Dublin area by the Geological Survey of Ireland
Priority status	Priority

Indicator name/reference number	**Change in coastal erosion impacts on protected habitats and species as a result of investment in coastal protection/management measures to mitigate impact of coastal erosion/Outcome 3**
Description	Measures change in coastal erosion impacts on protected habitats and species (habitat condition and species impacts) as a result of economic investment in coastal protection/ management measures to mitigate impact of coastal erosion
Measurement unit	Habitat condition and species numbers
Indicator type	Outcome
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	DCHG
Data availability	Good: coastal protected habitats and species data available under Article 17 of the Habitats Directive reporting
Priority status	Priority

Indicator name/reference number	**Change in damage costs incurred by rail due to coastal erosion as a result of coastal protection/management measures/Outcome 4**
Description	A measurement of change in economic costs incurred by rail due to coastal erosion as a result of coastal protection/management measures
Measurement unit	Euros
Indicator type	Outcome
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Irish Rail/Transdev
Data availability	Fair: captured by Irish Rail/Transdev
Priority status	Priority

Indicator name/reference number	**Change in agricultural losses reported as a result of drought/Outcome 5**
Description	Captures change in economic costs of agricultural losses reported as a result of drought
Measurement unit	Euros
Indicator type	Outcome
Relevant hazards	Drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc/DAFM
Data availability	Fair: captured in Teagasc Situation and Outlook reporting/DAFM reporting
Priority status	Priority

Indicator name/reference number	**Change in extent and grade of damage to roads due to coastal flooding as a result of proactive road drainage maintenance programme/Outcome 6**
Description	Measures the change in extent (km^2) and grade of damage to roads due to coastal flooding as a result of proactive road drainage maintenance programme
Measurement unit	km^2, level of damage
Indicator type	Outcome
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/TII/Department of Transport
Data availability	Fair: road condition captured under Pavement Surface Condition Index rating system
Priority status	Priority

Indicator name/reference number	**Change in impact on power lines as a result of implementation of Luas Severe Weather Management Plan/Outcome 7**
Description	Captures change in economic impact on power lines as a result of implementation of Luas Severe Weather Management Plan
Measurement unit	Euros
Indicator type	Outcome
Relevant hazards	Extreme wind
Relevance (to sectors and CAROs)	
Potential data source/provider	Transdev (Luas Operator)
Data availability	Fair: captured by reporting by Transdev
Priority status	Priority

Indicator name/reference number	**Change in incidence of other vegetation fires/Outcome 8**
Description	Captures change in incidence of and area impacted by other vegetation fires; normally fires on scrub, farm or marginal land
Measurement unit	km^2, number
Indicator type	Outcome
Relevant hazards	Wildfires
Relevance (to sectors and CAROs)	
Potential data source/provider	Local Authorities/DAFM
Data availability	Fair: limited data kept by landowners, local authorities and DAFM
Priority status	Priority

Indicator name/reference number	**Change in number/extent of native forestry projects on state-owned land to support flood water retention and biodiversity/Outcome 9**
Description	Captures change in number/extent of native forestry projects on state-owned land to support flood water retention and biodiversity
Measurement unit	km^2, number of schemes
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	DAFM
Data availability	Fair: data will be available from DAFM
Priority status	Priority

Indicator name/reference number	**Change in number of people impacted by heatwave events as a result of Heatwave Response Plan implementation/Outcome 10**
Description	Captures change in number of people impacted by heatwave events as a result of Heatwave Response Plan implementation – especially relevant for hospitals and nursing homes
Measurement unit	Change in number of people
Indicator type	Outcome
Relevant hazards	Extreme heat
Relevance (to sectors and CAROs)	
Potential data source/provider	Department of Health/Department of Housing, Planning and Local Government
Data availability	Poor: potential lead agencies – Department of Health, Department of Housing, Planning and Local Government
Priority status	Priority

Indicator name/reference number	**Change in number of properties at flood risk due to construction of new or enhanced coastal defences/Outcome 11**
Description	Captures change in number of properties at flood risk due to construction of new or enhanced coastal defences, including soft and hard defensive measures
Measurement unit	Change in number of properties
Indicator type	Outcome
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/insurance companies/OPW
Data availability	Fair: captured by local authorities/insurance claim data/OPW and other relevant agencies
Priority status	Priority

Indicator name/reference number	**Change in number of sustainable (urban) drainage systems (SUDs) in place/Outcome 12**
Description	Change in number of SUDs in place, where SUDs consist of a collection of water management practices that aim to align modern drainage systems with natural water processes by making urban drainage systems more compatible with components of the natural water cycle
Measurement unit	Number
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities
Data availability	Fair: detailed inventory of SUDs for Dublin case study region available through Smart Dublin/ Dublinked Open Data Store. Other local authorities also hold records of their SUDs schemes
Priority status	Priority

Indicator name/reference number	**Change in number of vulnerable priority heritage sites located in river/coastal floodplains/Outcome 13**
Description	Captures change in number of vulnerable heritage sites, including architectural and archaeological sites located in river/coastal floodplains. Note that some case study vulnerable sites are documented in the Built & Archaeological Heritage Climate Change Sectoral Adaptation Plan (https://assets.gov.ie/75639/a0ad0e1d-339c-4e11-bc48-07b4f082b58f.pdf)
Measurement unit	Change in number
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: OPW and local authorities with CRFAM/flood maps data have potential to map sites
Priority status	Priority

Indicator name/reference number	**Change in overhead power line damage by high winds/Outcome 14**
Description	Change in overhead power line damage by high winds within EirGrid Business Continuity Plan
Measurement unit	Euros
Indicator type	Outcome
Relevant hazards	Extreme wind
Relevance (to sectors and CAROs)	
Potential data source/provider	EirGrid
Data availability	Fair: data available within EirGrid Business Continuity Plan reporting. Case study information also available from published paper from EPA CIVIC report (Hawchar *et al*., 2020)
Priority status	Priority

Indicator name/reference number	Change in protected/vulnerable areas/Outcome 15
Description	Captures change in protected/vulnerable areas – prioritising assets such as roads, essential services
Measurement unit	Change in area/specific assets
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	OPW/local authorities
Data availability	Fair: local authority records and CFRAM schemes
Priority status	Priority

Indicator name/reference number	Change in rail network damage due to extreme heat as a result of climate mainstreaming in rail network management plans/Outcome 16
Description	Captures change in rail network economic damage due to extreme heat as a result of climate mainstreaming in rail network management plans
Measurement unit	Change in costs (euros)
Indicator type	Outcome
Relevant hazards	Extreme heat
Relevance (to sectors and CAROs)	
Potential data source/provider	Irish Rail/Transdev (Luas and DART Services)
Data availability	Fair: data held Irish Rail and Transdev
Priority status	Priority

Indicator name/reference number	Change in road settling impact as a result of proactive road maintenance programme/ Outcome 17
Description	Change in road settling impact as a result of proactive road maintenance programme where settling impact is the sinking/deterioration of road surfaces as a result of being built on soft/ limited foundations such as roads constructed across bogland/wetlands
Measurement unit	Change in cost (euros)
Indicator type	Outcome
Relevant hazards	Drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/TII/Department of Transport
Data availability	Fair: road condition captured under Pavement Surface Condition Index rating system
Priority status	Priority

Indicator name/reference number	Change in vulnerability of protected habitats to flooding impacts/Outcome 18
Description	Change in vulnerability of protected habitats to flooding impacts calculated through a vulnerability assessment exercise
Measurement unit	Habitat vulnerability rating
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	DCHG
Data availability	Fair: data available for area of restored peatlands – under the National Peatlands Strategy (NPWS, 2015)
Priority status	Priority

Indicator name/reference number	**Number of climate-adapted bridges/Outcome 19**
Description	Number of climate-adapted bridges, where climate adaptation is associated with strengthened and improved structures
Measurement unit	Number and measures taken
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/TII
Data availability	Fair: captured under bridge maintenance programme (under EIRSPAN Asset Management Programme: https://www.tiipublications.ie/library/AM-STR-06054-01.pdf)
Priority status	Priority

Indicator name/reference number	**Operational National Flood Forecasting and Flood Monitoring Service/Outcome 20**
Description	Operational National Flood Forecasting and Flood Monitoring Service
Measurement unit	Impact of service (measured through additional active interventions/warnings issued as a result of the service)
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	OPW/Met Éireann
Data availability	Good: available from OPW and Met Éireann
Priority status	Priority

Indicator name/reference number	**Percentage change in road flooding impacts/Outcome 21**
Description	Captures percentage change in road flooding impacts, such as surface damage, deposits of debris
Measurement unit	Percentage change in reported impacts
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: coordination with OPW national arterial drainage maintenance activities
Priority status	Priority

Indicator name/reference number	**Change in coastal erosion damage to property as a result of coastal protection/ management measures/Outcome 22**
Description	Change in economic cost of coastal erosion damage to property as a result of coastal protection/management measures
Measurement unit	Euros
Indicator type	Outcome
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW/Department of Housing, Planning and Local Government
Data availability	Fair: data available from providers above but consolidation needed
Priority status	Watching brief

Indicator name/reference number	**Change in coastal flooding impacts on built heritage as a result of construction of new or enhanced coastal defences/Outcome 23**
Description	Captures change in coastal flooding damage cost impacts on built heritage as a result of construction of new or enhanced coastal defences
Measurement unit	Euros
Indicator type	Outcome
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/Geological Survey of Ireland
Data availability	Fair: case study research underway in the Dublin area by the Geological Survey of Ireland
Priority status	Watching brief

Indicator name/reference number	**Change in damage costs incurred by rail due to coastal flooding as a result of investment in coastal protection/management measures/Outcome 24**
Description	Change in damage costs incurred by rail due to coastal flooding as a result of investment in coastal protection/management measures
Measurement unit	Euros
Indicator type	Outcome
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Irish Rail/Transdev
Data availability	Fair: captured by Irish Rail/Transdev
Priority status	Watching brief

Indicator name/reference number	**Change in economic impact of frost on forestry/Outcome 25**
Description	Captures change in economic impact of frost on forestry
Measurement unit	Euros
Indicator type	Outcome
Relevant hazards	Frost
Relevance (to sectors and CAROs)	
Potential data source/provider	DAFM
Data availability	Fair: captured for forestry sector in National Forest Inventory every 4 years
Priority status	Watching brief

Indicator name/reference number	**Change in extent of damage to roads due to coastal erosion as a result of coastal protection/management measures/Outcome 26**
Description	Captures change in extent of damage to roads due to coastal erosion as a result of coastal protection/management measures including hard and soft defences
Measurement unit	Change in km^2
Indicator type	Outcome
Relevant hazards	Coastal flooding and erosion
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/TII
Data availability	Fair: data available from TII
Priority status	Watching brief

Indicator name/reference number	**Change in forest fire impacts as a result of fire plans/Outcome 27**
Description	Change in forest fire impacts in terms of area and economic cost as a result of fire plans
Measurement unit	km^2, euros
Indicator type	Outcome
Relevant hazards	Wildfires
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc/COFORD/DAFM
Data availability	Fair: records kept by Teagasc/COFORD/DAFM
Priority status	Watching brief

Indicator name/reference number	**Change in incidence of road settling impact as a result of proactive road maintenance programme/Outcome 28**
Description	Change in incidence of road settling impact as a result of proactive road maintenance programme to reduce impacts of pluvial and fluvial flooding
Measurement unit	km^2
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/TII/Department of Transport
Data availability	Fair: road condition captured under Pavement Surface Condition Index rating system
Priority status	Watching brief

Indicator name/reference number	**Change in incidence of water-borne diseases as a result of drinking water improvement/Outcome 29**
Description	Change in incidence of water-borne diseases as a result of drinking water improvement
Measurement unit	Change in cases reported
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/Department of Health
Data availability	Fair: data available from local authority/Department of Health records
Priority status	Watching brief

Indicator name/reference number	**Change in investment in flood resilience/Outcome 30**
Description	Change in economic investment in flood resilience
Measurement unit	Euros
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	OPW
Data availability	Fair: investment records held by OPW
Priority status	Watching brief

Indicator name/reference number	**Change in road surface melting impact due to use of stiffer binder in road surfacing/ Outcome 31**
Description	Change in road surface melting impact (euros) due to use of stiffer binder in road surfacing. Note that use of stiffer binder in roads exposed to high temperatures increases the ability of roads to withstand extreme heat and avoid melting
Measurement unit	km^2
Indicator type	Outcome
Relevant hazards	Extreme heat
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/TII
Data availability	Fair: local authority and TII budget records
Priority status	Watching brief

Indicator name/reference number	**Change in soil organic carbon content in agricultural land/Outcome 32**
Description	Change in soil organic carbon content (%) in agricultural land
Measurement unit	Percentage change
Indicator type	Outcome
Relevant hazards	Drought
Relevance (to sectors and CAROs)	
Potential data source/provider	Teagasc
Data availability	Fair: based on in-house Teagasc soil organic carbon research
Priority status	Watching brief

Indicator name/reference number	**Change in windthrow tree fall due to implemented mitigation actions/Outcome 33**
Description	Change in windthrow tree fall due to implemented mitigation actions
Measurement unit	Change in volume (m^3), cost (euros)
Indicator type	Outcome
Relevant hazards	Extreme wind
Relevance (to sectors and CAROs)	
Potential data source/provider	DAFM
Data availability	Fair: captured for forestry sector in National Forest Inventory every 4 years
Priority status	Watching brief

Indicator name/reference number	**Extent of roads maintained (to lessen or prevent settling impact)/Outcome 34**
Description	Extent of roads maintained (to lessen or prevent settling impact)
Measurement unit	km^2
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/TII/Department of Transport
Data availability	Fair: road condition captured under Pavement Surface Condition Index rating system
Priority status	Watching brief

Indicator name/reference number	**Percentage change in number of properties located in river floodplain/Outcome 35**
Description	Percentage change in number of properties located in river floodplain
Measurement unit	Percentage change
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: floodplains captured under flood maps, i.e. local authorities can calculate in conjunction with their planning departments
Priority status	Watching brief

Indicator name/reference number	**Percentage change in embankments that include height to protect against future flood risk/Outcome 36**
Description	Percentage change in embankments that include height to protect against future flood risk
Measurement unit	Percentage change
Indicator type	Outcome
Relevant hazards	Pluvial and fluvial flooding
Relevance (to sectors and CAROs)	
Potential data source/provider	Local authorities/OPW
Data availability	Fair: data available from local authorities and OPW
Priority status	Watching brief

Appendix 2 Supporting Tables Providing Details on CAROs and Stakeholders Consulted

Table A2.1. The four CARO regions, constituent local authorities and associated lead authorities

CARO	Constituent authorities	Lead authority	Details
Atlantic Seaboard North	Donegal, Galway City, Galway County, Sligo, Mayo	Mayo County Council	The Atlantic Seaboard North Region has a population of approximately 600,000, with 305,000 people residing within 5 km of the coastline. Mayo County Council is the lead authority for the Atlantic Seaboard North region. The largest urban area in the region is Galway (population 80,000), followed by Sligo (population 19,200) and Castlebar (population 12,000). The region is characterised by an extensive coastline, large areas of blanket bog and other wetlands, and the Rivers Shannon, Moy and Corrib. It also contains several large lakes, among them Lough Corrib, Lough Mask and Lough Conn. The priority climate hazards identified by the Atlantic Seaboard North CARO were coastal flooding, storms, groundwater flooding and rural flooding
Atlantic Seaboard South	Clare, Cork City, Cork County, Kerry, Limerick	Cork County Council	The population of the region is approximately one million. Two major cities, Cork (population 208,000) and Limerick (population 94,000) are located in coastal areas within the region. The tidal area of the River Shannon (Shannon estuary) is found in Limerick. Cork County Council is the CARO lead authority for the region. The priority hazards identified in the Atlantic Seaboard South region were sea level rise, coastal flooding, storms, groundwater flooding and rural pluvial flooding
Eastern and Midlands	Carlow, Cavan, Kildare, Kilkenny, Laois, Leitrim, Longford, Louth, Meath, Monaghan, Offaly, Roscommon, Tipperary, Waterford, Westmeath, Wexford, Wicklow	Kildare County Council	Kildare County Council is the lead county for the Eastern and Midlands CARO. The Eastern and Midlands region was established based on topographical and climatic risk and consists of 17 of the 31 local authority areas, with a total population of approximately 1.6 million. The region includes the flat and fertile Midlands, with some hill country, especially in its southern half, notably the Wicklow Mountains just south of Dublin. The priority climate hazards in the Eastern and Midlands CARO focus on pluvial, fluvial and groundwater flooding, as well as coastal flooding and erosion in counties Wexford, Wicklow and Louth
Dublin Metropolitan	South Dublin, Fingal, Dún Laoghaire-Rathdown, Dublin City	Dublin City Council	Dublin Metropolitan Regional Office is managed by a consortium of the four Dublin local authorities, with Dublin City Council acting as the lead authority. Dublin, situated on a bay on the east coast at the mouth of the River Liffey, has an urban population of 1.2 million and a Greater Dublin Area population of 1.9 million. It covers 115 km^2 and is bordered by the Wicklow Mountains to the south and surrounded by flat farmland to the north and west. The priority climate hazards in the Dublin Metropolitan CARO are identified as urban pluvial flooding and extreme events linked with extreme heat and cold, including urban heatwaves

Table A2.2. Government departments and agencies consulted as part of the PCAS project

Department/agency	Role
OPW	The OPW is the lead organisation for flood risk management in Ireland. The OPW produces flood maps that provide a detailed picture of flood risk for a range of flood event scenarios, including climate change. The first Climate Change Sectoral Adaptation Plan for Flood Risk Management was produced by the OPW in 2015 under the mandate of the National Climate Change Adaptation Framework (DECLG, 2012). A new plan was prepared in 2019 under the NAF and as a key action under the Climate Action Plan 2019; it updates the 2015 plan and takes into account new information available on climate change and its potential impacts and developments in flood risk
DAFM	The department aims to develop a vibrant and sustainable agri-food sector, while continuing to play its part in reducing Ireland's greenhouse gas emissions. The Agriculture, Forest and Seafood Climate Change Sectoral Adaptation Plan sets out the projected changes in climate, focusing on those identified as most likely to affect the agriculture, forest and seafood sector
Department of Health	Under the NAF (2018) and the Climate Action and Low Carbon Development Act 2015, the department produced the first Climate Change Adaptation Plan for the health sector. The plan identifies the main climate change-related impacts and risks the health sector expects to face, and identifies concrete measures to build resilience and reduce vulnerabilities
DCHG and National Parks and Wildlife Service	The department has prepared two climate change sectoral adaptation plans to address the impacts of climate change on Ireland's heritage. The adaptation plans for biodiversity and for the built and archaeological heritage have been written in accordance with the Sectoral Planning Guidelines for Climate Change Adaptation produced by the DCCAE
DTTAS	The first adaptation plan for the transport sector, Developing Resilience to Climate Change in the Irish Transport Sector, was published in November 2017. The plan outlines climate research and analysis on the likely impacts of climate change on transport – including more frequent storm events, rising sea levels and increased incidents of flooding. The plan also highlights the positive ongoing work in climate change adaptation in the transport sector and other sectors
Met Éireann	Met Éireann works in measuring past and current climate, as well as helping to predict Ireland's future climate. The agency highlights the cooperation that is required at a national, European and global level when it comes to climate science, and examines how this knowledge helps Ireland make important decisions now
Irish Water	Irish Water is committed to using the best available techniques to assess the vulnerability of water and wastewater services to climate change
EPA	The EPA aims to be a leader in the climate debate in Ireland and provide up-to-date scientific information to a range of audiences, from policymakers to the general public. Its 2014–2020 research programme is framed by the vision of Ireland's transition to a carbon-neutral, low-emission and climate-resilient society and economy by 2050, as well as being a source of climate change information and solutions

AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL
Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

Eolas: *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

Ár bhFreagrachtaí

Ceadúnú
Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:
- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha)*;
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil
- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Uisce
- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol
- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Tháscairí)*.

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn
- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

Taighde agus Forbairt Comhshaoil
- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta
- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

Cosaint Raideolaíoch
- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas
- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol *(m.sh. Timpeall an Tí, léarscáileanna radóin)*.
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta
- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil
Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:
- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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Policy Coherence in Adaptation Studies: Selecting and Using Indicators of Climate Resilience

Authors: Stephen Flood, Ned Dwyer and Jeremy Gault

Identifying Pressures

Adaptation action is now urgently needed to reduce the social, economic and environmental impacts of present and future climate change to ensure resilience to both extreme and slow-onset events under a changing climate. The need for action necessitates a systematic understanding and measurement of key indicators of climate resilience. Indicators are needed that measure, monitor, track and communicate climate resilience by demonstrating the state or trend of certain environmental or societal conditions in a given area and over a specified period of time. These indicators need to address local and national strategic priorities and hazards. They need to be scalable from a local to a national context and they need to be appropriate for reporting at national and EU levels as well as for international agreements. This should ensure that progress on adaptation to climate change can be reviewed and updated regularly and systematically, as well as being delivered in a format that is understandable and usable by decision-makers.

Informing Policy

The National Adaptation Framework (NAF), published in 2018, provides a strategic policy focus to ensure that adaptation measures are taken across all sectors and levels of governance to increase Ireland's preparedness for, and reduce vulnerability to, impacts of climate change. To track progress in implementing adaptation actions and, more importantly, to evaluate the outcomes of such actions, it is necessary to ensure that a monitoring, reporting and evaluation (MRE) system is in place. Climate adaptation indicators, when properly designed and implemented, are valuable measures to incorporate into any MRE system and can provide information on the level of resilience of the system. Therefore, indicators have a potential role in reporting progress in relation to implementation of the sectoral adaptation plans and local authority adaptation strategies. There is a strong potential policy alignment of climate change adaptation monitoring and evaluation with emergency management planning, and sustainable development, in the context of developing green infrastructure and sustainable planning.

Developing Solutions

This project combines an analysis of international best practice and approaches to the development of climate adaptation indicators, co-designed by key stakeholder representatives from relevant state agencies and regional and national government, to identify a tailored suite of Ireland-relevant climate adaptation indicators. A literature analysis focused on both European and international approaches to understand the criteria that should be applied to the identification and selection of climate adaptation indicators. Priority climate hazards were identified, through a process of review and stakeholder consultation, as relating to sea level rise and coastal storms, pluvial and fluvial flooding, and extreme events (extreme heat, extreme wind, wildfires, drought and frost). The outcome of the co-design process was the identification of a suite of 127 recommended indicators – 15 are climatological indicators, 23 are impact indicators, 32 are implementation indicators and 21 are outcome indicators. Ninety-one of these indicators were identified as priority. A full list of indicators is tabulated in the report, with a description of each indicator, its sectoral relevance, potential data source, data availability and priority.

EPA Research: McCumiskey House,
Richiew, Clonskeagh, Dublin 14.

Phone: 01 268 0100
Twitter: @EPAResearchNews
Email: research@epa.ie

www.epa.ie

EPA Research Webpages
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