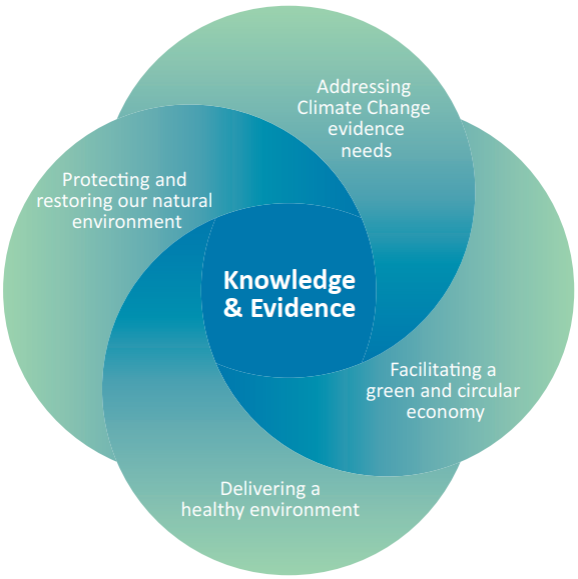
EPA Research 2030

Discussion Document supporting the

2021–2023 Thematic Research Areas Assessment



Putting science and innovation at the centre of environmental protection in Ireland through the development and proactive transfer of knowledge

March 2021

The EPA Research Programme is a Government of Ireland initiative funded by the Department of the Environment, Climate and Communications.

Contents

Abbreviations

AMR	Antimicrobial resistance
CAP	Common Agricultural Policy
CCAC	Climate Change Advisory Council
CEC	Contaminant of emerging concern
DCCAE	Department of Communications, Climate Action and Environment
EEA	European Environment Agency
END	Environment Noise Directive
EPA	Environmental Protection Agency
ETS	Emissions Trading System
EU	European Union
GCOS	Global Climate Observation System
GHG	Greenhouse gas
GMO	Genetically modified organism
HFC	Hydrofluorocarbon
ICOS	Integrated Carbon Observing System
ICT	Information and communications technology
IED	Industrial Emissions Directive
iNAP	Ireland National Action Plan
IPCC	Intergovernmental Panel on Climate Change
JPI	Joint Programming Initiative
LULUCF	Land use, land use change and forestry
MARPOL	International Convention for the Prevention of Pollution from Ships
MSFD	Marine Strategy Framework Directive
MSPD	Maritime Spatial Planning Directive
MSW	Municipal solid waste
NAF	National Adaptation Framework
NEC	National Emissions Ceiling Directive
NIR	Non-ionising radiation
NRCS	National Radon Control Strategy
OSi	Ordnance Survey of Ireland
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PFAs	Polyfluorinated alkyl substances
PM	Particulate matter
POP	Persistent organic pollutant
RBMP	River Basin Management Plan
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SDG	Sustainable Development Goal
SEA	Strategic environmental assessment
SMEs	Small and medium-sized enterprises
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WEEE	Waste electrical and electronic equipment
WFD	Water Framework Directive
WHO	World Health Organization

Context

Ireland is faced with new opportunities for protecting the environment, which has never been so central to national and European policy, as evidenced by the publication of the European Union (EU)'s European Green Deal, which is supported by the proposal for the 8th Environmental Action Programme calling for active engagement of all stakeholders at all levels of governance to ensure that EU climate and environment laws are effectively implemented. It also forms the EU's basis for achieving the United Nations 2030 Agenda and Sustainable Development Goals (SDGs).

There are, however, significant environmental challenges across all sectors of the economy and society, which are having an adverse impact on our wellbeing and on the health of the ecosystems we depend on. There are emerging risks too, e.g. exposure to new chemicals, contaminants of emerging concern (CECs), nanomaterials, zoonoses and antimicrobial resistance (AMR), that are not well understood. These existing thematic and sectoral challenges, both current and emerging, are well described in the recently published EPA State of the Environment Report 2020: *Ireland's Environment: An Integrated Assessment*[1].

Research is needed to support national efforts to achieve many of the targets set out in EU environmental directives. The EPA emphasises the implementation and enforcement of environmental policies through its key activities of monitoring, assessment and reporting and its regulatory role. For these activities to be effective and timely, evidence-based knowledge should be produced and transferred to support robust decision-making, behaviour change and policy development. An integrated and holistic approach underpinned by collaboration will be required in responding to the challenges identified. Robust and credible evidence-based research that is actionable and transferable will be key in helping to address these challenges.

Against a backdrop of climate change, resource limitations, poor consumption practices, diffuse pollution and ecosystem and biodiversity deterioration, the overarching national and global challenge is the need for urgent, pragmatic solutions and transformative systemic change to respond to local, national and international socio-economic and environmental challenges that will deliver a "just transition" for all. The unequal distribution of costs and benefits arising from systemic change requires greater understanding, citizen engagement, integration and effective responses. Accordingly, the transition will require the deployment of new models of engagement between citizens, sectors and regions by 2025, as outlined in the Programme for Government 2020 "Our Shared Future"[2]. EPA Research actively encourages the inclusion of citizen science as part of its funded research projects and will continue to do so.

Engaging with EU structures and processes, including Copernicus[3] and the European Strategic Framework for Research Infrastructures (ESFRI)[4], as well as with other relevant consortia, such as the European Research Infrastructure Consortium (ERIC)[5], will be required to ensure that Ireland has the research capacity to respond to these questions.

The importance of strong and cohesive partnerships and networks that allow for capacity building and developing expertise, as well as timely evidence-based knowledge transfer, is well recognised by the EPA and needs to be further strengthened. Collaborative and multidisciplinary research across all the sectors of society and the economy will be necessary to address the nature and scale of the systemic challenges being faced by society and to deliver on the "vision" of putting science and innovation at the centre of environmental protection in Ireland through the development and proactive transfer of knowledge.

[1] http://www.epa.ie/irelandsenvironment/stateoftheenvironmentreport/
[2] The Programme for Government 2020 "Our Shared Future
[3] https://www.copernicus.eu/en
[4] https://www.esfri.eu/esfri-roadmap
[5] https://ec.europa.eu/info/research-and-innovation/strategy/european-research-infrastructures/eric_en

EPA Research 2030

EPA Research 2030 is the ten-year high-level framework for the EPA's research programming over the period 2021–2030, designed to be agile, responsive and flexible.

EPA Research 2030 is built around four interconnected research hubs (**Figure 1**). The EPA Research 2030 thematic structure will bring an integrated and cross-sectoral approach, enabling holistic management and protection of our environment.

Consideration, understanding and acknowledgement of the interactions between social, behavioural and economic factors, as an integral component of environmental research, will lead to enhanced governance and more effective implementation of environmental policies and strategies.

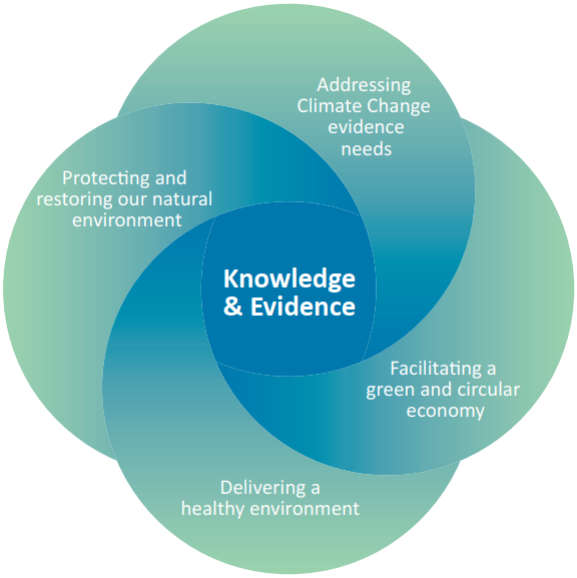


Figure 1: EPA Research 2030 thematic structure

EPA Research 2030 will be flexible, and emerging issues will be covered as required under the most relevant research hub. The research areas under each hub will evolve to accommodate emerging challenges, policy needs, and knowledge and evidence gaps. EPA Research 2030 will generate evidence crucial in assisting Ireland in meeting its commitments and requirements under the various international, European and national policies and strategies (**Figure 2**).

Environmental policies must be underpinned by an in-depth level of knowledge that needs to be delivered through a systematic programme of environmental research and assessment. Research can play an important role by generating evidence that will support the design of effective and robust policy, evaluate its outcomes and impact, and demonstrate its value.

This document is the Discussion Document supporting the EPA Research 2030: 2021–2023 Thematic Research Areas Assessment.

It was developed following an extensive consultation process in 2020[6], based on a review of medium to longer term policy needs, ongoing research funded by the EPA, consultation with relevant government departments and agencies, and alignment with the key activities of the EPA.

This document was finalised following the discussions and feedback received during the "Towards EPA Research 2030" online workshop (28 October 2020).

[6] www.epa.ie/researchandeducation/research/researchstrategy/consultationforeparesearch2030framework/

	National	European Regulations & Policies	Global
Radiation	• Ionising Radiation Regulations 2019 • National Radon Control Strategy • Radioactive (Substances in Drinking Water) Regulations 2016 • S.I. No. 190/2019 - Radiological Protection Act 1991 (Non-Ionising Radiation) Order 2019	• Basic safety standards • Euratom Drinking Water Directive • EC Recommendation from 1999 on the limitation of exposure of the general public to electromagnetic fields	• OSPAR Radioactive Substances Strategy • International Commission on Non-Ionizing Radiation Protection Guidelines • WHO Electromagnetic fields Project
Climate Action	• Climate Action Plan • National Adaptation Framework • National Policy Position on Climate Action and Low Carbon Development • **National Energy and Climate Plan (2021-2030)** • **Climate Action and Low Carbon Development (Amendment) Bill 2020** • Ag Climatise – National Climate & Air Roadmap for the Agriculture Sector	• **EU Climate Pact** • **EU Climate Law** • **2030 Climate and Energy Framework** • Climate & Energy Package • Emissions Trading Directive • Effort Sharing Regulation • Floods Directive 2017 • EU Strategy on Adaptation to Climate Change • **2030 Climate Target Plan** • **New EU strategy on Adaptation to Climate Change** • Integrated European Union policy for the Arctic • LULUCF Regulations	• Paris Agreement • United Nations Framework Convention on Climate Change (UNFCCC) • Montreal Protocol
Water Quality	• River Basin Management Plan • Marine Strategy Framework Directive Programme of Measures • Quality of Shellfish Waters Regulations • Drinking Water Regulations • Good Agricultural Practice for Protection of Waters Regulations 2018 • **Revised 5th Nitrates Action programme** • **Common Agricultural Policy (CAP) 2020** • Radioactive (Substances in Drinking Water) Regulations 2016	• Water Framework Directive • Marine Strategy Framework Directive • Bathing Water Directive • Groundwater Directive • Drinking Water Directive • Nitrates Directive • Urban Wastewater Treatment Directive • Floods Directive 2017 • EU Common Fisheries Policy 2014 • Euratom Drinking Water Directive	• OSPAR Convention • MARPOL Convention
Soils/ Land Use	• FoodWise2025 • Tourism Action Plan • Agri-Food 2030 Strategy • **Common Agricultural Policy (CAP) 2020** • **Revised 5th Nitrates Action Programme**	• LULUCF Regulations • A sustainable Bioeconomy for Europe • **EU Forest Strategy** • 2030 Farm to Fork Strategy • Sewage Sludge Directive (86/278/ EEC) • Sustainable Use of Pesticides Directive	• UN SDG Goals 2 & 15
Air Quality & Noise	• National Air Pollution Control Programme • **National Clean Air Strategy** • Environmental Noise Regulations SI 549 of 2018 • Medium Combustion Plant (MCP) & Large Combustion Plant (LCP) National Regulations • Air Pollution Act	• Clean Air Package • CAFÉ Directive • National Emissions Ceiling Directive • EU Air Quality Directive • Environment Noise Directive • Medium Combustion Plant (MCP) & Large Combustion Plant (LCP) Directives	• Convention on Long Range Transboundary Air Pollutants • WHO Air Quality Guidelines • WHO Environmental Noise Guidelines 2018
Nature	• National Biodiversity Action Plan • National Peatlands Strategy • National Raised Bog SAC Management Plan • All-Ireland Pollinator Plan • Land Use Strategy	• Habitats Directive • Birds Directive • EU Biodiversity Strategy 2030 • EU Invasive Alien Species Regulation 2014 • EU Common Fisheries Policy 2014	• Convention on Biological Diversity • Bonn Convention on International Trade in Endangered Species of Wild Fauna and Flora • Ramsar Convention
Contaminants	• Chemicals Act 2008 & 2010 and related Regulations • Dangerous Substances Act 1972 and related Regulations • Persistent Organic Pollutants (POPs) Regulations (including National Implementation Plan) • **2nd Ireland National Action Plan (INAP) on antimicrobial resistance** • Mercury Regulations • GMO (Contained use) (Amendment) Regulations, S.I. No 442 of 2010 - Amendment to the GMO (Contained Use) Regulations S.I. No. 73 of 2001	• REACH Regulations • Chemicals Strategy for Sustainability • Sustainable Use of Pesticides Directive • EU Classification, Labelling & Packaging (CLP) • POPs and Mercury Regulations • Directive 2009/41/EC - European Directive on the contained use of Genetically Modified Micro-organisms (GMMs) • RoHS (Restriction of Hazardous Substances) Directive	• UN Rotterdam Convention • Stockholm Convention • Minamata Convention • Montreal Protocol • UN Globally Harmonised System on Classification, Labelling & Packaging • UN Strategic Approach to International Chemicals Management
Waste and Circular Economy	• 2020 Waste Action Plan for a Circular Economy • National Hazardous Waste Management Plan • Waste shipment Regulation • National Policy Statement on the Bioeconomy	• EU Circular Economy Action Plan including the Bioeconomy • Waste Framework Directive • Individual directives on Packaging, Landfill, WEEE, Single-use Plastics, End-of-Life vehicles & Batteries, etc. • Empowering the consumer for the green transition • Eco-design Directive: Council Directive 2009/125/EC on Eco-Design • Zero-Pollution Action Plan	• Basel Convention
Cross Cutting Issues	• **National Marine Planning Framework** • National Implementation Plan for the SDGs • Project Ireland 2040 National Planning Framework • EPA Enforcement & Compliance Policy • National Risk Assessment 2019 • Green Public Procurement (GPP) • Programme for Government	• EU Green Deal • **8th EU Environmental Action Programme 2021-2030** • Marine Spatial Planning Directive • Industrial Emission Directive • Strategic Environmental Assessment Directive • Environmental Impact Assessment Directive • Environmental Liabilities Directive • **Strategy for sustainable and smart mobility**	• UN Sustainable Development Agenda 2030 • Sendai Framework for Disaster Risk Reduction • UN Decade of Ocean Science for Sustainable Development

● **In BOLD**: Planned / at draft stage at the time of publication of the EPA Research 2030 Framework

Figure 2: Key policies underpinning the 2021–2023 research areas

Identifying Research Areas for the EPA Research Programme for 2021–2023

This document provides for each of the four EPA Research 2030 interconnected hubs:

- an overview of the current key environmental challenges;
- research areas and an extensive but not exhaustive list of possible research actions identified to inform medium- and long-term policy needs and knowledge and evidence gaps;
- links with the National Research Priority Areas 2018–2023 and to international research funders' networks.

The document provides the basis for the 2021–2023 Thematic Assessment (EPA Research 2030: 2021–2023 Thematic Research Areas Assessment), which will be used as a resource to support and inform the preparation of the EPA research calls. It will provide an underlying framework for the selection of research topics for inclusion in the EPA research calls in 2021, 2022 and 2023, as part of the call preparation process (i.e. annual consultation and review and prioritisation of the research needs, including emerging challenges) (**Figure 3**).

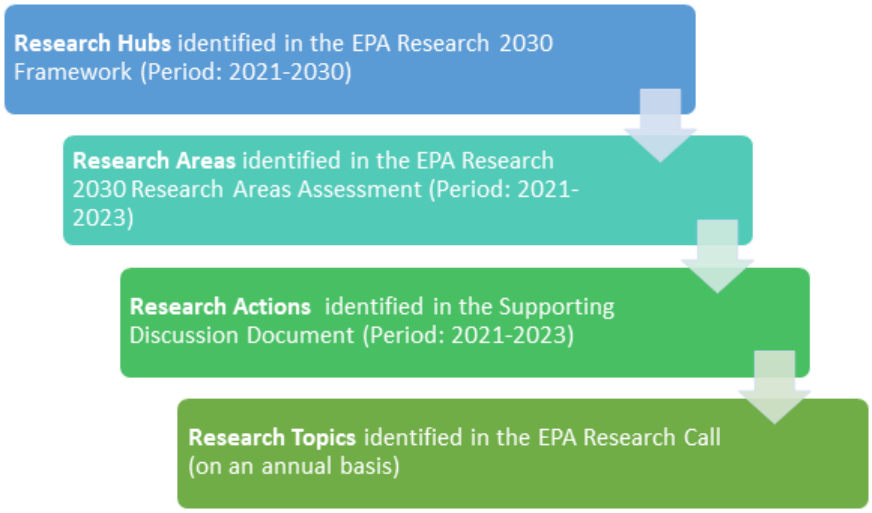


Figure 3: From research hub to research call topics

EPA Research 2030 will build on the success and key achievements of the previous EPA-funded research programmes[7].

Appendix 1 provides a non-exhaustive list of ongoing EPA-funded research, awaiting findings and recommendations, which will inform the research areas and actions for the period 2024–2026.

Appendix 2 provides selected examples of the key policy objectives and targets relevant to the Addressing the Climate Change Evidence Needs Research Hub for the period 2021–2023.

Appendix 3 provides selected examples of the key policy objectives and targets relevant to the Facilitating a Green and Circular Economy Research Hub for the period 2021–2023.

Appendix 4 provides selected examples of the key policy objectives and targets relevant to the Delivering a Healthy Environment Research Hub for the period 2021–2023.

Appendix 5 provides selected examples of the key policy objectives and targets relevant to the Protecting and Restoring our Natural Environment Research Hub for the period 2021–2023.

[7] http://www.epa.ie/researchandeducation/research/researchpublications/

2021–2023 Research Areas for the Research Hub on Addressing the Climate Change Evidence Needs

Climate change is already having an impact in Ireland, and strong mitigation and adaptation measures are needed. Research is essential in providing the evidence necessary to improve our knowledge systems and inform policy decisions that will advance our ambitions to be carbon neutral and resilient to climate disruption.

Challenges

Climate change is recognised as the defining challenge of this century. The EPA State of the Environment Report 2020[8] advises that addressing the causes and consequences of climate change represents a multi-generational challenge, with the scale of the future responses being uniquely determined by the effectiveness of actions taken now and in the coming years. The Paris Agreement[9] to the United Nations (UN) Framework Convention on Climate Change (UNFCCC)[10] provides the framework for global actions to prevent dangerous and irreversible global climate change. Its goals are to:

- hold the global average temperature increase to well below 2°C and pursue efforts to limit the increase to 1.5°C;
- enhance adaptive capacity and foster climate resilience and low-emission development in a manner that does not threaten food production;
- make finance flows consistent with a pathway towards low greenhouse gas (GHG) emissions and climate-resilient development.

It also recognises the important contributions of systematic observations under the Global Climate Observing System (GCOS)[11]. The goals of the Paris Agreement and the 2019 European Green Deal (including its Climate Law and Climate Neutrality Goal for 2050) were informed by the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, which found that warming of the climate system is unequivocal and that the human causes of this are clear. The EPA State of the Environment Report 2020 notes that this is evident globally and in Ireland: in general, the climate trends in Ireland have largely followed the global average. Both natural and human systems are experiencing diverse changes and impacts as a result of climate change. Adaptation planning to manage current and future unavoidable climate impacts and risks is required.

During its Sixth Assessment cycle[12], the IPCC provided three special reports on the topics of:

- global warming of 1.5°C (Special Report on Global Warming of 1.5°C, SR1.5C)[13];
- land (Special Report on Climate Change and Land, SRCCL)[14], and

[8] http://www.epa.ie/irelandsenvironment/stateoftheenvironmentreport/
[9] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[10] https://unfccc.int/
[11] https://gcos.wmo.int/en/home
[12] https://www.ipcc.ch/assessment-report/ar6/
[13] https://www.ipcc.ch/sr15/
[14] https://www.ipcc.ch/srccl/

- oceans and the cryosphere (Special Report on the Ocean and Cryosphere in a Changing Climate, SROCC)[15].

These reports highlight the complex challenges that exist in achieving the Paris Agreement goals. The IPCC Sixth Assessment Synthesis Report will be published in 2022 and inform the global stocktake under the Paris Agreement in 2023.

Ireland's current plans for a path to a low-carbon, climate-resilient economy are informed by the Climate Action and Low Carbon Development (Amendment) Bill 2020, Climate Action Plan 2019[16], National Adaptation Framework 2018[17] and the associated sectoral adaptation plans, and local authority adaptation strategies published since 2018, and the National Energy and Climate Plan 2021–2030[18], as well as the Programme for Government 2020[19].

The EPA State of the Environment Report 2020 notes the centrality of national and international research and data from systematic observations made in the atmosphere, in the oceans and on land to informing actions on climate change. Further research is required to support the implementation of current policies and plans established to set Ireland on a path to climate neutrality and climate resilience by 2050. Additional policies and actions will be required to meet our long-term policy goals adopted under the Paris Agreement and in the 2019 European Green Deal[20], the European Union (EU) Eighth Environment Action Programme[21], the EU Climate and Energy Framework 2030[22] and the Regulation on the Governance of the Energy Union and Climate Action[23].

The 2019 European Green Deal has the overall ambition of the EU achieving climate neutrality by 2050, as set out in the proposed EU Climate Law, which will guide the development of our 5-year nationally determined contributions, through which the Paris Agreement is implemented. In addition, the Green Deal provides for a new strategy on adaptation to climate change to be adopted in 2021, and the EU has adopted an Adaptation Mission under Horizon Europe. The Green Deal also includes a requirement to prepare a just transition plan to access the EU Just Transition Fund and a renewed sustainable finance strategy.

The first five-year assessment of climate research activities[24] in Ireland was recently initiated and is due to be completed in the period 2021–2022. The work will update national understanding of climate change, its impacts and response options and inform policy options for climate mitigation and adaptation. It will also identify, inter alia, evidence gaps and research needs. Accordingly, the report of this assessment will be a critical source of evidence for the EPA Research Framework, research prioritisation and planning processes.

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[15] https://www.ipcc.ch/srocc/
[16] https://www.gov.ie/en/publication/ccb2e0-the-climate-action-plan-2019/
[17] https://www.gov.ie/en/publication/fbe331-national-adaptation-framework/
[18] https://www.gov.ie/en/publication/0015c-irelands-national-energy-climate-plan-2021-2030/
[19] The Programme for Government 2020 includes A Green New Deal mission, with substantial proposals to address the climate change challenges. It includes a commitment to an average 7% reduction per annum in overall GHG emissions from 2021 to 2030 and to achieving net zero emissions by 2050, with the setting of 5-year carbon budgets. The Programme for Government 2020 includes a list of policy changes for every sector.
[20] https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf
[21] Under the proposed 8th Environmental Action Programme, a large amount of climate-related EU legislation is anticipated during the period 2020–2025. See https://ec.europa.eu/environment/pdf/8EAP/2020/10/8EAP-draft.pdf
[22] https://ec.europa.eu/clima/policies/strategies/2030_en
[23] https://ec.europa.eu/clima/policies/strategies/progress/governance_en
[24] http://www.epa.ie/climate/climres/5yar/

Key questions remain in relation to the scale, timing and details of the responses of the Earth's climate system to the additional energy being trapped by GHGs, i.e. how the planet will respond to global warming. The North Atlantic region has unique vulnerabilities arising from the impacts of loss of mass of ice from Greenland and the Arctic and the associated vulnerabilities of the Atlantic Meridional Overturning Circulation. Of central interest to Ireland is what it means for our environment, society and economy. Localisation of global and regional analysis of issues such as the global energy balance and associated carbon budgets that achieve the Paris Agreement temperature goal, emissions and removals trajectories and pathways required to balance these by 2050 and key gaps in understanding of the carbon cycle are all required.

In addition, the human dimensions and responses need to be addressed, e.g. through scenario development that links local analysis to analyses carried out at global and regional levels of emissions and their outcomes in terms of ranges of climate projections that can inform impacts analysis and adaptation planning. The ongoing changes that are occurring in the North Atlantic Ocean, including factors that may have an impact on the stability of key currents and ocean flows, are of critical importance for Ireland. These affect issues such as our weather patterns, sea level rise, ocean ecosystems and fisheries and the communities and economic activities that rely on ocean systems. Issues include trends and changes in key terrestrial domains, i.e. oceans, atmosphere and cryosphere. Large-scale irreversible changes and their impacts need to be explored. These include global and regional thresholds and tipping points, such as ongoing impacts and the accelerated loss of the Greenland ice sheet. These are projected to have major consequences for Ireland and Europe.

Research areas identified for 2021–2023 under this hub include:

1. **understanding and measuring fundamental cycles, processes, trends and drivers of climate change;**
2. **enabling the achievement of climate neutrality by 2050;**
3. **preparing for Ireland's future climate (i.e. achieving climate resilience);**
4. **realising the benefits of and opportunities arising from transition and transformation.**

Alignment with the EPA's Activities

The roles and responsibilities of the EPA relating to the issue of climate change comprise the following:

- The EPA is responsible for compiling inventories and projections of GHG emissions for Ireland. This requires an understanding of the fundamental cycles (notably carbon and nitrogen), processes, trends and drivers of climate change, not just to estimate current and past GHG emissions but also to make projections into the future and assess whether and how Ireland can meet its legislative targets.
- The EPA is the competent authority for implementing the EU Emissions Trading System (ETS) in Ireland.
- The EPA provides the secretariat for the National Dialogue on Climate Action. This aims to engage the public on the challenge of climate change, motivating changes in behaviour and creating structures at local, regional and national levels to support the generation of ideas and their transition into appropriate actions.
- The EPA provides the secretariat for the Climate Change Advisory Council (CCAC), an independent body tasked with reviewing national climate policy.
- The EPA is the competent authority for carrying out strategic environmental assessment (assessing the impact of proposed plans and programmes on the Irish environment).

- Under the Climate Bill 2020[25], the EPA now has greater responsibilities related to managing climate impacts through adaptation, in particular through the Climate Ireland platform.

Research Areas for 2021–2023

Understanding and measuring fundamental cycles, processes, trends and drivers of climate change

Understanding the fundamental cycles, processes, trends and drivers of climate change provides the context for short- to medium-term policy actions and long-term policy goals. These are linked by the need to inform actions that take account of their cascading effect over these time horizons. These should also build on existing and emerging structures that support and inform policy. For climate change, effective management of GHG emissions and removals is central to policy. The National Inventory provides the integrated understanding of GHG emissions and removals in Ireland. Hence, ensuring that the inventory can capture emerging solutions and responses in the context of policy intervention is essential. This requires investment in research on the activities and processes that are producing emissions or removals and ensuring that these reflect the best available scientific understanding.

It is a priority for the EPA Research Programme to support the ongoing development of the National Inventory of GHG emissions, which is the key tool for informing policy and for assessing the effectiveness of policy interventions. The objective is to continuously improve the representation of real-world activities in the inventory in a manner than can both inform and reflect policy. This should also allow for the inclusion of management or technological interventions in a manner that is measurable, reportable and verifiable at national, EU and UN levels.

In this context, the knowledge and evidence gaps include:

1. improving our understanding of emissions and removals of GHGs based on land use and changes in land use/land management options, including nature-based solutions [26];
2. addressing areas of uncertainty identified during the annual development and review process and having a pipeline of projects that address these areas over relevant timelines;
3. developing GHG emissions and removals analysis tools at scales that enable actions by leaders in regions, communities and economic sectors;
4. advancing top-down analysis of GHG emissions and removals in a manner that supports actions at a range of temporal and spatial scales.

Points 3 and 4 listed above are linked and would aim to enhance the use of advanced observation systems and EU infrastructures, e.g. ICOS, and work with initiatives such as Copernicus.

Enabling achievement of climate neutrality by 2050

The EPA State of the Environment Report 2020 advises that Ireland is not on the pathway required to meet its 2020 targets and that it will need to fully implement the additional measures outlined in the 2019 Climate Action Plan to meet its targets over the period 2021–2030. The 2019 Climate Action Plan commits to evaluating in detail the changes that would be necessary in Ireland to achieve the net

[25] https://www.gov.ie/en/publication/984d2-climate-action-and-low-carbon-development-amendment-bill-2020/

[26] http://www.climatecouncil.ie/ The CCAC has advised that an urgent assessment and implementation of appropriate management options for degraded peatlands is required, as set out in the National Peatlands Strategy.

zero target by 2050[27]. The EPA State of the Environment Report 2020 highlights that Ireland must maximise the use of land as carbon stores to meet its targets[28].

From global to local levels, there is a need to develop and explore scenarios and pathways for GHG emissions and removals that enable the achievement of climate neutrality by 2050. These include socio-economic, nature-based and technological solutions, as well as an assessment of the diversity of barriers to deploying and taking up of solutions. While considerable work has been advanced on decarbonising pathways (e.g. for energy), further work is needed on energy use in buildings and transport and on technologies to support energy security through storage and management. Pathways to 2050 for other sectors and gases are also needed. The CCAC reported in its 2019 Annual Review that, "the continued failure to set out detailed pathways on the cost-effective route to decarbonising the Irish economy by 2050 is a major obstacle to progressing policy on climate change."

In this context, knowledge and evidence gaps include:

1. further developing energy systems solutions across heating, industry, transport and buildings sectors, as well as analysing deployment options and barriers to their uptake, including costs and systemic inertia;
2. exploring management and policy options in land use and agriculture sector.

Research in these areas will necessarily be carried out in conjunction with other relevant national stakeholders active in these sectors, e.g. the Sustainable Energy Authority of Ireland (SEAI), Teagasc and the Department of Agriculture, Food and the Marine (DAFM).

Preparing for Ireland's future climate (i.e. achieving climate resilience)

Research should consider the current and projected impacts of climate change from global to national to local scales, sectoral and geographical impacts, extremes and slow onset changes, and vulnerability, exposure and risk assessment of infrastructure, population displacement, food systems and supply chains. It should also consider the impact of climate change on health and wellbeing and terrestrial and aquatic ecosystems. Research could assist in informing actions and mitigation measures through the provision of projections to inform planning and providing an outlook to increase the resilience of our waters, air and soil to the impact of climate change.

The National Adaptation Framework (NAF) 2018 identified that, as we move into the implementation of climate change adaptation policy, there will be an increased need for interdisciplinary research that will require input from all of the sciences. This was identified through a research prioritisation exercise that took place during the development of the NAF and the research priorities are included in the final NAF document. Some sectoral adaptation plans also intend to assess research needs to address knowledge gaps in relation to climate adaptation options. According to the CCAC, resilience and adaptation issues for coasts, housing and planning are not sufficiently addressed under current plans. The CCAC also noted that awareness of and willingness to act on adaptation remains poor and that co-benefits with mitigation are underexplored.

[27] The Climate Action Plan also requires building the required enterprises and upskilling the workforce to enable households and businesses to adopt low-carbon technologies. It also envisages enhanced governance arrangements, including carbon-proofing policies, establishing carbon budgets, a strengthened CCAC and greater accountability for the Oireachtas.

[28] The EPA State of the Environment Report 2020 notes that forest-based solutions are currently the main focus for carbon removals in Ireland and that the development of wider solutions across all land use types and systems (e.g. grasslands and wetlands) is needed. This should focus on sustainable land management to enable the accumulated removal of carbon. Additional technologies will also be needed, including direct air capture and bioenergy with carbon capture and storage.

In this context, the knowledge gaps and evidence needs include:

1. investigating adaptation options and building resilience and the benefits and opportunities from planned adaptation;
2. using shared socio-economic pathways to explore climate-resilient pathways for sustainable development;
3. investigating the benefits and challenges of grey, green, soft adaptation options and how these options can double up as mitigation options.

Realising the benefits of and opportunities arising from transition and transformation

The EPA State of the Environment Report 2020 notes that the ethical framing of climate actions has become increasingly core to discussions, and the 2019 European Green Deal emphasises that the transition must be just and inclusive, putting people first, and must pay attention to the regions, industries and workers facing the greatest challenges. Therefore, dialogue to develop responses needs to be considered and deliberate, in order to understand the hopes and concerns of individuals and communities and to reduce the risk of policy failure.

The EPA has commissioned Yale University (through its Climate Change Communications Programme) to carry out a survey in 2021 of the Irish population with regard to its values, beliefs etc. However, this will need to be followed up at a finer scale to investigate who believes what and why at a community level.

Research is also needed to assist the development of tools and supports for education and communication that connect the local with the global level, e.g. assessment of national and local contributions to carbon dioxide emissions and removals and linking phenological analysis with observations of the global carbon cycle and local actions to enhance terrestrial sinks, including through the use of *in situ* and remote data, e.g. through links with European Space Agency and Copernicus projects and services.

The EPA State of the Environment Report 2020 notes that a successful transition to a low-carbon economy will require a redirection of investment towards 'green growth', which offers many employment opportunities and economic benefits. It observes that private sources of finance flows will be required to achieve the economy-wide transformation envisaged by 2050[29]. Further research on assessment of financial flows, including support for unsustainable activities (e.g. fossil fuel subsidies) and how these may be addressed, is warranted.

Achieving climate neutrality by 2050 and meeting our Paris Agreement targets will require not only research into pathways that will balance emissions and removals of GHGs but also considering which ones provide the best cross-sectoral co-benefits and opportunities and considering which policy responses to climate change correspond to a "just transition", not least to obtain buy-in from people but also to make the most (in terms of sustainable development) of the opportunities in what is expected to be substantial system change[30].

[29] The EPA State of the Environment Report 2020 advises that Individuals, households and businesses will have to be motivated, supported or incentivised to finance their decarbonisation efforts. It also advises that climate action can be the lever to attract more international finance flows to Ireland. The European Investment Bank has a mandate to increase the share of its finance dedicated to climate action and environmental sustainability to 50% of its operations by 2025.

[30] The Climate Action Plan reported that buildings in Ireland are 70% reliant on fossil fuels and that over 80% of the homes and other buildings assessed have a Building Energy Rating of C or worse, issues for tackling both air pollution and energy poverty. In particular the Plan noted that the current annual retrofitting of existing stock is far too limited, and the challenge now is to develop new funding delivery models that move beyond individual grants in a way that drives large-scale retrofitting to bring economies-of-scale benefits and to signal advanced performance requirements.

As biodiversity loss and the climate crisis are inextricably linked, our natural environment should be recognised as a vital ally in the fight against climate change. Healthy ecosystems underpin solutions to climate change mitigation and adaptation. With land use planning being central to the protection and restoration of the natural environment, planning must consider the projected impacts of climate change.

In this context, the knowledge and evidence gaps include:

1. envisaging transition and transformation and the human and environmental benefits of the adoption of sustainable solutions;
2. exploring our understanding of policy integration and coherence and developing approaches to reduce cross-sectoral risks that may arise from climate action;
3. exploring how people understand the transition to a climate-neutral, climate-resilient future and how they might be supported during this transition;
4. understanding behaviours around climate action and how we can foster long-term interventions.

Research in the areas of points 3 and 4 above is particularly important to support the work of the National Dialogue on Climate Action.

Appendix 1 provides a non-exhaustive list of ongoing EPA-funded research, awaiting findings and recommendations, which will inform the research areas and actions for the period 2024–2026.

Appendix 2 provides selected examples of the key policy objectives and targets relevant to the Addressing the Climate Change Challenges Research Hub for the period 2021–2023.

Research Actions Identified

The following research actions were identified during the consultation process in 2020 and are relevant to policy and aligned with the key activities of the Agency.

These include, but are not limited to:

Understanding and measuring fundamental cycles, processes, trends and drivers of climate change

- CC-1. Improving emissions inventories and projections, where appropriate, e.g. for the land use, land use change and forestry (LULUCF) sector and for removals.
- CC-2. Expanding the range of GHGs tracked, and at finer spatial resolutions, using Earth observation data.
- CC-3. Developing emissions verification systems for GHG emissions.
- CC-4. Developing monitoring, reporting and verification systems for climate mitigation and adaptation measures, e.g. in agriculture and other land uses.
- CC-5. Developing a system for measuring national consumption-based carbon intensity.
- CC-6. Understanding climate change impacts at local and regional levels within Ireland (by downscaling international projections).
- CC-7. Developing integrated assessment modelling of mitigation, adaptation and Earth observation pathways at a national level by fully exploring the shared socio-economic pathway solution space at a national level with probabilistic pathways to achieve a net zero 2050 society. Specifically, understanding the impact of extreme climate events on physical systems and the mitigation infrastructure is necessary, given their investment cycle timescales.

CC-8. Assessing the impact of climate change on emissions and removals of GHGs associated with the agriculture, forestry and land use sectors and developing appropriate mitigation and adaptation strategies to achieve climate neutrality and climate resilience.

CC-9. Developing a sustainable observation system for key climate parameters, providing data analysis and delivery, that facilitates the integration of emerging requirements.

Enabling achievement of climate neutrality by 2050

CC-10. Identifying and assessing scenarios for the future development of long-term pathways for each GHG and each sector to achieve current ambitions to reduce GHG emissions by 7% per year in the period 2021–2030 and to ensure that climate neutrality and the Paris Agreement targets are achieved by 2050.

CC-11. Supporting the development and implementation of carbon budgets (e.g. at various scales and in various sectors) and how they inform long-term strategies and annual climate action plans.

CC-12. Identifying opportunities for areas and communities that are leading in the transition away from carbon-intensive activities to sustainability and identifying lessons from Ireland and elsewhere and the potential for scaling up.

CC-13. Assessing the potential to sequester, store and reduce emissions of carbon and nitrogen through the management, restoration and rehabilitation of peatlands, forestry and soils.

CC-14. Assessing management options for degraded peatlands to reduce GHG emissions and enhance carbon storage potential.

CC-15. Identifying the risk of inadequate policy responses (and the implications for future stranded assets[31]), including consideration of short- and longer-term investment risks.

CC-16. Developing negative emissions technologies (including natural climate solutions, carbon capture and storage, including with biomass and biomethane, and direct air capture) and developing renewable fuel technologies to achieve climate neutrality.

CC-17. Exploring the options and regulatory requirements for industry in mitigation and the low-carbon transition.

Preparing for Ireland's future climate (i.e. achieving climate resilience)

CC-18. Measuring climate resilience.

CC-19. Assessing the societal, economic and environmental impacts of extreme events.

CC-20. Identifying climate-resilient pathways for Ireland, linked to shared socio-economic pathways and commitments made under the Paris Agreement.

CC-21. Generating adaptation decision-making information on decision-making frameworks, such as adaptation pathways, to meet short-, medium- and long-term resilience goals.

CC-22. Detailing the climate vulnerability of each sector and identifying critical thresholds, considering spatial, sectoral, social and ecological vulnerabilities.

CC-23. Achieving coastal resilience by addressing knowledge gaps, erosion, flooding, infrastructure, acceptable levels of risk and the role of communities.

CC-24. Analysing climate change impacts temporally, spatially and under different emission scenarios (including higher warming) to maintain a state-of-the-art understanding of future climate change at resolutions and over timelines appropriate to national, regional and local decision-making.

CC-25. Exploring the implications for Ireland of global impacts (e.g. large-scale singular events, food security, climate migration) and secondary impacts (knock-on effects) and the interplay between impacts at sectoral level.

[31] Assets that turn out to be worth less than expected as a result of changes associated with the low-carbon transition.

CC-26. Costing adaptation impacts and actions in the Irish context.

Realising the benefits of and opportunities arising from transition and transformation

CC-27. Exploring the pathways for realising a just transition by mitigating and adapting to climate change, taking into consideration the policy, finance, business models, societal engagement aspects, etc., in an integrated manner and including consideration of the following questions:
- defining what just transition means in an Irish context, with reference to how it is considered in the 2019 European Green Deal and the UNFCCC;
- optimising smart financing options, e.g. to overcome the high upfront costs to consumers in the uptake of new technologies, especially in the residential heating and transport sectors;
- creating a fair environmental taxation and carbon pricing system to effect behaviour change, without undue impact on low-income groups and vulnerable communities;
- defining the role of the financial sector in a just transition to a climate-neutral economy and society;
- exploring how novel technologies can support decarbonisation through behaviour change, with a particular emphasis on mobility and behavioural shift in rural areas;
- furthering our understanding of how stakeholders understand the transition to a climate-neutral, climate-resilient future;
- effecting community engagement and implementation of climate policies;
- identifying the barriers and challenges in communities and opportunities for co-creation of solutions;
- exploring, in an Irish context, the law–policy interface, with respect to (i) public participation and the just transition, (ii) enforcement and accountability, (iii) human rights and climate change, and (iv) the youth dimension;
- exploring the most effective means of communication.

CC-28. Integrating climate resilience into economic and fiscal frameworks.

CC-29. Developing approaches to reduce cross-sectoral risks associated with climate change.

CC-30. Exploring the availability of hydrofluorocarbon (HFC)-free/climate-neutral heat pumps on the Irish and EU markets and options for switching from using HFC-based equipment in the refrigeration/air conditioning sectors.

CC-31. Assessing adaptation and mitigation co-benefits.

CC-32. Exploring the levels of policy integration and coherence between policy objectives and between mitigation, adaptation and sustainable development (includes exploring the capacity of the planning and policymaking community in the development and use of climate services and how this may be enhanced).

CC-33. Exploring “enhanced” restoration of degraded peatlands from industrial activities and adjacent carbon-rich soils in the midlands, which considers the requirements of integrated pollution control regulation of peatlands, thereby improving water quality, improving air quality and improving LULUCF reporting.

CC-34. Exploring how climate services can be delivered on the ground.

Links with the National Research Priority Areas 2018–2023

The research areas and actions outlined under this hub are of relevance in addressing the national research priority areas identified in 2018 for the period up to 2023, namely:

- ICT – Future Networks, Communications and Internet of Things.
- ICT – Data Analytics, Management, Security, Privacy, Robotics and Artificial Intelligence.
- ICT – Digital Platforms, Content and Applications, and Augmented Reality and Virtual Reality.
- Food – Food for Health.
- Food – Smart and Sustainable Food Production and Processing.
- Health and Wellbeing – Connected Health and Independent Living.
- Energy, Climate Action and Sustainability – Decarbonising the Energy System.
- Energy, Climate Action and Sustainability – Sustainable Living.

Links to International Networks

Examples of the relevant international research networks include:

- Horizon Europe missions: Climate-neutral and smart cities; Adaptation to climate change, including societal transformation; and Healthy oceans, seas, and coastal and inland waters.
- Horizon Europe clusters: Health; Climate, Energy and Mobility; and Food, Bioeconomy, Natural Resources, Agriculture and Environment.
- EU networks/Horizon Europe proposed partnerships: BiodivERsA network; Biodiversity Partnership; Joint Programming Initiative (JPI) Urban Europe; JPI Climate; Water JPI; Water4All Partnership; JPI FACCE (Agriculture, Food Security and Climate Change); and JPI Oceans.

2021–2023 Research Areas for the Research Hub on Facilitating a Green and Circular Economy

Environmental and sustainability challenges are inextricably linked to economic activities and lifestyles. Research conducted under this hub will contribute to the mainstreaming of the sustainable management of natural resources and waste, unlocking the potential of the circular and bioeconomies, and boosting competitiveness, through resource efficiency and deploying innovative technologies and solutions.

Challenges

Ireland, as a small open economy, is currently characterised by a large foreign direct investment sector, intensive agriculture, a large number of small and medium-sized enterprises (SMEs) and a competitive world-leading bio-pharmaceutical sector. The traditional linear economic model in Ireland of take – make – dispose has resulted in socio-economic and environmental challenges. Environmental and sustainability challenges are inextricably linked to economic activities and lifestyles. Research conducted under this hub will provide robust evidence to inform systemic transformation that aligns with key policy and strategy commitments, while at the same time acknowledging and understanding Ireland's unique socio-economic and environmental characteristics.

The EPA State of the Environment Report 2020[32] highlights that the majority of Ireland's agreed environmental targets will not be met. Despite progress in some areas, the scale of improvements being made is insufficient to meet long-term objectives. The scale of the problem must be known across society if we are to appreciate the scale of the solutions needed to reverse these trends. The report states that, although environmental regulation is sometimes perceived as a threat to industrial competitiveness, it brings a large dividend in terms of environmental and human health improvements. Industry can gain competitive advantages and more local support from being sustainable and having a good compliance history.

The circular economy has become a more prominent policy priority, most recently in the 2019 European Green Deal and the proposal for the 8th Environmental Action Programme. The United Nations (UN) Sustainable Development Goals (SDGs) and in particular SDG 12, Responsible Consumption and Production, provides a framework to support the transition to more circular economy practices characterised by a more regenerative growth model. The national policy, *A Resource Opportunity: Waste Management Policy in Ireland*, expired in mid-2020 and, as detailed in the Programme for Government 2020, it was replaced with a new policy document, *Waste Action Plan for a Circular Economy*[33]. Rates of circular (secondary) material use have remained consistently low in Ireland since 2010 at below 2%, compared with a (European Union (EU) average of 11% in 2017. Further research will be required to support the implementation of the *Waste Action Plan for a Circular Economy*, moving beyond the management of waste to answering questions about our use of resources and materials. The goal of halving food waste by 2030 represents a formidable challenge, and research will be fundamental in the development of viable solutions.

[32] http://www.epa.ie/irelandsenvironment/stateoftheenvironmentreport/
[33] https://www.gov.ie/en/publication/4221c-waste-action-plan-for-a-circular-economy/

In September 2020, the Department of Environment, Climate and Communications launched *A Waste Action Plan for a Circular Economy*. The new policy recognises that there are opportunities to introduce circular economy measures as part of our national recovery post COVID-19. Circular economy measures present opportunities for job creation in design, reuse, repair, re-manufacturing and recycling, which have the potential to reduce our carbon footprint and meet our climate targets. The EPA State of the Environment Report 2020 highlights that rates of circular (secondary) material use have remained consistently low in Ireland since 2010 at below 2%, compared with an EU average of 11% in 2017.

The EPA State of the Environment Report 2020 recommends more integrated, coherent and ambitious policy frameworks to deliver on the climate action and sustainable development agendas and yield maximum benefit from the transition for the environment, citizens and communities. Allied to this is better implementation and enforcement of existing legislation, plans and programmes, including more focus on monitoring and *ex-post* evaluation of effectiveness.

There is a role for research to address unanswered questions and provide up-to-date information on waste prevention (including reuse and repair), generation, characterisation, treatment and needs that will be available for effective regulation of Ireland's transition. This will then inform policy that unlocks the potential of the circular and bioeconomies and boosts competitiveness through better understanding and assessment of environmental pressures. This will facilitate the co-design of behavioural interventions for the transition towards greener and more circular and, where feasible, bio-based practice. This evidence will inform innovative and more resource-conscious opportunities in priority areas of secondary raw materials, sustainable products and materials (including packaging materials), food and bio-based waste, the sharing economy and production and consumption across all sectors. The development of a green and circular economy and the bioeconomy will be facilitated and enhanced by the digitalisation of the economy.

The EPA Green Enterprise Scheme is a funding programme to support innovators in Ireland to develop and demonstrate consumer and business solutions that will stimulate the circular economy. It is managed through the National Waste Prevention Programme and is co-funded by EPA Research. Research conducted within the Facilitating a Green and Circular Economy Hub complements and is aligned with the Green Enterprise Scheme.

Research areas identified for 2021–2023 under this hub include:

1. **improving waste management in Ireland, particularly repair for reuse and recycling;**
2. **"greening" production practices in Ireland;**
3. **"greening" consumption practices in Ireland;**
4. **identifying barriers to and opportunities for the circular economy and using bio-based "wastes" in the bioeconomy in Ireland.**

Alignment with the EPA's Activities

The EPA plays key roles in environmental regulation, provision of knowledge and advocacy for the environment. The Agency compiles national statistics on waste generation and management in Ireland. National waste statistics are produced to meet European legislative reporting obligations and for other purposes such as informing national waste management and prevention policy and tackling waste crime.

CIRCULÉIRE is a public–private partnership created in 2020 by Irish Manufacturing Research and the Department of the Environment, Climate and Communications, the EPA, and the European Institute

of Innovation and Technology Climate Knowledge and Innovation Community (EIT Climate-KIC) with 25 founding industry members. Between 2020 and 2022, CIRCULÉIRE will take manufacturers and their supply-chains on a journey from linear to circular business models through baselining, auditing, business case development and deep demonstration innovation projects, delivering significant reductions in greenhouse gas (GHG) emissions (scopes 1, 2 and 3) and in waste production across the network. The mission of CIRCULÉIRE, as the national platform for circular manufacturing, is to demystify, de-risk, and deliver circular business model innovation by unlocking the value that resides in an Irish circular economy. EPA-funded research will provide robust evidence to facilitate the EPA's role as a strategic partner to CIRCULÉIRE.

Research Areas for 2021–2023

Improving waste management in Ireland

The waste sector was responsible for 1.5% of Ireland's GHG emissions in 2018. This includes emissions from solid waste disposal, composting, waste incineration, open burning of waste and wastewater treatment and discharge. Each year, every Irish household produces on average around 1 tonne of waste. Whether it is recycled or ends up in a landfill, all of that waste must be transported, treated and disposed of[34]. Revisions to the Waste Framework Directive introduced the following recycling targets for municipal solid waste (MSW):

- 55% by 2025
- 60% by 2030
- 65% by 2035.

In addition, the Landfill Directive has been amended to require that by 2035 no more than 10% of MSW goes to landfill[35].

The UK left the EU on 31 January 2020 and the transition period ended on 31 December 2020. From 1 January 2021, Brexit-related research may be required in the areas of market surveillance and transboundary pollution in the context of any Brexit-related changes to waste legislation and the border with Northern Ireland. As part of the European Commission's Circular Economy Package, legislative targets for reducing and recycling waste have increased and will be more challenging to achieve. Research will also be required to examine waste practices during times of unplanned for and unforeseen events, e.g. COVID-19.

Greening production practices in Ireland

Current estimates are that 45% of global GHG emissions are directly linked to the production of goods and the management of land (including agriculture and forestry). For this reason, there is a pressing need to reduce the amount of goods purchased and discarded in Ireland. In addition, the application of sustainable production approaches to the supply of necessary goods and services is a critical aspect of tackling climate change.

The 2020 Circular Economy Action Plan contains 35 actions to be taken throughout the entire lifecycle of products to make sustainable products the norm, and it focuses on the key product value chains

[34] https://www.gov.ie/en/publication/60a0a-sd-test-climate-action-waste/#the-importance-of-waste-and-the-circular-economy
[35] https://ec.europa.eu/environment/waste/landfill_index.htm

electronics and information and communications technology (ICT), batteries and vehicles, packaging, plastics, textiles, construction and buildings, food, water and nutrients. Although waste legislative targets to-date have focused on recovery (including energy recovery) and recycling, the next focus will be on increasing recycling and increasing the preparation of waste for reuse with a view to increasing prevention in the future. It will be challenging for Ireland to increase recycling rates, particularly given our heavy dependence on external markets for recycling glass, metal, paper and cardboard, and plastic. Allied to the technical barriers from a regulatory perspective is the issue of the quality of products that have be redesigned or refurbished to achieve circularity.

Greening consumption practices in Ireland

The promotion of more resource-conscious production has been the focus of research and policymakers under the implicit assumption that the observable increase in consumers' "green" values would be matched by growing sustainable consumption practices. However, it has been found that consumers' actual purchasing behaviour often deviates from their "green" attitudes. This phenomenon is called the attitude–behaviour gap. It is influenced by individual, social and situational factors. For example, the main barriers to purchasing sustainable (organic) food are price, lack of immediate availability, sensory criteria, lack or overload of information and the low-involvement nature of food products, in conjunction with well-established consumption routines, and lack of transparency and trust of labels and certification schemes[36].

There is a need to address barriers to maximising the circular economy linked to enforcement of EU regulations and directives, particularly in terms of the presence of harmful chemical additives [heavy metals, persistent organic pollutants, flame retardants in textiles, waste electrical and electronic equipment (WEEE), plastic and household insulation]. Research that is aligned with the key roles of the EPA can help to gain more insight and understanding of the motivations that influence production and consumption practices and provide solutions and pathways to more circular patterns of behaviour. The 2019 European Green Deal and the proposal for the 8th Environmental Action Programme are also supported by the 2020 EU Chemicals Strategy for Sustainability, which has a core objective of boosting innovation for safe and sustainable chemicals. One of the actions proposed under the strategy is "boosting the investment and innovative capacity for production and use of chemicals that are safe and sustainable by design, and throughout their life cycle"[37]. Funding research on green public procurement will further inform solutions and interventions for greening production and consumption patterns.

Identifying barriers to and opportunities for the circular economy

The transition to a more circular economy will require disruptive changes and radical innovation, and it needs to be seen in relation to the abilities of managing disruptiveness and radical innovation in industry. Identified barriers to the circular economy include financial, structural, operational, attitudinal and technological. These barriers are partly similar to the barriers to integrating sustainability issues in general; however, they reveal even more severe difficulties, as the business perspective needs to be integrated, taking sustainability issues to a critical strategic level[38].

[36] Terlau, W. and Hirsch, D. 2015. Sustainable consumption and the attitude-behaviour-gap phenomenon – causes and measurements towards a sustainable development. *Internal Journal on Food System Dynamics* International Center for Management, Communication, and Research, vol. 6(3), pages 1-16. https://doi.org/10.18461/ijfsd.v6i3.634

[37] https://ec.europa.eu/environment/strategy/chemicals-strategy_en

[38] Ritzéna, S. and Sandström, G, 2017. Barriers to the circular economy – integration of perspectives and domains. *Procedia CIRP* 64: 7–12. https://isiarticles.com/bundles/Article/pre/pdf/100048.pdf

Plastic is a ubiquitous material that consumes large amounts of finite resources in its manufacture and is often discarded after a short service life – including many single-use items. Owing to the array and mixture of plastics in the market and its relatively low cost, it can be difficult to establish recycling systems for all plastics – particularly soft plastics and films. Barriers to establishing plastics recycling in Ireland include technical challenges and also market and scale issues. Plastics are an area of particular focus for the national waste policy, and the EU's Circular Economy Action Plan, with a number of new targets and legislative instruments, focuses on the prevention and recycling of plastic waste.

Construction and demolition material is the largest waste stream in Ireland and is a key opportunity in terms of the circular economy. Key changes needed in the building sector include the introduction of prevention best practice to reduce the wastage of materials on site and increase the segregation of site wastes to allow for efficient and cost-effective recycling. The implementation of material passports and eco-design principles can drive prevention before construction commences. With regard to demolition, the auditing and careful deconstruction of buildings offers the prospect of recovery of significant amounts of materials.

The revised Common Agricultural Policy 2020 and the Farm to Fork Strategy 2020 aim to promote sustainable and socially responsible production methods and circular business models in food processing and retail, including models specifically for SMEs, in synergy with the objectives and initiatives put forward under the new Common Agricultural Policy. The deployment of a circular and sustainable EU bioeconomy provides business opportunities, for instance those linked to making use of food waste. Some of the priorities raised in the Programme for Government 2020 will require research to support their implementation.

Ireland's National Policy Statement on the Bioeconomy (2018)[39] proposes integrating sustainable economic development into our economic model as we transition to a low-carbon and circular economy. This presents opportunities for the research sector in relation to advancing knowledge and solutions to turn renewable biological resources and residual side streams into value-added bio-based products, such as food, feed, chemicals, raw materials, construction materials and bio-energy.

The EPA's Green Enterprise: Innovation for a Circular Economy programme provides grant aid to demonstration-type projects to support innovators in Ireland to develop and demonstrate consumer and business solutions that will stimulate the circular economy. Green Enterprise is under the umbrella of the Government of Ireland National Waste Prevention Programme (NWPP), which focuses on six priority areas: food waste, construction and demolition, plastics, agriculture, resources and raw materials, and local waste prevention. A number of producer responsibility initiatives have been assigned to the EPA for enforcement. The essence of producer responsibility lies in the "polluter pays" principle[40], making sure that the producer is responsible for items at their end of life, when they become waste. This responsibility has been given a legal basis in Ireland and is being enforced by the EPA. The producer responsibility initiatives being enforced by the Agency include WEEE, waste batteries and accumulators, and tyres. Research within the Facilitating a Green and Circular Economy Hub complements and is aligned with the Green Enterprise funding call.

Appendix 1 provides a non-exhaustive list of ongoing EPA-funded research (including projects funded under Green enterprise), awaiting findings and recommendations, which will inform the research areas and actions for the period 2024–2026.

Appendix 3 provides selected examples of the key policy objectives and targets relevant to the Facilitating a Green and Circular Economy Research Hub for the period 2021–2023.

[39] The National Policy Statement on the Bioeconomy (https://assets.gov.ie/2244/241018115730-41d795e366bf4000a6bc0b69a136bda4.pdf).

[40] http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=OCDE/GD(92)81&docLanguage=En

Research Actions Identified

The following research actions were identified during the consultation process in 2020 and are relevant to policy and aligned with the key activities of the Agency.

These include, but are not limited to:

Improving waste and resource management in Ireland, particularly repair for reuse and recycling

- GCE-1. Identifying barriers to developing indigenous waste management solutions, repair for reuse and recycling.
- GCE-2. Developing solutions to use waste and by-products as secondary raw materials.
- GCE-3. Gathering information on waste disposal practices during times of unforeseen and unplanned events, such as COVID-19.
- GCE-4. Advancing remote sensing solutions for waste enforcement.
- GCE-5. Assessing construction and demolition waste solutions with an emphasis on prevention and circularity.
- GCE-6. Developing circular value chains and industrial symbiosis approaches to enable recycling of industrial by-products and reuse of the logistics infrastructure.

Greening production and consumption practices in Ireland

- GCE-7. Gaining more insight and understanding of production and consumption practices.
- GCE-8. Developing communication tools to encourage more sustainable production and consumption behaviours.
- GCE-9. Improving the reduction, reuse and recycling of packaging.
- GCE-10. Identifying measures to enable the "licensed/permitted" sectors to move beyond compliance.
- GCE-11. Developing an evidence base for the integration of "waste to energy" in renewable energy production and the transport sector.
- GCE-12. Producing clean recyclate by removing hazardous and legacy chemicals from waste to produce recycled material fit for purpose as a secondary raw material for use in food contact materials.
- GCE-13. Conducting risk analysis research on environment-enhancing alternatives to pesticides and plastics to ensure food safety and food security.
- GCE-14. Developing new more resource=conscious food labelling solutions.
- GCE-15. Advancing the potential for eco-design of goods and services in all sectors that are aligned with the EPA's key roles.
- GCE-16. Advancing information on the carbon footprint of products placed on the Irish market and how to reduce it.
- GCE-17. Identifying consumption and production behaviours from a generational perspective (e.g. younger people's attitudes to environmental issues).
- GCE-18. Developing novel materials to replace fossil fuel-based plastics in packaging and other applications.

Identifying barriers to and opportunities for the circular economy and using bio-based "wastes" in the bioeconomy in Ireland

GCE-19. Identifying ways to facilitate locally produced sustainable food and bio-based systems.
GCE-20. Exploring "place-based" urban/rural solutions to facilitate circular and bioeconomy practices.
GCE-21. Identifying and overcoming barriers to the circular economy and bioeconomy in Ireland.
GCE-22. Exploring opportunities for making more use of "Smart" design.
GCE-23. Supporting the development of a comprehensive monitoring system to measure and analyse biomass flows and implementing comparative sustainability assessments.
GCE-24. Identifying innovative sharing and service-based economic models to include industrial symbiosis and "renting models", deposit-and-return programmes and other initiatives for traditionally owned goods, e.g. clothing, electronics, furniture, modes of transport.
GCE-25. Identifying opportunities for greater integration, collaboration and efficiencies between actors along the value chain from raw material suppliers to end users.

Links with the National Research Priority Areas 2018–2023

The research areas and actions outlined under this hub are of relevance in addressing the national research priority areas identified in 2018 for the period up to 2023, namely:

- ICT – Future Networks, Communications and Internet of Things.
- ICT – Data Analytics, Management, Security, Privacy, Robotics and Artificial Intelligence.
- ICT – Digital Platforms, Content and Applications, and Augmented Reality and Virtual Reality.
- Food – Food for Health.
- Food – Smart and Sustainable Food Production and Processing.
- Health and Wellbeing – Connected Health and Independent Living.
- Energy, Climate Action and Sustainability – Decarbonising the Energy System.
- Energy, Climate Action and Sustainability – Sustainable Living.
- Manufacturing and Materials - Advanced and Smart Manufacturing.
- Manufacturing and Materials – Manufacturing and Novel Materials.

Links to International Networks

Examples of the relevant international research networks include:

- Horizon Europe missions: Healthy oceans, seas, and coastal and inland waters; and Soil health and food.
- Horizon Europe clusters: Food, Bioeconomy, Natural Resources, Agriculture and Environment.
- EU networks/Horizon Europe proposed partnerships: Joint Programming Initiative (JPI) Urban Europe, "Driving Urban Transitions towards a Sustainable and Liveable Urban Future"; Water JPI; Water4All Partnership; JPI Antimicrobial Resistance; JPI Climate; and JPI Oceans.

2021–2023 Research Areas for the Research Hub on Delivering a Healthy Environment

A clean, vibrant and safe environment is a prerequisite for good health and wellbeing. Environmental degradation, pollution and known and emerging substances of concern threaten our health and that of our supporting ecosystems. Research conducted under this hub will contribute to understanding the risks and benefits and to identifying appropriate policy and behavioural responses.

Challenges

The EPA State of the Environment Report 2020[41] recognises health and wellbeing as being inextricably linked to our surrounding environment. Many of the issues we face that damage our environment and our health and wellbeing are closely interconnected. Ireland is facing key environmental and health challenges linked to climate change, landscape changes, contaminants of emerging concern (CECs), antimicrobial resistance (AMR), zoonoses, chemical and noise pollution and exposure, radiation, radon, air and water quality. Harnessing the co-benefits of solutions is essential for effective environmental and health protection. Solutions that can help to address one issue can deliver substantial co-benefits for others. The report states that a good-quality, well-protected environment has significant health and wellbeing benefits.

Targeted research under this hub will contribute to preventing and removing pollution and will inform the need for healthy air, soil, land, freshwaters and seas for all. It will also increase our understanding of the influence that our environment has on our health and wellbeing. Such research should also further assist in developing solutions and addressing knowledge gaps to support the EPA's key activities in environmental assessment, advocacy, regulation, enforcement and monitoring.

The 2019 European Green Deal and the proposal for the 8th Environmental Action Programme[42], which refer to wellbeing as a "compass" for policy development, are now driving a "zero pollution ambition for a toxic free environment"[43]. This will further be supported by the 2020 European Union (EU) Chemicals Strategy for Sustainability[44] and the Zero-Pollution Action Plan (expected to be published in 2021). The United Nations (UN) Sustainable Development Goals (SDGs) in particular SDG 3, Good Health and Well-being, has a strong focus on reducing environmental pollution. Specifically, SDG Target 3.9 seeks to "substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination" by 2030. The European Environment Agency (EEA) recently published a comprehensive assessment of how the environment influences health and wellbeing in Europe[45]. It reported that "a significant proportion of the burden of disease in Europe continues to be attributed to environmental pollution resulting from human activity".

[41] http://www.epa.ie/irelandsenvironment/stateoftheenvironmentreport/
[42] https://ec.europa.eu/environment/pdf/8EAP/2020/10/8EAP-draft.pdf
[43] The Zero Pollution Action Plan, which the European Commission aims to adopt in 2021, intends to achieve no pollution from "all sources", cleaning the air, water and soil by 2050. The environmental quality standards are to be fully met, enforcing all industrial activities to be conducted within toxin-free environments.
[44] https://ec.europa.eu/environment/strategy/chemicals-strategy_en
[45] https://www.eea.europa.eu/soer/2020

A more integrated cross-cutting approach across all policy areas is needed, rather than addressing individual problems separately, in particular when considering health and wellbeing. The EPA State of the Environment Report 2020 states that an "Environment Health in All Policies" approach should be adopted across government, whereby policies across all sectors must systematically consider the implications of decisions on the environment and human health, capture synergies and prevent negative impacts and inequity in exposures and outcomes.

The "One Health" approach seeks to bring research and policies together to generate understanding and evaluate the links between human activity, ecosystems and human health. The success of the One Health approach will be dependent upon addressing challenges associated with data availability and access to data. Delivering a safe and healthy environment is essential for transitioning to a sustainable, climate-neutral future and ensuring health protection for all. The achievement of this ambition will not be immediate, and significant research is required.

Research areas identified for 2021–2023 under this hub include:

1. **aiming for zero pollution to protect and restore our environment and to have a positive impact on health and wellbeing;**
2. **realising the co-benefits and opportunities for citizens from transition and transformation to sustainable behaviours by putting health and wellbeing at the centre of all policy areas;**
3. **reducing the socio-economic inequalities related to exposure to unhealthy environmental conditions;**
4. **understanding the increased environmental and human health risks posed by exposure to legacy and new chemicals, radiation (non-ionising and ionising), pharmaceuticals, AMR, environmental noise, etc., in different environmental media and ecosystems.**

Alignment with the EPA's Activities

The EPA puts a clean, protected environment for our health, wellbeing and quality of life at the centre of its activities, such as regulation, monitoring, assessment, provision of knowledge and advocacy for the environment. The recently established EPA Environment and Health Programme further strengthens its role in this regard.

The EPA is responsible for the national monitoring programmes for and assessments of water and air quality, noise, chemicals, AMR and radiation. These programmes provide information on environmental status, including indicator trends analysis, and inform measures that need to be put in place to mitigate against environmental degradation, in turn assisting in Ireland's delivery of its obligations under, for example, the Water Framework Directive and the Air Pollution Act. The EPA is the competent authority for carrying out strategic environmental assessment (SEA) by assessing the impact of proposed plans and programmes on the Irish environment.

These programmes also support the EPA's remit in environmental regulation and licensing as the competent licensing authority for its Environmental Licensing Programme in Ireland. The EPA is responsible for licensing and regulating emissions under the Industrial Emissions Directive and the National Emissions Ceiling Directive, as well as for regulating and reporting urban wastewater discharges, the safety of public drinking water supplies and the licensing of sources of ionising radiation.

The EPA's advocacy role in providing independent evidence-based reporting, advice and guidance to government, industry and the public on environmental and radiological protection topics, such as promoting radon testing in homes and workplaces, is further supported by sound research. Research that is aligned with key activities of the EPA can help to gain more insight and understanding of the

risks and practices that negatively affect our environment and provide solutions and pathways to deliver a healthier one.

Research Areas for 2021–2023

Aiming for zero pollution to protect and restore our environment and to have a positive impact on health and wellbeing

The EPA State of the Environment Report 2020 highlights an emerging area that needs more attention, namely the environmental impact of chemicals. Action in this area will both protect health and deliver on the zero-pollution ambition for a toxin-free environment proposed in the 2019 European Green Deal. In general, further research is needed to better understand the lifecycle of chemicals in the environment in Ireland and to establish the links between chemicals in the environment and human health and wellbeing.

The EPA monitors water and air across Ireland for a range of priority and priority hazardous substances, including herbicides, insecticides, polyaromatic hydrocarbons, solvents and metals. The EU Persistent Organic Pollutants (POPs) Regulation recast (EU 2019/1021)[46] came into force in July 2019, resulting in stricter obligations in relation to eliminating and controlling POPs. In addition, new substances are continually being prohibited through this regulation. The 2020 EU Chemicals Strategy for Sustainability sets out a roadmap for addressing the risks associated with chemicals. The role of the EPA in the reduction and elimination of chemicals, e.g. specifically POPs in Ireland, is outlined in the Irish POPs Regulations[47].

The EPA's role in monitoring and assessing the environment, coupled to its regulatory remit, will benefit from research into determining detection limits for some chemicals, e.g. particularly hazardous substances, POPs and chemicals restricted under the REACH Regulation[48] (on the registration, evaluation, authorisation and restriction of chemicals) that have an environmental impact in various matrices and will require novel approaches for detection and quantification.

As part of the 2019 European Green Deal, the EU Farm to Fork Strategy 2020 and the Biodiversity Strategy for 2030, in 2021 Ireland will introduce a legally binding 50% reduction in pesticide use and a reduction of 20% in fertiliser use in agriculture to be achieved by 2030. The substitution of hazardous substances with those less hazardous in products and processes could potentially provide significant environmental and commercial benefits. Further research is needed into the examination of the impacts and benefits of the use and reduction/substitution of hazardous substances for Ireland.

The EPA State of the Environment Report 2020 highlights that one area in which Ireland risks not achieving a zero-pollution and non-toxic environment is the land spreading of sewage sludge from wastewater treatment plants. The 2020 EU Circular Economy Action Plan[49] highlights the need to undertake an impact assessment of revising the Sewage Sludge Directive (86/278/EEC)[50]. The European Commission launched a study in 2020 to assess the effectiveness, relevance and added value of the Sewage Sludge Directive in Member States. The current legislation outlines the potential risk posed by substances in sludges that are applied to agricultural land and on our soils. Further

[46] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1021&from=EN
[47] Irish POPs Regulations, S.I. No. 146/2020.
[48] https://echa.europa.eu/regulations/reach/understanding-reach
[49] https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf
[50] https://ec.europa.eu/environment/waste/sludge/

research can increase our knowledge of the impact of legacy and new substances in the environment and of increasing amounts of unregulated substances from sewage sludge and biosolid disposal.

As noted in the Organisation for Economic Co-operation and Development (OECD)[51] review of the EPA's work, it would be timely to look at quantifying pollution trends and carbon footprints of EPA-regulated industries (industrial emissions/integrated pollution control/waste) in Ireland and compare them with trends found in 2010[52]. Research could support such a trend analysis of emissions.

Realising the co-benefits and opportunities for citizens from transition and transformation to sustainable behaviours by putting health and wellbeing at the centre of all policy areas

The EPA State of the Environment Report 2020 recommends the adoption of an "Environment Health in All Policies" approach. There is an opportunity to use research to improve regulatory decision-making and policy development and assist in the development of technologies and solutions to reduce unnecessary exposure to radiation and poor air (including indoor air) and water quality. Recognising and demonstrating the benefits and opportunities for society is key if research outputs are to be put into action that in turn improves our health and wellbeing. How to ensure knowledge transfer, measure co-benefits and develop standard metrics for effective policy decisions can be informed by research.

The EPA's advocacy role in providing robust evidence-based information assists in facilitating this transformation. Research could assist in communicating the message by simplifying the process and looking at measures that can help people to change their habits. The government's National Adaptation Framework 2040 requires the preparation of sectoral adaptation plans, including a plan for the health sector. The EPA's SEA remit will be central in influencing the effectiveness of these plans and of other sector plans and programmes. Research could inform the provision of guidance to ensure the timely and effective integration of health and wellbeing in these plans.

There are numerous strategies and plans related to air quality: the Air Quality Directive/CAFÉ 2008[53], UN Convention on Long Range Transboundary Air Pollution[54], World Health Organization (WHO) guidelines[55], the Medium Combustion Plant Directive[56] and the Large Combustion Plants Directive[57], the Air Pollution Act[58] and the planned National Clean Air Strategy[59]. The EPA has responsibility for the national ambient air monitoring programme, and its Air Quality Index for Health (AQIH)[60] is an example of how citizens can benefit from being informed by real-time air quality information from the station nearest to their location.

Research has established that air pollution from solid fuel burning and transport is an issue in Ireland[61]. With 20% of the proposed transport budget being allocated to pedestrian and cycling

[51] https://www.oecd.org/gov/regulatory-policy/driving-performance-at-ireland-s-environmental-protection-agency-009a0785-en.htm

[52] *Emissions from IPPC Industry: Quantifying Pollution Trends and Regulatory Effectiveness in 2010* (http://www.epa.ie/newsandevents/news/2010/name,47878,en.html).

[53] https://www.epa.ie/air/quality/standards/

[54] http://www.unece.org/env/lrtap/welcome.html

[55] https://www.who.int/airpollution/guidelines/en/

[56] https://ec.europa.eu/environment/industry/stationary/mcp.htm

[57] https://ec.europa.eu/environment/archives/industry/stationary/lcp/implementation.htm

[58] http://www.irishstatutebook.ie/eli/1987/act/6/enacted/en/print.html

[59] https://www.gov.ie/en/consultation/0b94e-national-clean-air-strategy-consultation/

[60] https://www.epa.ie/air/quality/index/#:~:text=The%20Air%20Quality%20Index%20for%20Health%20(AQIH)%20has%2010%20points,the%20quality%20of%20the%20air

[61] https://www.epa.ie/researchandeducation/research/researchpublications/researchreports/research324.html

transport infrastructure under the Programme for Government 2020, this will potentially change our physical built environment, with the aim of reducing air pollution levels and providing opportunities to increase physical activity and improve health and wellbeing. The EPA State of the Environment Report 2020 highlights the co-benefits of improved air quality, reduced congestion, reduced nitrate pollution, enhanced nature and ecosystem services and improvements in health and wellbeing. Research will allow us to gather data and communicate clear evidence for the benefits of significantly improving air quality in our communities.

Reducing the socio-economic inequalities related to exposure to unhealthy environmental conditions

The EEA[62] has highlighted social inequity in exposure to air pollution in Europe, with those in lower socio-economic groups more likely to be exposed to higher levels of air pollution. It also highlights social inequity with regard to access to good-quality green space and the higher susceptibility of those lower socio-economic groups to the effects of climate change. The EPA State of the Environment Report 2020 points out that issues such as energy poverty, dependence on fossil fuels and a lack of non-fossil solutions are considerable in Ireland. Findings highlighted in EPA-funded research on access to blue/green spaces in Ireland [63] highlights a growing range of health and social problems, and the authors call for "practitioners, policymakers and decision-makers to identify sustainable opportunities to integrate nature and human health without causing further inequality".

Further research is needed at a national level to assess the extent of such exposure to unhealthy environmental inequities in Ireland and inform the development of potential solutions to reduce inequality and address this disparity.

Understanding the increased environmental and human health risks posed by exposure to legacy and new chemicals, radiation (non-ionising and ionising), pharmaceuticals, AMR, environmental noise, etc., in different environmental media and ecosystems

The EPA State of the Environment Report 2020 and the EU Chemicals Strategy for Sustainability[64] both call for the need for a much more integrated policy approach to address the complex risks posed by chemicals. The impact of chemicals, pesticides and genetically modified organisms (GMOs) in the environment on our health and wellbeing is currently not fully understood, especially with respect to mixtures of chemicals and substances and the human exposure pathways for these chemicals. The pace at which new chemicals are being listed is increasing. The EPA State of the Environment Report 2020 categorises a number of chemicals of concern, such as pharmaceuticals, endocrine disruptors, POPs, ozone depleting substances and fluorinated greenhouse gases, and areas of concern, such as AMR. Existing legislation, such as the REACH Regulation[65] and revisions to legislation, such as the Sustainable Use of Pesticides Directive[66] in 2022, will all have an impact on Irish regulation in the coming years. For example, the EU Chemicals Strategy is non-legislative but sets out medium-term actions for new legislation.

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[62] https://www.eea.europa.eu/soer/2020
[63] http://www.epa.ie/pubs/reports/research/health/researchsheer.html
[64] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12264-Chemicals-strategy-for-sustainability-
[65] https://echa.europa.eu/regulations/reach/understanding-reach
[66] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12413-Sustainable-use-of-pesticides-revision-of-the-EU-rules

The EPA is responsible for enforcing POP laws, for completing POP reporting obligations and for the overall coordination of efforts to monitor and control POPs in Ireland. The country currently delivers legislatively in this area as part of the National POP Action Plan and National Implementation Plan[67]. Research can assist in providing strong evidence-based science for how to improve the plan in line with these changes and ensure that it will be fit for purpose into the future (refer to the research area Aiming for zero pollution to protect and restore our environment and to have a positive impact on health and wellbeing for further details). The EU Chemicals Strategy also flags the need for more consistent market surveillance activities to identify, in particular, products and materials imported from outside the EU that may contain regulated substances. Research could assist in developing new approaches to address these challenges, including in supporting the market surveillance activities of the EPA in identifying substances of concern in relevant consumer products (such as those controlled under the Restriction of Hazardous Substances Directive[68] and in developing emerging technologies to monitor nitrogen dioxide for air quality assessments.

EPA activities such as regulation and licensing are driven by policy. The EPA report Drinking Water Quality in Public Supplies 2019[69] highlighted that, in addition to the standard monitored and regulated contaminants of drinking water, knowledge about further risks to water quality is emerging from a better understanding of the issues around new chemical formulations and the combined use of chemicals (adverse impacts of mixtures) and their occurrence in the environment. The new EU Drinking Water Directive[70] will come into force in 2022. There are indications that there will be risk-based approaches to determining some of the key criteria for substances to be licensed and regulated. Many of these substances, such as endocrine disruptors, verotoxigenic *Escherichia coli*, (VTEC) *Cryptosporidium*, nanomaterials, microplastics, and existing and emerging chemicals (e.g. polyfluorinated alkyl substances (PFAs)), are not currently regulated and not regularly monitored in our water supplies. Research is needed, in the medium and longer term, to better understand the significance of these substances and develop methods for managing and regulating them in terms of their impacts on the environment and our health.

Improving the effectiveness of approaches to preparing for, responding to and recovering from nuclear and radiological emergencies will in turn ensure a better environment and overall wellbeing. The EPA has monitoring and regulatory roles under the Ionising Radiation Regulations 2019[71], the Euratom Drinking Water Directive and the Radioactive (Substances in Drinking Water) Regulations 2016[72]. Research is needed to respond to knowledge gaps and evidence needs relating to the detection of radioactivity in drinking water, addressing emerging issues in radioecology, and the identification and minimisation of potential exposures of both people and the environment.

The EPA is responsible for monitoring public exposure to Non-Ionising Radiation (NIR) and providing advice to government policymakers. The National Policy Framework 2040 emphasises the need to ensure that Ireland's telecommunications and electricity infrastructure takes full advantage of new technologies and meets future connectivity needs. Examples of this are the deployment of 5G and the proposed electricity interconnectors. Research will help to assess the impact that the deployment of new technologies and these major projects have on the public's exposure to NIR and help the EPA

[67] https://www.epa.ie/water/wastewater/nip/
[68] https://ec.europa.eu/environment/waste/rohs_eee/index_en.htm
[69] https://www.epa.ie/pubs/reports/water/drinking/drinkingwaterqualityinpublicsupplies2019.html
[70] https://www.europarl.europa.eu/committees/en/drinking-water-in-the-eu-better-quality-/product-details/20200302CAN53581
[71] S.I. No. 30/2019 (http://www.irishstatutebook.ie/eli/2019/si/30/made/en/pdf).
[72] S.I. No. 160/2016, European Union (Radioactive Substances in Drinking Water) Regulations 2016 (http://www.irishstatutebook.ie/eli/2016/si/160/made/en/print).

meet its statutory functions and guide policy. In addition, building research capacity and expertise in NIR in Ireland is needed.

Radon is linked to the development of approximately 300 cases of lung cancer each year in Ireland, according to the EPA State of the Environment Report 2020. The EPA, in partnership with other government departments and agencies, is responsible for delivering on the government's National Radon Control Strategy[73] (NRCS). The research needed to support the NRCS actions is set out in the report *National Radon Control Strategy: Knowledge Gaps, Phase 2*[74]. This document sets out the key research topics for the period 2019–2023, which include the impact of the planned retrofitting of Ireland's housing stock on indoor radon levels and the identification of karst limestone areas with anomalously high radon levels.

The EPA State of the Environment Report 2020 identifies AMR as a strategic risk to our health and wellbeing. Assessing their impact on soil, water quality, drinking water, recreational and bathing waters and what the subsequent impacts will have on human beings, is critical for our health and wellbeing. Ireland's first National Action Plan on AMR (iNAP)[75] was published in 2017 and recognises that joint coordinated action is needed to deal with the threat of AMR to public health, animal health and the environment. The second iNAP on AMR is currently being prepared for the period 2021–2025. The EPA has a number of key roles under the iNAP on AMR: to promote research (both national and international, funded by the EPA) on antibiotics in the environment and antibiotic resistance; to promote best practice in the management of hazardous waste; and to monitor for antibiotics in the environment, under the national water monitoring programme. The findings and recommendations from ongoing research in Ireland on AMR in relation to drinking water, recreational waters and the health impacts of exposure to AMR will inform the identification of research needs for the period 2024–2026. The EPA is funding a gap analysis of research needs as part of the preparation of the second iNAP will also provide information on existing gaps in our knowledge, that may need to be addressed by research during the period 2021–2023.

In 2018, the WHO Regional Office for Europe published the *Environmental Noise Guidelines for the European Region*[76]. These guidelines linked environmental noise to some 48,000 new cases of heart disease and 12,000 premature deaths in Europe each year. An assessment carried out under the Environment Noise Directive (END)[77] indicates that road transport noise is the most significant noise pollution contributor in Ireland. The END assessment is based on modelling of noise levels from a strategic viewpoint and does not take into consideration localised impacts. Government policy, under objective 65 of the National Policy Framework calls for the aims of the END to be supported through national planning guidance and noise action plans. The EPA oversees the implementation of END in Ireland and coordinates noise mapping guidance by providing support and advice to ensure that local authorities and relevant bodies have a robust noise monitoring framework and noise action plans in place. Research is therefore required to develop a framework for the proactive management of environmental noise, especially transport noise, particularly where it is likely to have adverse impacts on health and quality of life, and to aid the development of national planning guidance for 2040. Such research will also help to grow national expertise in the area and provide co-benefits in terms of air quality improvements. The findings and recommendations from ongoing research in Ireland will assess the health impacts of exposure to environmental noise in Ireland and inform the identification of research needs on noise and health for the period 2024–2026.

[73] https://www.epa.ie/radon/getinformed/nationalradoncontrolstrategy/
[74] http://www.epa.ie/pubs/reports/radiation/Knowledge%20Gaps%20Phase%202.pdf
[75] https://www.gov.ie/en/publication/ec1fdf-irelands-national-action-plan-on-antimicrobial-resistance-2017-2020/
[76] https://www.euro.who.int/__data/assets/pdf_file/0008/383921/noise-guidelines-eng.pdf
[77] European Communities (Environmental Noise) Regulations, S.I. No 549/2018 (http://www.irishstatutebook.ie/eli/2018/si/549/made/en/print).

Appendix 1 provides a non-exhaustive list of ongoing EPA-funded research, awaiting findings and recommendations, which will inform the research needs for the period 2024–2026.

Appendix 4 provides selected examples of the key policy objectives and targets relevant to the Delivering a Healthy Environment Research Hub for the period 2021–2023.

Research Actions Identified

The following research actions were identified during the consultation process in 2020 that are relevant to policy and aligned with the key activities of the Agency.

These include, but are not limited to:

Aiming for zero pollution to protect and restore our environment and to have a positive impact on health and wellbeing

- HE-1. Generating novel approaches for detection and quantification of the levels of chemicals and substances, such as POPs, PFAs, pesticides and GMOs in various environmental media, e.g. water, air and soil.
- HE-2. Identifying the characteristics of a healthier environment in terms of acute pollution and chronic exposure and increasing our understanding of the key environmental contributors to chemical exposure in Irish citizens.
- HE-3. Increasing our knowledge on the impact of legacy and new substances in the environment and increasing amounts of unregulated substances from sewage sludge and biosolid disposal.
- HE-4. Quantifying pollution trends and the carbon footprints of EPA-regulated industries (industrial emissions/integrated pollution control/waste) in Ireland.
- HE-5. Understanding the lifecycle of chemicals in the environment in Ireland to assist in establishing the links between chemicals in the environment and human health and wellbeing.
- HE-6. Developing novel management approaches for odour abatement at waste treatment and industrial facilities.

Realising the co-benefits and opportunities for citizens from transition and transformation to sustainable behaviours by putting health and wellbeing at the centre of all policy areas

- HE-7. Addressing knowledge gaps and challenges and developing tools for environmental protection, taking account of societal needs and concerns for improved regulatory decision-making.
- HE-8. Improving the need to link health and environmental policy, e.g. health impact assessment and SEA, by developing good practice guidance and methodology (including monitoring key performance indicators) for addressing health in SEA.
- HE-9. Examining how to influence behavioural change by better communicating the benefits of a good-quality environment for health and wellbeing.
- HE-10. Exploring opportunities to apply best practice with respect to measures to reduce pollution, and thereby improve health and wellbeing, that could be replicated within an Irish context.
- HE-11. Increasing our knowledge on multiple environmental stressors and how they affect health and wellbeing.

Reducing the socio-economic inequalities related to exposure to unhealthy environmental conditions

HE-12. Gaining insight into how different parts of our society tend to be disproportionately affected by poor environmental conditions.
HE-13. Increasing our understanding of the linkages between poor environmental quality and impacts on human health and wellbeing.
HE-14. Modelling the direct and indirect health impacts of odour and climate change, e.g. stress, eco-anxiety and other mental health issues.
HE-15. Informing the development of a cross-sectoral framework for blue/green spaces that is linked with health, water and air quality, climate-proofing, housing and other related issues.

Understanding the increased environmental and human health risks posed by exposure to legacy and new chemicals, radiation (non-ionising and ionising), pharmaceuticals, AMR, environmental noise, etc., in different environmental media and ecosystems

HE-16. Addressing the knowledge gaps set out in *National Radon Control Strategy: Knowledge Gaps, Phase 2*, in particular the impact of the planned retrofitting of Ireland's housing stock on indoor radon levels and the identification of karst limestone areas with anomalously high radon levels.
HE-17. Improving our knowledge of how public exposure to NIR in Ireland is affected by new telecommunications technologies or the introduction of major electricity infrastructure.
HE-18. Increasing our understanding of the sources, pathways and significance of legacy, existing and emerging substances in terms of their impact on the environment and our health.
HE-19. Providing solutions to track and mitigate against CECs, chemicals (e.g. PFAs), endocrine disruptors, pesticides, zoonoses and microplastics in drinking water supplies and aquatic ecosystems.
HE-20. Identifying the risk factors associated with zoonotic pathogens, pollutants and contaminants in public and private water supplies (in particular in rural locations) and identifying structural and behavioural strategies to mitigate these risks.
HE-21. Understanding the health impacts of the interactions between chemical and physical agents (e.g. air pollution and radiation).
HE-22. Identifying the elements needed for the proactive management of environmental noise to prevent adverse impacts on health and quality of life and aid the development of national planning guidance.
HE-23. Improving the detection of radioactivity in drinking water and addressing emerging issues in radioecology, allowing the identification and minimisation of potential exposures of both people and the environment.
HE-24. Developing new techniques to support market surveillance of products and materials imported from outside the EU (e.g. analytical methods, sampling techniques, risk assessment methods).
HE-25. Increasing research on human biomonitoring to capture the full range of contaminants originating from our environmental activities (e.g. POPs and metabolisable contaminants such as phthalate plasticisers).
HE-26. Improving our knowledge of the fate and transport of antimicrobial-resistant microorganisms in the environment, from point and diffuse pollution sources.
HE-27. Developing technologies that reduce and control antimicrobial-resistant microorganisms in wastewater treatment plants.
HE-28. Identifying medical ionising radiation protection and associated radiation protection needs.

Links with the National Research Priority Areas 2018–2023

The research areas and actions outlined under this hub are of relevance in addressing the national research priority areas identified in 2018 for the period up to 2023, namely:

- ICT – Future Networks, Communications and Internet of Things.
- ICT – Data Analytics, Management, Security, Privacy, Robotics and Artificial Intelligence.
- ICT – Digital Platforms, Content and Applications, and Augmented Reality and Virtual Reality.
- Food – Food for Health.
- Food – Smart and Sustainable Food Production and Processing.
- Health and Wellbeing – Connected Health and Independent Living.
- Energy, Climate Action and Sustainability – Decarbonising the Energy System.
- Energy, Climate Action and Sustainability – Sustainable Living.

Links to International Networks

Examples of the relevant international research networks include:

- Horizon Europe missions: Healthy oceans, seas, and coastal and inland waters; and Soil health and food.
- Horizon Europe clusters: Health; Civil Security for Society; and Food, Bioeconomy, Natural Resources, Agriculture and Environment.
- EURATOM Research Programme.
- EU networks/Horizon Europe proposed partnerships: European Partnership for Chemicals Risk Assessment; European Partnership for Innovative Health; European Partnership for One Health/AMR; BiodivERsA network, Biodiversity Partnership, Joint Programming Initiative (JPI) Urban Europe, “Driving Urban Transitions towards a Sustainable and Liveable Urban Future”; Water JPI; Water4All Partnership; JPI AMR; JPI Climate; and JPI Oceans.

2021–2023 Research Areas for the Research Hub on Protecting and Restoring our Natural Environment

Our natural environment provides us with clean air and water, food and the raw materials to sustain us and our economy. Research is required to inform and support a cross-sectoral approach to managing our natural environment and for the development of policies relating to the regulation of emissions and activities and the protection of our water, land and ecosystems.

Challenges

The EPA State of the Environment Report 2020[78] highlights that the overall current state of our natural environment is very poor. It states that, nationally, Ireland needs to intensify its efforts to protect nature. It calls for a "halt to any further deterioration in our natural environment; to start restoring the precious habitats and water bodies that we have lost and to leave space for nature as part of a new approach to biodiversity protection".

Our natural environment provides us with critical goods and services that society relies on, such as clean air and water, food, flood and drought control and the raw materials to support our economy and produce many medical treatments. It is also important to our wellbeing and affords us many opportunities for recreation[79]. Ireland faces persistent problems in relation to biodiversity loss and human-induced degradation of natural ecosystems, with land use demands and practices being at the heart of these national challenges. According to the European Commission, Ireland needs to do more to ensure compliance with the European Union (EU) nature directives and protect designated areas. Transformative change is needed to achieve the vision in the National Biodiversity Action Plan 2017–2021[80].

In 2019, the United Nations (UN) General Assembly declared 2021–2030 the "UN Decade on Ecosystem Restoration"[81]. The 2019 European Green Deal states that all EU policies should contribute to preserving and restoring Europe's biodiversity and natural capital. The EU Biodiversity Strategy for 2030, *Bringing Nature Back into our Lives*, will drive this agenda forward, with legally binding targets set to reduce pollution in water, air and soil and dedicated targets to restore and protect the Natura 2000 network, including extending this to the marine environment. The 2020 report on the state of Europe's environment from the European Environment Agency adds to the growing body of evidence from international organisations advocating for more urgency in protecting the environment, safeguarding biodiversity and tackling climate change. The UN Sustainable Development Goals (SDGs), in particular SDG 15, Life on Land, calls on us to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". Other cross-cutting and relevant SDGs are SDG 3, Good Health and Well-being, and SDG 6, Clean Water and Sanitation, and SDG 14, Life Below Water. SDG 14 aims to ensure the sustainable use of our marine environment.

[78] https://www.eea.europa.eu/soer/2020
[79] https://ipbes.net/global-assessment
[80] https://www.cbd.int/doc/world/ie/ie-nbsap-v3-en.pdf
[81] https://www.unenvironment.org/news-and-stories/press-release/new-un-decade-ecosystem-restoration-offers-unparalleled-opportunity

The Programme for Government 2020 also includes objectives on improving the management of peatlands and soils, tackling the impact of invasive species on our ecosystems and using the carbon sink potential of our marine environment, without overexploitation. A cross-sectoral and whole-of-government approach to managing our natural environment is needed, linking it to economic and social policies. The ecosystem approach, incorporating natural capital accounting, seeks to ensure that biodiversity is recognised as part of a wider socio-economic ecological system and is considered in decision-making. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way and needs to be adapted.

According to the EPA State of the Environment Report 2020, the main threats and pressures reported on habitats and species in Ireland are from land use activities, intensification of agriculture, forestry and fisheries, natural system modifications (including drainage), quarrying, peat extraction, climate change, diffuse pollution and invasive species. There are opportunities to change how we interact with our natural environment for the better, including investing in nature-based solutions, accounting for natural capital, and promoting the use and generation of green and blue infrastructure.

Research is required to inform and support policies relating to the protection, restoration and management of our water, air, land, soil, biodiversity and ecosystems and the associated natural capital provided. Allied to this is the need to continually monitor, measure and evaluate the status of ecosystems within the context of socio-economic and environmental factors driving change. Research conducted under this hub will contribute to informing measures to halt the decline of biodiversity and to preserve and restore ecosystems on land, in water and at sea through improved knowledge and innovation.

Research areas identified for 2021–2023 under this hub include:

1. protecting our natural environment by halting the decline in the quality and quantity of our natural habitats, including halting the decline in biodiversity and protecting ecosystem health;
2. reversing and halting the continuing negative trends in water, air and soil quality;
3. improving the understanding of and communicating the value of our natural environment and how it affects society and the economy;
4. understanding the sources and impact of human-induced pollution on ecosystems and ecosystem services and how to respond to this;
5. understanding the impact of environmental policies on our terrestrial and aquatic ecosystems.

Alignment with the EPA's Activities

The EPA State of the Environment Report 2020 reiterates the objectives of the National Biodiversity Action Plan in recognising the need to "strengthen the knowledge base for conservation, management, and sustainable use of biodiversity". The EPA Research Programme can assist in delivering this objective, as the EPA is the recognised lead partner for reviewing priority needs for biodiversity research in the National Biodiversity Action Plan, including priorities identified in the Biodiversity Climate Change Sectoral Adaptation Plan. Under the National Peatlands Strategy [82]the EPA has a role in monitoring and assessing water quality and greenhouse gas emissions and again supporting priority research.

[82] https://www.npws.ie/peatlands-and-turf-cutting/peatlands-council/national-peatlands-strategy

The EPA is responsible for national monitoring programmes for and assessments of water and air quality and emissions from licensed facilities. The EPA is also responsible for the National Ecosystem Monitoring Network, under obligations set out in the National Emissions Ceiling Directive (NEC).

These programmes provide information on environmental status, including indicator trends analysis, and informs measures that need to be put in place to mitigate environmental degradation. Such assessments highlight that the decline in water quality, for example, is associated with nutrient pollution coming from agriculture and wastewater sources.

These programmes also support the EPA's remit in environmental regulation and licensing as the competent licensing authority under the EPA's Environmental Licensing Programme (ELP) in Ireland. The EPA is responsible for licensing and regulating emissions under the Industrial Emissions Directive (IED) and the NEC is also informed by such monitoring; the results show that Ireland is not meeting EU targets on emissions of ammonia to air under the NEC, with agriculture being the main source of ammonia emissions. The latter is a major issue for Ireland.

In partnership with the Ordnance Survey of Ireland (OSi), the EPA is producing a National Land Cover Map. Related to this, the EPA is collating a national land use archive for the purposes of Land Use, Land-use Change and Forestry (LULUCF). As part of this remit, the Agency is collating a national land use archive. The EPA is the also the competent authority for carrying out strategic environmental assessment (SEA) by assessing the impact of proposed plans and programmes on the Irish environment. There is certainly scope for greater application of statutory assessments such as SEA and Appropriate Assessment to improve the systematic mainstreaming of environmental considerations into sectoral plans and programmes, which could assist in protecting our natural environment.

Research that is aligned with the key activities of the EPA can help to gain more insight and understanding of the risks and practices that have negative impacts on our environment and provide solutions and pathways to restore and protect our natural environment.

Research Areas for 2021–2023

Protecting our natural environment by halting the decline in the quality and quantity of our natural habitats, including halting the decline in biodiversity and protecting ecosystem health

The EPA State of the Environment Report 2020[83] states that "habitat changes point towards a deteriorating trend in overall biodiversity" and that "interactions between different types of human activity, such as farming, forestry and town and country planning, shapes our environment, biodiversity and landscape. Land is often subjected to competing demands from different sectors. Measures are needed to ensure that these areas can add value to the network of protected areas across the country through linking habitats and enhancing landscapes to help reverse the current decline in habitats and species. Leaving space for our natural environment and nature should be as part of a new approach to biodiversity protection."

More innovative sustainable land use planning that supports a real integrated land use strategy, as proposed in the National Planning Framework 2040 (Project Ireland 2040) and the National Landscape Strategy, represents ways to integrate protection of biodiversity and ecosystems along with improved air quality, less odour, reduced noise, and better health and wellbeing. These strategies and frameworks enable us to better understand and take account of the interactions between environmental and landscape sensitivities in our sectoral and land use planning activities and enhance our environmental monitoring programmes. Our natural environment is influenced by, for

[83] https://www.eea.europa.eu/soer/2020

example, nature-based solutions, such as flood protection and the wide-spread roll-out of green and blue infrastructure and managing changes in our landscapes in a coherent manner can support the delivery of this national policy. In partnership with the Ordnance Survey of Ireland (OSi), the EPA is producing a National Land Cover Map. Related to this, the EPA is collating a national land use archive for the purposes of Land Use, Land-use Change and Forestry (LULUCF). As part of this remit, the Agency is collating a national land use archive; however, knowledge and data gaps still exist. Research could assist in developing automated validation mechanisms, e.g. through Earth observations and machine learning, to identify land use change trends and enhance our environmental monitoring programmes and assessments. The EPA SEA Action Plan 2021–2025, recognises the need to ensure the effectiveness of these plans and assessments. Research is required to ensure that these policies and assessments sustain and add to our biodiversity and ecosystems, while at the same time harnessing the co-benefits from nature-based solutions for the benefit of society and the economy.

There is a need for increased knowledge of habitat condition, ecosystem function and integrated, long-term, large-scale monitoring, in turn allowing for more accurate scenario modelling at local, catchment, regional and national scales. The impact of invasive species on Ireland's protected species list is expected to increase over the next decade. An interim review of the National Biodiversity Action Plan 2017–2021[84] highlighted that there has been limited progress in tackling invasive species. Further research is needed to fill current knowledge gaps in baseline information on invasive species, in particular their impact on aquatic ecosystems. Research will inform how to manage the risks caused, mitigate their increase and develop options to remediate them.

Reversing and halting the continuing negative trends in water, air and soil quality

Water, air and soil have been polluted with hazardous substances (from diffuse and direct sources) at rates that exceed what the environment is capable of dissipating. Climate change can also have direct impacts on the environment, for example where flooding can cause erosion of soils, reducing fertility and increasing pollutant run-off into water bodies. The EPA State of the Environment Report 2020 indicates that, over the past 20 years, there has been a deteriorating trend in water quality. According to the EPA's *Water Quality in 2019 – An Indicators Report*[85], elevated nutrient concentrations are contributing to pollution in our freshwaters and estuaries and causing difficulties with drinking water standards in some areas. Urgent action is now needed to reduce nutrient inputs (nitrogen, phosphate and ammonia) and sediment. There are numerous interlinking polices and strategies that will all have an influence on assisting in improving water quality if adopted and implemented. The Programme for Government 2020 highlights many areas of support to ensure that national and EU targets are met, for example:

- the EU Water Framework Directive (WFD) 2000[86], River Basin Management Plan (RBMP) 2018–2021[87], Floods Directive 2017 and Good Agricultural Practice for Protection of Waters Regulations 2018[88];

[84] https://www.npws.ie/interim-review-implementation-national-biodiversity-action-plan-2017-2021
[85] http://www.epa.ie/pubs/reports/water/waterqua/waterqualityin2019-anindicatorsreport.html
[86] European Commission, EU water legislation fitness check (https://ec.europa.eu/environment/water/fitness_check_of_the_eu_water_legislation/). European Commission, 2017. Fitness check of the WFD and the Floods Directive (https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2017-5128184_en).
[87] https://www.gov.ie/en/publication/429a79-river-basin-management-plan-2018-2021/?referrer=http://www.housing.gov.ie/water/water-quality/river-basin-management-plans/river-basin-management-plan-2018-2021
[88] S.I. No. 65/2018, European Union (Good Agricultural Practice for Protection of Waters) (Amendment) Regulations 2018 (http://www.irishstatutebook.ie/eli/2018/si/65/made/en/print?q=65&years=2018).

- the new Common Agricultural Policy 2020 strategic plan, the revised Fifth Nitrates Action Programme[89], Food Wise 2025[90], the national Agri-food Strategy 2030[91] potential revisions to the Sewage Sludge Directive[92] and the SEA Directive [93];
- the Climate Action Plan 2019, the National Adaptation Framework 2018, including some specific sectoral adaptation plans, e.g. the Water Quality and Water Services Infrastructure Adaptation Plans, the EU Habitats Directive and Birds Directive[94] and the EU Biodiversity Strategy for 2030[95].

The EPA's roles in monitoring, assessing, characterising and reporting on the quality of rivers, lakes, transitional and coastal waters, bathing waters and groundwaters and in measuring water levels and river flows form the scientific foundation on which mitigation measures and the programme of measures (POM) for the RBMPs are built. Multidisciplinary interconnected catchment and land use approaches are needed to examine short- to medium-term and longer-term water quality scenarios. The impact of sediment, diffuse pollution and chemicals on water quality, in particular in high-status water bodies, which are being rapidly lost, is a major issue in Ireland. The EPA State of the Environment Report 2020 highlights the increase in the number of water bodies in poor ecological health and clearly states that, "Rescue plans are now needed for our remaining high-status water bodies to halt their decline." The LIFE project Waters of LIFE'[96] will target work towards protecting and halting the decline in Ireland's high-status waters and will support the work of the Blue Dot Programme[97], by acting as a demonstration testing site for the efficacy of POMs in place and those being developed. In addition to delivering Ireland's obligations under the WFD, the Waters of LIFE project will support objectives under the Birds and Habitats Directives, the Nitrates Directive and the Floods Directive. Research could assist in informing actions and mitigation measures by providing projections of pollution sources and pathways. Research is also required to inform policies on alternative pathways for land use activities that support high-value ecosystems.

Heavily modified water bodies and hydromorphological pressures need pragmatic and workable solutions to meet the "good objective" under the WFD. The EU Biodiversity Strategy for 2030[98] is proposing a legally binding target of at least 25,000 km of rivers being restored into free-flowing rivers by 2030. Research will need to assist in developing these solutions.

While overall air quality in Ireland is good, as highlighted by the EPA State of the Environment Report 2020, there are still exceedances of nitrogen dioxide in some of our major urban centres. Air quality does not always meet the World Health Organization (WHO) guideline values for some air pollutants and is not meeting EU targets on emissions of ammonia to air under the NEC. The EPA monitors air quality and implements the EU Clean Air for Europe Directive, the Convention on Long Range Transboundary Air Pollution and the NEC. The EPA *Air Quality in Ireland 2019* report[99] also highlights exceedance trends in our air quality that need to be addressed at various levels. Research could help further tackle Ireland's issues in relation to increases in air pollutants (existing and emerging) from solid fuel burning, agricultural sources and transport, e.g. fine particulate matter (PM), ammonia, nitrogen dioxide, ozone, sulfur dioxide and heavy metals, and allow us to explore mechanisms for achieving the highest international air quality standards.

[89] https://www.gov.ie/en/consultation/6c940-public-consultation-on-irelands-nitrates-action-programme/
[90] https://www.agriculture.gov.ie/foodwise2025/
[91] https://www.gov.ie/en/consultation/786c25-public-consultation-on-irelands-agri-food-strategy-to-2030/
[92] https://ec.europa.eu/environment/waste/sludge/
[93] https://ec.europa.eu/environment/eia/sea-legalcontext.htm
[94] https://www.npws.ie/legislation/eu-directives
[95] https://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm
[96] https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=7403
[97] https://www.catchments.ie/the-blue-dot-catchments-programme/
[98] https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en
[99] https://www.epa.ie/pubs/reports/air/quality/epaairqualityreport2019.html

Improving the understanding of and communicating the value of our natural environment and how it affects society and the economy

The EPA State of the Environment Report 2020 advises that "implementing national biodiversity policies, such as the National Biodiversity Action Plan, requires an increased level of collaboration and coordination across multiple sectors and the whole of society. This can also give rise to indirect co-benefits for other sectors and environmental issues such as climate change and water quality."

There is a need to link social science, economics of land use and environmental sciences to understand which policy levers can effectively deliver the benefits to society at various scales. Demonstrating and effectively communicating the benefits of restoration and protection requires connecting quantity, quality and location of natural capital with the ecosystem services provided and highlighting who/where the benefits accrue to. This will help to illustrate the value of our natural environment and guide investment to areas where the greatest benefits will accrue to the most people.

Understanding the sources and impact of human-induced pollution on ecosystems and ecosystem services and how to respond to this

As an island nation, we need to protect and restore our transitional and coastal waters. The WFD, the Marine Strategy Framework Directive (MSFD)[100] and the Maritime Spatial Planning Directive (MSPD) [101] are the main legislative drivers for the protection of these water bodies, which are impacted by pollution and upstream catchment activities, leading to eutrophication, and from pollutive impacts, such as plastics and nutrients. The findings and recommendations from ongoing research in Ireland on microplastics' impact on freshwater and marine ecosystems will inform the identification of research needs for the period 2024–2026. The WFD objectives of good water quality status and the MSFD good ecological status are key drivers. The EPA State of the Environment Report 2020 advises that our estuaries now have the lowest water quality ranking overall. Research can provide methods to mitigate pollution and the impact of climate change. The EU Biodiversity Strategy for 2030 is proposing very ambitious, legally binding targets for the protection and restoration of up to 30% of Europe's seas, as well as of 10% under "strict protection" in 2021, including greater protection for the Marine Natura 2000 areas. Research will be required at a national level to support the development of policy to implement these new initiatives and meet the proposed legally binding targets. Such research would be carried out in conjunction with agencies such as the Marine Institute.

Under the National Emissions Ceiling Directive[102], Ireland must maintain a national ecosystem monitoring network. This activity is overseen by the EPA. Findings and recommendations from ongoing research in Ireland to support the implementation of this directive, by improving our understanding of how pollutants impact terrestrial ecosystems, will inform the identification of research needs for the period 2024–2026.The EPA also has an enforcement role in emissions under the IED. Research into the impact of ammonia from a number of sectors, such as agriculture and industrial facilities, on nearby designated natural areas and air quality is urgently needed and would inform measures to protect these areas.

[100] https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm
[101] https://www.eea.europa.eu/policy-documents/directive-2014-89-eu-maritime
[102] https://www.eea.europa.eu/themes/air/air-pollution-sources-1/national-emission-ceilings

Understanding the impact of environmental policies on our terrestrial and aquatic ecosystems

Healthy ecosystems underpin solutions to many of the issues we face with the decline in the quality of our terrestrial and aquatic environments. With land use planning being central to protection and restoration of the natural environment, planning must consider the projected impacts of policy change.

Assessing how the application of nature-based solutions can assist in protecting and restoring peatlands, woodlands, soils and wetlands to act as natural solutions (green and blue) for national challenges should be informed by strong evidence-based research and offer significant opportunities to achieve improvements in water quality, while delivering multiple benefits for the environment including climate, air quality and biodiversity. The LIFE-funded integrated project targeting blanket bog restoration, LIFE Wild Atlantic Nature[103] programme, aims to protect and restore Ireland's blanket bog in 24 of the Natura 2000 sites along the Atlantic seaboard. The LIFE Peatlands and People programme[104] aims to drive enhanced restoration of peatlands, not only for carbon sequestration but also for water quality and biodiversity improvements that may arise from peatland restoration (refer to the 2021–2023 Research Areas for the Research Hub on Addressing the Climate Change Evidence Needs for further detail). Both of these projects will have major co-benefits for water quality, flood abatement and climate change mitigation. Research may be needed to provide baseline and trend data to assist in monitoring improvements.

The Common Agricultural Policy Strategic Plan 2020, the Farm to Fork Strategy 2020, the National Policy Statement on the Bioeconomy and the forthcoming national Agri-Food Strategy 2030 will play central roles in putting biodiversity centre stage, encouraging and incentivising farmers to restore and protect our natural environment, e.g. reduce fertiliser and pesticide use. Research in relation to the impact (positive and negative) of farming practices, land use changes and systems on the natural environment is necessary to support efforts to improve environmental sustainability and understand the added value that ecosystems and biodiversity bring to soil health and carbon storage.

As biodiversity loss and the climate crisis are inextricably linked, our natural environment should be recognised as a vital ally in the fight against climate change. "Biodiversity protection, land use and Ireland's transition to a climate-neutral, climate-resilient society are linked, for example, and can be worked on together", and the EPA State of the Environment Report 2020 clearly highlights this interconnectivity. The application of nature-based solutions can assist in climate change mitigation, flood protection and reduction in run-off from pollution by protecting and restoring peatlands, woodlands, soils and wetlands, allowing them to be naturally used as carbon sinks and to act as natural buffers against flooding, for example.

The carbon sequestration value of forestry, peatlands, soils and wetlands is critical in achieving the national climate action ambitions set out in the Climate Action Plan 2019. The Climate Change Advisory Council also noted that awareness of and willingness to act on adaptation remains poor, and co-benefits with mitigation are underexplored (refer to the 2021–2023 Research Areas for the Research Hub on Addressing the Climate Change Evidence Needs for further detail).

[103] https://ec.europa.eu/ireland/news/new-eu-projects-launched-to-restore-irelands-blanket-bogs-and-protect-water-quality_en

[104] https://cordis.europa.eu/article/id/429005-irish-peatlands-central-to-a-new-eu-funded-climate-action-initiative

Appendix 1 provides a non-exhaustive list of ongoing EPA-funded research, awaiting findings and recommendations, which will inform the research needs for the period 2024–2026.

Appendix 5 provides selected examples of the key policy objectives and targets relevant to the Protecting and Restoring our Natural Environment Research Hub for the period 2021–2023.

Research Actions Identified

The following research actions were identified during the consultation process in 2020 that are relevant to policy and aligned with the key activities of the Agency.

These include, but are not limited to:

Protecting our natural environment by halting the decline in the quality and quantity of our natural habitats, including halting the decline in biodiversity and protecting ecosystem health

- NE-1. Addressing data gaps in habitat conditions, quality of the habitat and ecosystem functions.
- NE-2. Providing a greater understanding of the interconnectivity between aquatic (freshwater, groundwater, transitional and marine) and terrestrial ecosystems (trends, condition, pressures).
- NE-3. Developing *in situ* automated validation mechanisms, e.g. through Earth observations and machine learning, to identify land use change trends and enhance our environmental monitoring programmes and assessments.
- NE-4. Restoring and protecting high-status sites that are being lost rapidly and understanding the implications of this loss.
- NE-5. Addressing current knowledge gaps in baseline information on invasive species and on how to manage the risks caused and mitigate against their increase (including options to remediate), in particular in relation to aquatic-dependent ecosystems.
- NE-6. Developing integrated good practice guidance and methodology (including monitoring key performance indicators) for a holistic approach to landscape assessment at different spatial levels in SEA.

Reversing and halting the continuing negative trends in water, air and soil quality

- NE-7. Informing the development of mitigation measures to achieve WFD objectives, especially those on diffuse pollution, sediment and hydromorphology.
- NE-8. Improving our understanding of the impacts of agricultural activities on air pollution and associated impacts on sensitive ecosystems in Ireland.
- NE-9. Protecting soil health and ensuring sustainable management of soil resources and sustainable food production to benefit our health and wellbeing.
- NE-10. Assessing the effectiveness and resilience of available mitigation measures for water, air and soil pollution in the context of climate change, agricultural production and land use, resilience of ecosystems, and natural capital accounting.
- NE-11. Protecting our water resources and ensuring safe, accessible and resilient water supplies for drinking, economic and recreational uses.
- NE-12. Assessing and quantifying the environmental impacts associated with critical infrastructure, particularly in terms of air quality and noise in relation to major transport hubs (in particular rail) and wind turbines.

NE-13. Addressing the knowledge gaps in relation to the impacts of poor air quality (indoors/in vehicles) from air pollutants (existing and emerging) from solid fuel burning and transport, e.g. fine PM, nitrogen dioxide and ozone pollution (refer to the 2021–2023 Research Areas for the Research Hub on Delivering a Healthy Environment).

Improving the understanding of and communicating the value of our natural environment and how it affects society and the economy

NE-14. Assessing the short-term and local value of ecosystem services and the longer-term value of the services they provide.

NE-15. Exploring the positive impact and value of mitigation measures already introduced, such as the introduction of wildflower areas, rewilding and increased green spaces, where we live.

NE-16. Developing evaluation methodologies to assess the social and economic value of ecosystem services.

NE-17. Identifying the co-benefits for society and the economy, both direct and indirect, of natural capital (including accounting) and ecosystem services protection and restoration.

NE-18. Understanding the role of wetlands, peatlands, soils and woodlands in providing climate and environmental resilience and understanding their rehabilitation and restoration and their valuation in terms of natural capital accounting.

NE-19. Designing approaches to better integrate the ecosystem services approach into practical actions and policies, at national and local levels, that would have positive impact on society and the economy.

NE-20. Understanding how people view or relate to nature and developing approaches to raise stakeholders' awareness of the long-term value of our natural environment.

NE-21. Demonstrating the benefits of restoration and protection by linking quantity, quality and location of natural capital with ecosystem services provided and to whom and where the benefits accrue.

Understanding the sources and impact of human-induced pollution on ecosystems and ecosystem services and how to respond to it

NE-22. Assessing the effectiveness, response and resilience of ecosystems to human activities in the natural environment and supporting transdisciplinary ecosystem restoration strategies through pilot research sites at various scales and over different timeframes.

NE-23. Increasing our knowledge on how ecosystems increase nutrient recycling and absorption of waste applied to our soils.

NE-24. Anticipating the response of national ecosystems and biodiversity to pandemics.

NE-25. Understanding the impact (positive and negative) of human activity on the natural environment, such as the value of ecosystems and biodiversity to soil and marine health and carbon storage.

Understanding the impact of environmental policies on our terrestrial and aquatic ecosystems

NE-26. Assessing and realising the multiple environmental benefits of implementing nature-based solutions in the Irish context.

NE-27. Providing knowledge to inform the development of national monitoring networks looking at habitat quality and habitat change over time.

NE-28. Exploring how consideration of carbon sequestration, climate change adaptation, biodiversity and wider ecosystem services can be incorporated into the national land use review.

Links with the National Research Priority Areas 2018–2023

The research areas and actions outlined under this hub are of relevance in addressing the national research priority areas identified in 2018 for the period up to 2023, namely:

- Food – Food for Health.
- Food – Smart and Sustainable Food Production and Processing.
- Health and Wellbeing – Connected Health and Independent Living.
- Energy, Climate Action and Sustainability – Decarbonising the Energy System.
- Energy, Climate Action and Sustainability – Sustainable Living.

Links to International Networks

Examples of the relevant international research networks include:

- Horizon Europe missions: Healthy Oceans, Seas, and Coastal and Inland Waters; Soil Health and Food.
- Horizon Europe clusters: Food, Bioeconomy, Natural Resources, Agriculture and Environment.
- EU networks/Horizon Europe proposed partnerships: BiodivERsA network; Biodiversity Partnership; European Partnership for a climate neutral, sustainable and productive blue economy; Ecosystem Services Partnership; Joint Programming Initiative (JPI) Urban Europe, "Driving Urban Transitions towards a Sustainable and Liveable Urban Future"; Water JPI; Water4All Partnership; JPI AMR; JPI Climate; and JPI Oceans.

Cross-cutting and Emerging Research Areas

Cross-cutting Research Areas

EPA Research 2030 recognises that there are cross-cutting issues between the hubs, and accordingly it will bring an integrated and cross-sectoral approach enabling holistic management and protection of our environment. Moreover, consideration of the interactions between social, behavioural and economic factors, as an integral component of environmental research, will lead to enhanced governance and more effective implementation of environmental policies and strategies. It should support the facilitation of the EPA's key roles in environmental monitoring, assessment, regulation and providing knowledge and advocacy for the environment.

There are undoubtedly cross-cutting issues between the four hubs. The reason is that the hubs share drivers (economic activity and human behaviour) that can put pressure on the environment but in different ways. For example, livestock rearing causes emissions that can have an impact on air quality and the climate system, water quality, nature protection and the generation of wastes that can be difficult to manage. However, the solutions may be cross-cutting and have multiple co-benefits. The development of the bioeconomy (e.g. producing new added-value whey products from dairy waste) can potentially reduce reliance on fossil fuels, reduce carbon emissions, reduce plastic waste, and in turn result in less pollution of microplastics in freshwater and marine ecosystems. This more holistic approach also presents socio-economic opportunities to develop in a more sustainable manner.

Indeed, the Climate Change Advisory Council report[105] advised that, "there is also an opportunity within the Agriculture, Forestry and Land Use sector to advance progress on the national policy position, while providing multiple co-benefits to society. Mitigation activities within this sector can provide additional ecosystem services including: protecting biodiversity; improving soil, air and water quality; ensuring resilience to climate change; and enhancing Ireland's natural environment."

Cross-cutting dimensions may also include the application of the rapidly expanding digital economy technologies and solutions (e.g. Earth observation/remote sensing, artificial intelligence, analytics) to addressing environmental challenges in the domains of monitoring, assessment and policy implementation.

The Programme for Government 2020[106] provides for a "transformational programme of research and development to ensure Ireland is at the cutting edge of scientific and technological innovation in meeting our climate change targets, including in the bioeconomy, in marine sequestration, in green hydrogen, in wave technology, in developing floating offshore wind turbines to take advantage of the Atlantic coastline, and in agriculture to improve breeding programmes, feed additives to reduce biogenic methane, agroforestry, paludiculture and nutrient management."

The potential for multiple benefits strengthens policy initiatives, especially if potential trade-offs and synergies have been robustly considered. How do we measure their impact not just in terms of the EPA's activities in monitoring emissions and regulating pollution but also in terms of capturing co-benefits in a convincing and logical way that would allow for more comprehensive assessment of policy options by policymakers? Research can support the development of policy initiatives that demonstrate greater policy coherence, are robust and more likely to support the "just transition" that is looked for in the Programme for Government 2020, in the forthcoming European Union (EU) Eighth Environmental Action Plan, and in globally agreed goals such as the United Nations (UN) Sustainable Development Goals (SDGs) and those referred to in the Paris Agreement.

105 https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/publications/CCAC_AnnualReview2020FINAL.pdf

106 https://assets.gov.ie/94092/50f892b9-a93e-43fc-81d1-778ff9954d9f.pdf

Emerging Research Areas

EPA Research 2030 will be flexible and emerging issues will be covered as required under the most relevant research hub. The priority research areas under each hub and under the guidance of the Research Coordination Groups, will evolve to accommodate emerging challenges and knowledge needs.

The COVID-19 pandemic has highlighted how new research needs can emerge in ways that are both unanticipated and urgent. It demonstrates the critical role of our natural environment in protecting and maintaining a safe and healthy environment by avoiding the transmission to humans of zoonoses. It has also demonstrated the ways in which environmental pollution (air pollution in this case) can have greater than expected health impacts, and wastewater analysis has shown how environmental research can support efforts to track disease and how contaminants of emerging concern can come from biological as well as chemical origins. The pandemic has also highlighted how policies designed for economic recovery can be designed to support the "just transition", in which the potential losers from the low-carbon economy are given due care and attention. The unequal distribution of costs and benefits arising from systemic changes is now recognised by policymakers, but it requires solid understanding, citizen engagement and effective responses.

Another area is the impact of Brexit. For example, any Brexit-related changes to UK environmental legislation, will have a direct impact on the border shared between Northern Ireland and Ireland, where environmental protection requirements will remain in line with EU directives. A changed policy and legislative environment in Northern Ireland could have an impact on the protection of shared natural resources (e.g. water catchments, protected areas) and transboundary pollution issues, such as national policies to address air pollution. Brexit highlights how changes in governance as well as new developments in our understanding of the environment can generate emerging research needs.

Appendix 1: Selection of Ongoing EPA-funded Projects Currently Awaiting Findings and Recommendations

The full list of EPA-funded projects is available online: https://erc.epa.ie/smartsimple/

Project code	Title	Indicative completion date
Addressing the Climate Change Evidence Needs – Understanding fundamental cycles, processes, trends and drivers of climate change		
2015-CCRP-MS.30	AUGER: peAtland properties inflUencing greenhouse Gas Emissions and Removals	01/01/2021
2016-CCRP-MS.40	Soil Organic carbon and Land Use Mapping (SOLUM)	29/11/2020
2018-CCRP-LS.1	Evaluating Land Use and Land Management Impacts on Soil organic Carbon in Irish Agricultural Systems	30/06/2022
2018-CCRP-LS.2	Smart Observations of Management Impacts on Peatland Function	01/01/2024
2018-CCRP-MS.55	Improvements in Inverse Modelling of Ireland's Greenhouse Gas Emissions	31/12/2021
2019-CCRP-DS.22	Assessing Potential for National Integrated Atmospheric Research	06/09/2021
2019-CCRP-MS.65	Fire, Land and Atmospheric Remote sensing of Emissions	01/04/2022
2020-CCRP-LS.6	Source Apportionment of Air Pollution in the Dublin Port Area	29/02/2024
Addressing the Climate Change Evidence Needs – Achieving climate neutrality by 2050		
2018-CCRP-FS.36	Climate Change and Land Use in Ireland	05/03/2021
2018-CCRP-MS.57	Scenarios Quantifying land Use and Emissions Transitions towards Equilibrium with Removals	24/03/2020
2019-CCRP-DS.20	Diversification of Dairy and Beef Production for Climate Smart Agriculture	30/06/2021
2019-CCRP-MS.64	Farm-Carbon: Hedgerows and Other Non-forest Woodland Carbon	30/03/2022
Addressing the Climate Change Evidence Needs – Preparing for Ireland's future climate (i.e. achieving climate resilience)		
2018-CCRP-MS.50	Multifactorial Causes of Fodder Crises in Ireland and Risks Due to Climate Change	30/09/2022
2018-CCRP-MS.51	HydroPredict – Ensemble Riverflow Scenarios for Climate Change Adaptation	31/12/2022
2018-CCRP-MS.56	Ireland's Contribution to CMIP6 and High-res Regional Climate Projections for Ireland	31/03/2022
2018-CCRP-MS.59	Achieving Resilience in the Marine and Coastal Environment of Ireland	03/03/2021
2018-NC-LS-3	Land2Sea: Integrated Modelling of Terrestrially Derived and Climatic Impacts on Freshwater and Marine Ecosystems	03/01/2022

Project code	Title	Indicative completion date
2019-CCRP-DS.21	BE-Resilient: Built Environment Resilient Futures. Best practice in implementing climate adaptation	01/03/2021
2019-CCRP-DS.23	Enhancing Integration of Disaster Risk and Climate Change Adaptation into Irish Emergency Planning	01/03/2021
2019-CCRP-DS.24	Climate Change Adaptation: Risks and Opportunities for Irish Businesses	22/03/2021
2019-CCRP-MS.60	CROSSDRO –Cross-sectoral Impact Assessment of Droughts in Complex European Basins	31/08/2022
2019-CCRP-MS.62	Climate Change in the Republic of Ireland: Societal Health Impacts and Solutions	01/03/2023
2019-CCRP-MS.63	High-resolution Coupled Atmosphere–Ocean–Wave Regional Climate Projections for Ireland	05/01/2022
2019-CCRP-MS.66	SOil MOisture estimates from SATellite based Earth observations	01/09/2022
2020-CCRP-MS.70	Irish Peatland Resilience to Changing Climate and Increased Frequency and Severity of Drought	28/02/2023
2020-W-CD-3	WFD Future Scenarios and Management Tools	30/03/2025
Addressing the Climate Change Evidence Needs – Realising the benefits of and opportunities arising from transition and transformation		
2017-CCRP-MS.49	Imagining2050: Engaging, Envisaging and Enabling Dialogue on Pathways towards a Low Carbon, Climate Resilient Ireland	02/05/2021
2018-CCRP-MS.58	Residential Solid Fuel Use in Ireland and the Transition Away from Solid Fuels	01/01/2021
2019-CCRP-DS.25	Connecting People to Climate Change Action: Longitudinal Analysis for Informing Participatory Frameworks in the NDCA	01/03/2021
2019-CCRP-MS.61	Transboundary Adaptation Learning Exchange	12/01/2022
2020-CCRP-MS.69	Challenging the Climate Crisis: Children's Agency to Tackle Policy Underpinned by Learning for Transformation	30/11/2023
Facilitating a Green and Circular Economy – Resource efficiency and socio-economic aspects of sustainable environmental research		
2016-ET-CP-86	Exploring Cradle to Cradle Opportunities in the Irish Construction Sector	31/07/2020
2017-RE-MS-8	Raw Materials Ireland	24/06/2020
2017-SE-MS-6	Co-designing for Resilient Rural Community Development through P2P Knowledge Networks and STEAM Place-based Learning Interventions	16/10/2020
2017-SE-MS-7	Framework for Achieving Environmental Sustainable Development Goals (SDGs)	22/03/2020
2018-ET-CP-94	Marine Plastic Waste – Closing the Loop (MARplas)	31/12/2020
2018-ET-CP-95	PROducing a composite from plastic BOTtles	17/08/2020
2018-NC-LS-2	Irish Natural Capital Accounting for Sustainable Environments – INCASE	28/02/2023

Project code	Title	Indicative completion date
2018-RE-DS-10	To Develop a National End-of-waste Standard for Quality Compost and Digestate	30/06/2020
2018-RE-DS-11	An Assessment of Used EEE Exports from Ireland	28/09/2020
2018-RE-LS-3	Screening of the Irish Waste Stream for Persistent Organic Chemicals	31/01/2022
2018-RE-MS-14	Advancing Packaging Waste Statistics and Recycling	28/11/2021
2018-RE-MS-15	Valorisation Alternatives to Landfill for Organic Residues	28/12/2021
2018-RE-MS-17	Qualifying and Quantifying the Reuse Sector in Ireland	24/03/2021
2018-SE-MS-11	Sustainable Production and Consumption: The Influence of Social Norm	30/10/2020
2018-SE-MS-12	Identifying Interactions for SDG Implementation in Ireland	07/12/2020
2018-W-MS-34	An Integrated System to Mitigate Environmental Impact from Disposal of Difficult Ammoniacal Wastes and Residues	13/01/2021
2019-ET-CP-100	Women's Environmental Community Activation Network	01/03/2021
2019-ET-CP-99	Rezero: Research and Implementation of Deposit–Return System	02/11/2020
2019-NC-MS-11	Relationships between Functional Diversity and Food Production and Quality under Ecological Intensification – FunProd	01/01/2023
2019-RE-DS-14	A Model for Setting Targets for Management of Long-life Products at their End of Life	01/03/2021
2019-RE-DS-15	Efficient Food	03/03/2021
2019-RE-PhD-3	Repurposing of Batteries from End of Life Electric Vehicles	31/10/2023
2019-SE-DS-21	Tiering of Environmental Assessment – The Influence of SEA on Project Level EIA	30/03/2021
2019-SE-MS-14	Optimising Behaviour Change Initiatives for Food Waste Prevention in Ireland	30/03/2023
2019-SE-MS-15	Sustainable and Holistic management of Irish Ports (SHIP)	08/03/2023
2019-SE-PhD-2	The Role of Science in Environmental Policy and Law-making: A Critical Legal Analysis	31/08/2022
2019-SE-PhD-3	STEP³ – Sustainability in Technology Engineering for Products, People, Planet	31/08/2021
2019-W-LS-21	Industrial Water 4.0 – A Framework for Catchment-based Digitally Integrated Industrial Water Stewardship	01/07/2022
Facilitating a Green and Circular Economy – Bioeconomy		
2016-W-LS-11	Novel Eco-sensitive Wastewater Treatment Recovering Dairy Industry Effluent NuTrientS (NEWTRIENTS)	30/09/2021
2017-RE-MS-10	An Irish Nutrient Platform to Underpin Sustainable Development	30/11/2020
2019-CCRP-DS.20	Diversification of Dairy and Beef Production for Climate Smart Agriculture	30/06/2021
2019-ET-CP-101	Development of a Sustainable Protein Production System through Insect Farming in Ireland	20/07/2021
2019-ET-CP-102	SymbioBeer	30/03/2021

Project code	Title	Indicative completion date
2019-ET-CP-96	Scoping the Irish Fruit and Vegetable Supply chain for Valuable Biomass Resources for Upgrade	31/07/2020
2019-NC-PhD-10	Towards Establishing Hemp as a Sustainable Crop for Irish Agriculture	31/08/2022
2019-RE-LS-4	Sustainable, Biodegradable, Compostable and Recyclable Plastics for Packaging and End-of- life Management	30/03/2023
Delivering a Healthy Environment – AMR research		
2017-HW-LS-1	Antimicrobial Resistance and the Environment – Sources, persistence, Transmission and risk management – AREST	31/03/2022
2018-HW-LS-2	Public health Impact of Exposure to antibiotic Resistance in recreational waters – PIER	30/03/2023
2018-W-PhD-11	Survival of Mobile Antibiotic Resistance in Water – SWAM	06/01/2023
2019-NC-MS-9	Biodiversity as an Ecological Barrier for the Spread of Clinically Relevant Antibiotic Resistance in the Environment – ANTIVERSA	01/02/2023
2019-W-PhD-14	Analysis of Antimicrobial Resistance in Private Water Drinking Supplies – WADA	31/08/2023
2020-HW-DS-15	Research Gap Analysis – Antimicrobial Resistance and the Environment	03/05/2021
Delivering a Healthy Environment – Noise research		
2017-HW-MS-10	Noise and Health: Evidence from Ireland – NOISE-HEALTH	01/08/2021
2017-HW-MS-9	Transitioning to Strategic Noise Mapping under CNOSSOS-EU – NOISE-ADAPT	01/08/2020
Delivering a Healthy Environment – Other research		
2018-CCRP-MS.58	Residential Solid Fuel Use in Ireland and the Transition Away from Solid Fuels	01/01/2021
2018-HW-PhD-3	Ammonia Cycling and Emerging Particulate Matter Pollutants under Arable Land Use Management	31/01/2022
2019-CCRP-MS.62	Climate Change in the Republic of Ireland: Societal Health Impacts and Solutions	01/03/2023
2019-CCRP-MS.65	Fire, Land and Atmospheric Remote sensing of EmissionS	01/04/2022
2019-CCRP-MS.67	Roadside Emissions in Dublin: Measurements and Projections	30/03/2022
2019-NC-MS-10	Managing Biodiversity in Forests and Urban Green Spaces: Dilution and Amplification Effects on Rodent Microbiomes and Rodent-borne Diseases – BioRodDis	02/12/2023
2019-SE-MS-15	Sustainable and Holistic management of Irish Ports (SHIP)	08/03/2023
Protecting and Restoring our Natural Environment – Natural capital and ecosystem services research		
2016-W-LS-10	Sources, Pathways and Environmental Fate of Microplastics	16/06/2021
2016-W-MS-23	Impacts of Microplastics on the Irish Fresh Water Environment	30/09/2020
2017-NC-PhD-1	Enhancing Natural Capital for Ecosystem Service Provision	30/09/2020

Project code	Title	Indicative completion date
2018-CCRP-MS.51	HydroPredict – Ensemble Riverflow Scenarios for Climate Change Adaptation	31/12/2022
2018-NC-LS-2	Irish Natural Capital Accounting for Sustainable Environments – INCASE	28/02/2023
2018-NC-LS-3	Land2Sea: Integrated Modelling of Terrestrially Derived and Climatic Impacts on Freshwater and Marine Ecosystems	03/01/2022
2018-NC-LS-4	Habitat Mapping, Assessment and Monitoring with High-resolution Imagery – iHabiMap	18/10/2023
2018-NC-PhD-4	Informing Monitoring and Conservation of Pollinator Natural Capital in Species-rich Grasslands	01/10/2022
2018-NC-PhD-5	Brilliant Bees: The Importance of Managed and Wild Pollinators to Irish Natural Capital	01/10/2022
2018-NC-PhD-6	Maximising Macroalgal Diversity and Ecosystem Function on Coastal Infrastructure – An Eco-engineering Approach	01/10/2022
2018-NC-PhD-8	Developing effective non-thermal interventions to Address Very complex diseases in factory farmed Bumblebees – SAVE-Bee	03/02/2023
2019-CCRP-LS.3	NEC Indicators for Air Pollution Effects on Terrestrial Ecosystems	01/01/2025
2019-CCRP-MS.66	SOil MOisture estimates from SATellite based Earth observations	01/09/2022
2019-NC-MS-10	Managing Biodiversity in Forests and Urban Green Spaces: Dilution and Amplification Effects on Rodent Microbiomes and Rodent-borne Diseases – BioRodDis	02/12/2023
2019-NC-MS-11	Relationships between Functional Diversity and Food Production and Quality under Ecological Intensification – FunProd	01/01/2023
2019-NC-MS-12	From the Microbiome to the Ecosystem: Unravelling the Effects of Marine Protected Areas on Ecosystem Services – METRODIVER	01/03/2023
2019-NC-MS-9	Biodiversity as-an Ecological Barrier for the Spread of Clinically Relevant Antibiotic Resistance in the Environment – ANTIVERSA	01/02/2023
2019-SE-MS-15	Sustainable and Holistic management of Irish Ports (SHIP)	08/03/2023
2020-CCRP-MS.70	Irish Peatland Resilience to Changing Climate and Increased Frequency and Severity of Drought	28/02/2023
2020-W-CD-3	WFD Future Scenarios and Management Tools	30/03/2025

Appendix 2: Examples of Key Policy Objectives and Targets Relevant to the Addressing the Climate Change Evidence Needs Research Hub for the Period 2021–2023

Policy objectives and targets	Policy	Target year(s)
Reducing overall greenhouse gas emissions by 7% per annum.	Programme for Government 2020	2021–2030
Aiming for a net zero emissions by 2050.	Programme for Government 2020	2050
• Reviewing greenhouse gas emissions on a consumption basis, with a goal, or • Ensuring that Irish and EU action to reduce emissions supports emission reductions globally as well as on our own territories.	Programme for Government 2020	2025
• Within 24 months, evaluate the potential for contributions towards our climate ambition from land use improvements and set in train the development of a land use plan based on the findings	Programme for Government 2020	2023
• Reviewing greenhouse gas emissions on a consumption basis, with a goal, or • Ensuring that Irish and EU action to reduce emissions supports emission reductions globally as well as on our own territories.	Programme for Government 2020	2025
Decarbonising energy production: • Just transition for the workers and regions impacted as peat and coal-fired power generation is phased out. • Consideration of the implementation of a carbon price floor in the EU Emissions Trading System to support the transition from fossil fuels to renewables.	Programme for Government 2020	2025
"Enhanced" restoration of degraded peatlands.	Programme for Government 2020, LIFE project, National Peatlands Strategy	2025
Regulation to drive climate action will include new stress tests for financial institutions to look at the impact of tangible risks of higher temperature scenarios and involvement with the fossil fuel economy on their portfolios as recommended by the Taskforce on Climate Financial Disclosures.	Programme for Government 2020	2025
Initiating a land use review (including farmland, forests, and peatlands), which will balance environmental, social and economic considerations and involve a process of evaluation of the ecological characteristics of the land. This should take into consideration emissions to air and water and carbon sequestration, as well as climate adaptation challenges.	Programme for Government 2020	2025
Progressing a national policy on coastal erosion and flooding having regard to climate change.	Programme for Government 2020	2025

Policy objectives and targets	Policy	Target year(s)
Making growth less transport intensive through better planning, remote and home working and a modal shift to public transport.	Climate Action Plan 2019, National Planning Framework 2018	Ongoing
Development of blue bioeconomy.	Climate Action Plan 2019, National Policy Statement on bioeconomy, Harnessing Our Ocean Wealth and successor plan, SDG 14	Ongoing
Strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.	SDG Target 13.1	2030
Integrating climate change measures into national policies, strategies and planning.	SDG Target 13.2	2030
Improving education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.	SDG Target 13.3	2030
Promoting mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing states, including focusing on women, young people and local and marginalised communities.	UN SDG Target 13.	2030
The development and implementation of sectoral adaptation plans and local authority/regional adaptation strategies by: • Ensuring that local authorities, regions and key sectors can assess the key risks and vulnerabilities of climate change, implement climate resilience actions and ensure that climate adaptation considerations are mainstreamed into all local, regional and national policymaking. • Minimising costs and maximising the opportunities arising from climate change. • Building adaptive capacity (e.g. increasing awareness, sharing information and targeted training). • Developing policy- and finance-based adaptation actions. • Ensuring that adaptation actions are risk based and informed by existing vulnerabilities of our society and systems and an understanding of projected climate change. • Integrating emergency planning (particularly disaster risk reduction) and climate change adaptation. • Considering the impacts on other sectors and levels of governance of the adaptation actions taken to increase climate resilience.	National Adaptation Framework (NAF) 2018 and associated sectoral adaptation plans and local/regional adaptation strategies	Ongoing (NAF and sectoral adaptation plans to be reviewed every 5 years)

SDG, Sustainable Development Goal.

Appendix 3: Examples of Key Policy Objectives and Targets Relevant to the Facilitating a Green and Circular Economy Research Hub for the Period 2021–2023

Policy objectives and targets	Policy	Target year(s)
Reducing municipal waste generated by 55%, 60% and 65%. Reducing construction and demolition waste by 70%	Waste Framework Directive (2008, 2018)[107], Industrial Emissions Directive (2010)[108]	2020/2025/2030/2035
Reducing landfill of biodegradable municipal waste to 75%/50%/35% of the same waste generated in 1995. Reducing landfill to a maximum of 10% of municipal waste generated.	Landfill Directive (1999)[109], Landfill Directive (2018)[110]	2006/2009/2013/2035
Increasing collection of waste electrical and electronic equipment (WEEE) to 65%.	WEEE Directive[111], End-of-life Vehicles Directive (2000)[112], Batteries Directive (2006)[113]	2008–2030
Increasing the amount of plastic packaging recycled from 34% (2017) to 55% by 2030.	European Plastics Strategy (2018)[114]	2030
Reducing the per capita global food waste by 50% at the retail and consumer levels and reducing food losses along production and supply chains, including post-harvest losses.	SDG Target 12.3 (2015)	2030
Greening national public spending and investment by including green criteria in all procurements using public funds to be completed within 36 months and in turn advancing eco-design for national goods and services.	Programme for Government 2020, Environmental Products Declaration.	2023–2025
Reducing single-use plastics in government departments, public bodies and schools and in turn advancing eco-design for national goods and services.	DCCAE[115] Statement 2019–2020 on plastics[116] on Single Use Plastics Directive (EU 2019/904)[117]	2021
Reduction of up to 50% in the use of chemical pesticides.	New Common Agricultural Policy (CAP) 2020 strategic plan, Agri-Food Strategy 2030, Sustainable Use of Pesticides Directive, Farm to Fork Strategy, REACH Regulation, Chemicals Strategy	2022–2030
• Reducing the use of and risk from chemical pesticides by 50% and the use of more hazardous pesticides by 50%. • Reducing fertiliser use by 20% in agriculture by 2030. • 50% reduction in sales of antimicrobials used for farm animals and in aquaculture.	New CAP 2020 strategic plan, Agri-food Strategy 2030, EU Farm to Fork Strategy, Sustainable Use of Pesticides Directive, REACH Regulation, and pending Chemicals Strategy and revised Sewage Sludge Directive.	2021–2030

[107] Council Directive 2008/98/EC on waste (Waste Framework Directive) (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098).

Policy objectives and targets	Policy	Target year(s)
Decarbonising energy production: • Just transition for the workers and regions impacted as peat and coal-fired power generation is phased out. • Consideration of the implementation of a carbon price floor in the EU Emissions Trading System to support the transition from fossil fuels to renewables.	Programme for Government 2020	2025
Making growth less transport intensive through better planning, remote and home working and a modal shift to public transport.	Climate Action Plan 2019, National Planning Framework 2018	Ongoing

DCCAE, Department of Communications, Climate Action and the Environment (now Department of the Environment, Climate and Communications); REACH, Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation); SDG, Sustainable Development Goal.

[108] https://ec.europa.eu/environment/industry/stationary/ied/legislation.htm
[109] Council Directive 1999/31/EC on the landfill of waste (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A31999L0031).
[110] Council Directive 1999/31/EC on the landfill of waste 2018 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A31999L0031).
[111] Council Directive 2012/19/EU on WEEE (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32012L0019).
[112] Council Directive (2000/53/EC) on end-of-life vehicles (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02000L0053-20130611&qid=1405610569066&from=EN).
[113] Council Directive (2006/66/EC) on waste batteries (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006L0066).
[114] https://ec.europa.eu/environment/waste/plastic_waste.htm
[115] https://www.dccae.gov.ie/en-ie/Pages/default.aspx
[116] https://www.dccae.gov.ie/en-ie/news-and-media/press-releases/Pages/Minister-Bruton-Announces-Government-will-Lead-the-Way-in-Reducing-Single-Use-Plastics-.aspx
[117] Council Directive (EU) 2019/904 on single-use plastics (https://eur-lex.europa.eu/eli/dir/2019/904/oj).

Appendix 4: Examples of Key Policy Objectives and Targets Relevant to Delivering a Healthy Environment Research Hub for the Period 2021–2023

Policy objectives and targets	Policy	Target year(s)
• Ensuring clean drinking water supplies by 2030 (SDG 6). • Achieving universal and equitable access to safe and affordable drinking water for all. • Integrating the risk assessment frameworks for ionising radiation and chemicals in drinking water.	EU Drinking Water Directive, Water Framework Directive (WFD), Euratom Drinking Water Directive, Radioactive (Substances in Drinking Water) Regulations 2016, REACH Regulation and pending Chemicals Strategy, pending Second Ireland National Action Plan (INAP), Programme for Government 2020, SDG 6, Zero Pollution Action Plan (expected to be published in 2021)	2022–2030
• Achieving good ecological status for water by 2027 and beyond. • Informing actions/mitigation measures between 2027 and 2040 and beyond. • Protecting and restoring water-related ecosystems, including coastal, marine, wetlands, rivers, aquifers and lakes, by 2030 (SDG 6).	WFD and River Basin Management Plan, Programme for Government 2020, the revised Common Agricultural Policy (CAP) 2020 strategic plan, revised Fifth Nitrates Action Programme, Food Wise 2025, Agri-food Strategy 2030, National Landscape Strategy for Ireland 2015, EU Habitats Directive and Birds Directive, EU Biodiversity Strategy for 2030, Good Agricultural Practice for Protection of Waters Regulations 2018, SDG 6, Zero-Pollution Action Plan (expected to be published in 2021)	Short/medium term 2022–2027–2040
• Reducing the use of and risk from chemical pesticides by 50% and the use of more hazardous pesticides by 50%. • Reducing fertiliser use by 20% in agriculture by 2030.	Revised CAP 2020, Agri-food Strategy 2030, EU Farm to	2021–2030

Policy objectives and targets	Policy	Target year(s)
• 50% reduction in sales of antimicrobials used for farm animals and in aquaculture	Fork Strategy, Sustainable Use of Pesticides Directive, REACH Regulations, and pending Chemicals Strategy, revised Sewage Sludge Directive, Zero Pollution Action Plan (expected to be published in 2021)	
Assessing the impact of transport noise, which is considered to be the most significant contributor to noise pollution in Ireland, as the European Environment Agency predicts a 20% increase in noise pollution by 2030. Reducing noise nuisance and promoting the proactive management of noise to align with WHO guidelines and National Planning Framework objective 65.	Environment Noise Directive, Programme for Government 2020, SDG 3, SDG 11, National Planning Framework (objective 65)	2025–2030
Ensuring delivery of WFD requirements for heavily modified water bodies and the hydromorphological goal to meet the "good objective" beyond 2027, which needs research now to determine how to achieve this. This may be achieved by increasing and restoring up to 25,000 km of rivers into free-flowing rivers by 2030.	WFD, River Basin Management Plans, Floods Directive, Climate Action Plan 2019, National Adaptation Framework 2018, National Planning Framework 2040, National Landscape for Ireland 2015–2025, EU Biodiversity Strategy for 2030	2030
Reducing particulate matter (PM), nitrogen dioxide and ozone pollution, in air, to align with WHO guidelines.	Programme for Government 2020, planned National Clean Air Strategy, Air Quality Directive/CAFÉ 2008, UN Convention on Long-Range Transboundary Air Pollution, MCP Directive and LCP Directive, WHO guidelines, Zero-Pollution Action Plan (expected to be published in 2021)	2025
Making information and expertise available that can inform policy on how public exposure to non-ionising radiation in Ireland is impacted by new telecommunications technologies (5G or subsequent technologies) or the introduction of major electricity infrastructure.	Radiological Protection Act 1991, (Non-Ionising Radiation) Order 2019, National Planning Framework, EPA SEA Action Plan	2025

Policy objectives and targets	Policy	Target year(s)
	2021–2025 (to be published in 2021)	
Reducing the number of radon-related lung cancers in Ireland.	Ionising Radiation Regulations 2019, Technical Guidance Document C, National Radon Control Strategy (NRCS); NRCS Knowledge Gaps, Phase 2	Ongoing
A policy framework for low-emission zones.	Programme for Government 2020	2025

LCP, Large Combustion Plant; MCP, Medium Combustion Plant; SDG, Sustainable Development Goal; SEA, strategic environmental assessment; WHO, World Health Organization.

Appendix 5: Examples of Key Policy Objectives and Targets Relevant to the Protecting and Restoring our Natural Environment Research Hub for the Period 2021–2023

Policy objectives and targets	Policy	Target year(s)
Adhering to the potential legally binding protection measures of a minimum of 30% of the EU's land and sea areas by 2030.	EU Biodiversity Strategy for 2030, European Landscape Convention, National Landscape Strategy for Ireland 2015–2015, National Biodiversity Action Plan 2017–2021	2021–2030
Increasing restoration levels by up to 30% in line with targets being proposed in 2021.	EU Biodiversity Strategy for 2030, EU Habitats Directive and Birds Directive, European Landscape Convention, National Biodiversity Action Plan 2017–2021, National Landscape Strategy for Ireland 2015–2025, New Common Agricultural Policy (CAP) 2020 strategic plan, All Ireland Pollinator Plan, Woodlands for Water	2021–2030
Improving the management of peatlands and soils.	Climate Action Plan 2019, National Peatlands Strategy, Programme for Government 2020, National Landscape Strategy for Ireland 2015–2025, EPA SEA Action Plan 2021–2025 (to be published in 2021)	2025–2030
Reduction of up to 50% in the use of chemical pesticides.	New CAP 2020 strategic plan, Agri-Food Strategy 2030, Sustainable Use of Pesticides Directive, Farm to Fork Strategy, Ag-Climatise, REACH Regulation, and the pending Chemicals Strategy	2022–2030
Addressing the limited progress in tackling invasive species by reducing the number of Red List species threatened by invasive	National Biodiversity Action Plan 2017–	2025–2030

Policy objectives and targets	Policy	Target year(s)
alien species by 50% and in turn reducing the impact of invasive alien species on land and water ecosystems (SDG 15).	2021, the EU Invasive Alien Species Regulation 2014, EU Biodiversity Strategy for 2030, Programme for Government 2020, SDG 15	
Increasing the use and development of nature-based solutions, such as flood protection and the widespread roll-out of green and blue infrastructure.	National Planning Framework 2040, Climate Action Plan 2019, National Adaptation Framework 2018, Biodiversity Climate Change Sectoral Adaptation Plan, Flood Risk Management Adaptation Plan 2019, EPA SEA Action Plan 2021–2025 (to be published in 2021)	2040
Ensuring that good ecological status is attained for marine waters, marine resources are protected, restored to prevent further deterioration and managed sustainably. This may be achieved by increasing the marine Natura 2000 areas to 30% and 10% under "strict protection" in 2021, as set out by the EU Biodiversity Strategy for 2030.	EU Biodiversity Strategy for 2030, MSFD, MSPD, EU Common Fisheries Policy 2014, Farm to Fork Strategy 2020	2023
Evaluating and implementing plans to realise the carbon sink potential of our marine environment based on marine protection areas.	Programme for Government 2020	2025

MSFD, Marine Strategy Framework Directive; MSPD, Maritime Spatial Planning Directive; REACH, Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation); SDG, Sustainable Development Goal; SEA, strategic environmental assessment.