Vision for 2050 Working Paper

Vision for 2050

1. Introduction

Following discussion at the September 2022 Council Meeting and an email poll of Council members, the 'Vision for 2050' was identified as a priority issue for discussion at the April 2023 Council meeting. This working paper was presented to the Council at its April 2023 meeting for discussion and is being presented to the Carbon Budgets Working Group for information for its May meeting in order to inform a discussion on the development of appropriate scenarios and pathways.

As set out in the Terms of Reference for the Carbon Budgets Working Group, '*the Council will specify the key outputs for the term of the Working Group*' and '*may give direction as to other key areas of work that it considers important which can be incorporated on an ad hoc basis*.' The aim of this paper is to inform the work of the Carbon Budgets Working Group in terms of the preparation of a number of baseline scenarios in 2030 to 2040, which align with climate neutrality in 2050, accounting for the role of negative emissions.

This paper looks to;

1. Assess the current literature and evidence base looking at what climate neutrality might mean for Ireland in 2050. This includes a preliminary literature review and discussions relevant to the Irish context and how climate neutrality is defined.

2. Review the availability of pathways from an integrated cross-sectoral perspective along with sector specific scenarios where they are available, at an Irish, EU and IPCC level.

3. Provide context for a broader discussion on what 2050 might look like for Ireland and the technological, societal, and economic changes we might see at that point, along with potential impacts by 2050 from climate change under a number of temperature scenarios.

Understanding the end goal in relation to what we are trying to achieve is the most important next step.

The latest physical science assessment of the Intergovernmental Panel on Climate Change (IPCC) highlights that limiting global warming to a specific level requires global cumulative carbon dioxide (CO_2) emissions to be kept within a global CO_2 emissions budget (or a 'global carbon budget') together with deep reductions in other greenhouse gas emissions (ESAB, 2022). This will require rapid, deep, and in most cases immediate GHG emissions reductions in all sectors (IPCC AR6 SYR, 2023).

There are a variety of pathways which might be taken to achieve a climate neutral economy in Ireland which will require distinct policy choices and understanding of their implications. The aim of this discussion and further discussions as part of the carbon budgets process will be to consider the high-level trade-offs and approaches to different pathways.

In addition, budget was approved at the December CCAC meeting for a consultancy package of work considering pathways to 2050 in Ireland to inform and provide a benchmark for the work of the Carbon Budgets Working Group. This 3-month project is due for completion in Q4 2023 and will consider emissions reduction pathways within each sector from 2030 to 2040 on a trajectory to climate neutrality in 2050 under different 2030 scenarios, sharing assumptions and spreadsheet analysis of pathways modelled. This analysis will be used as a basis for initial carbon budget reference points and overall work as a benchmark to outputs of TIM, FAPRI Goblin and iterations with other models.

Feedback from the Council's thematic discussion on the vision for 2050 and the Carbon Budgets Working Group subsequent discussion of the vision for 2050 paper will be used to inform the scope of a consultancy package of work considering pathways to 2050, along with discussions at the Carbon Budgets Working Group.

It is also expected that further publications in 2023, such as Ireland's updated long term climate strategy, could inform future iterations of this working paper.

2. Introduction & Relevant Legislation

Global and EU goals are important in considering a vision for Ireland in 2050 and a pathway to achieve these goals, which will inform each 5-year carbon budget between now and 2050.

As part of the second carbon budgeting process, the development of scenarios at a sectoral level will need to consider;

1. The start point, in terms of emissions in 2030, under scenarios where Carbon Budget 1 (2021-2025) and Carbon Budget 2 (2026 – 2030) have either been met or where excess emissions will need to be considered in the third carbon budget.

2. The target in 2050, in terms of whether 'climate neutrality' as set out in the Climate Action and Low Carbon Development Act represents a balance of accounted GHG emissions or the temperature impact of emissions to stay within the temperature goals under the Paris Agreement.

Historically, climate ambition has either been formulated as a stabilised level of atmospheric concentrations of certain greenhouse gases (for example, in the 1992 United Nations Framework Convention on Climate Change) or as a percentage emissions reduction target such at the 51% emissions reduction target by 2030 set out in the Climate Action and Low Carbon Development Act (Fankhauser et al., 2022). In recent EU and national legislation, this has been expressed as a specific target date for reaching climate neutrality or 'Net Zero' emissions, generally by 2050 or earlier.

Most countries have made Net Zero commitments as of early 2023, but in many cases these are not yet backed by detailed, economy wide pathways or interim targets on the path to Net Zero (UK CCC, 2023).

2.1 National Legislation

The Climate Action and Low Carbon Development Act (as amended 2021)[1] defines a 'climate neutral economy' as a sustainable economy and society where greenhouse gas emissions are balanced[2] or exceeded by the removal of greenhouse gases. Section 3(1) sets out the national climate objective; *'The State shall, so as to reduce the extent of further global warming, pursue and achieve, by no later than the end of the year 2050, the transition to a climate resilient, biodiversity rich, environmentally sustainable and climate neutral economy'.*

The Act also acknowledges the '*distinct characteristics of biogenic methane'* under Section 7 in relation to the long-term climate action strategy and under Section 6 in relation to the preparation of carbon budgets.

The FAQ[3] published with the revised Act noted that the 'climate neutral' objective is consistent with EU climate ambition and international obligations under the Paris Agreement to pursue a net zero target for all greenhouse gases.

---

[1] A consolidated version of the Act can be found here; https://revisedacts.lawreform.ie/eli/2015/act/46/revised/en/html

[2] In its letter of advice to the Government on the Bill in 2020, the CCAC noted that 'the definition of climate neutral economy '*means a sustainable economy, where greenhouse gas emissions are* ***balanced*** *or exceeded by the removal of greenhouse gases'* which could be interpreted as either a balance of accounted emissions or of the climate impact of those emissions (e.g., temperature).' See: https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/documents/news/WEB%20Appendix%20to%20Letter%20of%20Advice%20on%20Climate%20Action%20(Amendment)%20Bill%202020.pdf

[3] https://www.gov.ie/pdf/?file=https://assets.gov.ie/128070/c55193e6-6917-4c56-b01d-78d1b868ec3d.pdf#page=null

The Regulatory Impact Assessment[4] for the Act notes that '*The pathway to a climate-neutral economy will likely impact certain sectors and industries at varying levels and will be an important consideration in the development of alternative job opportunities. Appropriate policy planning and cooperation will be necessary to manage employment related migratory flows and ensure sustainable, balanced, and fair regional development. Increased cooperation will be necessary with neighbouring jurisdictions in adapting to climate change threats such as rising sea levels, coastal inundation, and flooding; as well as harnessing mitigation opportunities in areas such as electricity interconnection, and the development of our significant offshore wind potential.'*

In its advice to Government concerning the Climate Action and Low Carbon Development (Amendment) Bill 2020[5], while the CCAC welcomed the proposal to adopt the objective of a 'climate neutral economy' by 2050, it was concerned that more precision was required to make the objective clear, with clarification needed on the emissions and removals to be accounted towards the 2050 objective.

The recently published Long Term Strategy on Greenhouse Gas Emissions Reductions for Ireland, currently undergoing public consultation prior to an updated strategy being published later in 2023, notes that reaching climate neutrality will mean that Ireland will have no further negative impacts on the climate system by mid-century. It notes '*To reach this point, Ireland will have to achieve net zero emissions for long-lived greenhouse gases combined with a substantial reduction in methane emissions by 2050*.'

2.2 EU and International Legislation

The 2015 Paris Agreement established the long-term goal of '*holding the increase in global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels'* and of achieving '*a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century'*. As set out in the CCAC's Technical Report on Carbon Budgets, the stabilisation of greenhouse gas concentrations in the atmosphere and the establishment of a climate neutral economy requires that emissions of long-lived greenhouse gases such as CO_2 and N_2O must reduce to net zero, and strong, rapid, and sustained reductions in methane emissions are required by 2050.

The European Commission set out a vision for a climate-neutral EU in November 2018, looking at all the key sectors and exploring pathways for the transition[6]. As part of the European Green Deal, the Commission proposed on 4 March 2020 the European Climate Law to enshrine the 2050 climate-neutrality target into law.

The European Climate Law, Regulation (EU) 2021/1119[7] adopted by the European Union on 30 June 2021, sets a legally binding objective for Europe to become climate neutral by 2050 in pursuit of the long-term temperature goal set out in point (a) of Article 2(1) of the Paris Agreement, by achieving net zero greenhouse gas emissions for EU countries as a whole[8]. This also includes an aim to achieve negative emissions after 2050.

---

[4] https://www.gov.ie/pdf/?file=https://assets.gov.ie/136803/667bb25f-c366-4de8-9a56-3e9f2f30417c.pdf#page=null

[5] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/documents/news/WEB%20Council%20Advice%20Climate%20Action%20and%20Low%20Carbon%20Development%20(Amendment)%20Bill%202020.pdf

[6] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773

[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32021R1119

[8] This is expressed in the legislation as *'emissions and removals of greenhouse gases regulated in Union law shall be balanced at the latest by 2050, thus reducing emissions to net-zero by that date'*

The European Commission is mandated to propose an EU-wide climate target for 2040 in the first half of 2024, within six months of the conclusion of the first Global Stocktake under the Paris Agreement, along with a projected indicative greenhouse gas budget for the 2030-2050 period. This budget represents the cumulative greenhouse gas emissions in the EU over the 2030-2050 period expressed in CO_2 equivalence using the GWP_{100} metric.

In its recent advice to the European Commission, the European Scientific Advisory Board noted *'The European Climate Law sets out the legally binding objective of achieving climate neutrality in the EU (**meaning net zero greenhouse gas emissions**) by 2050, with the aim of achieving net negative greenhouse gas emissions thereafter.'*

As part of the second carbon budgeting process, the development of scenarios at a sectoral level will need to consider;

1. The start point, in terms of emissions in 2030, under scenarios where carbon budgets 1 and 2 have either been met or where excess emissions will need to be considered in the third carbon budget.

   It would seem most appropriate that scenarios used to determine the starting point in 2030 for the development of CB3 and CB4 should assume achievement of the first and second carbon budgets as a primary assumption, with alternative scenarios developed based on other assumptions. Sections 6D (4) and (5) of the Act consider situations where a surplus from a preceding carbon budget may be carried forward where there is overperformance against a budget and where excess emissions are carried forward where there is underperformance against a budget.

2. The target in 2050, in terms of whether 'climate neutrality' as set out in the Climate Action and Low Carbon Development Act represents a balance of accounted GHG emissions or the temperature impact of emissions to stay within the temperature goals under the Paris Agreement. The recently published Long Term Strategy on Greenhouse Gas Emissions Reductions for Ireland, currently undergoing public consultation, notes that reaching climate neutrality will mean that Ireland will have no further negative impacts on the climate system by mid-century. It notes '*To reach this point, Ireland will have to achieve net zero emissions for long-lived greenhouse gases combined with a substantial reduction in methane emissions by 2050.'*

   It may be appropriate for scenarios based on climate neutrality, understood in the context of their temperature impact, to be developed for the purposes of the next carbon budgets process and assessed against the temperature goals of the Paris Agreement. Analysis of the impact of an emissions trajectory towards net zero greenhouse gas emissions in 2050 should also be carried out.

The development process of the Climate Action and Low Carbon Development Act (as amended 2021) is considered here along with relevant EU legislation.

3. Net Zero, Climate Neutrality and Temperature Neutrality

This section considers the use of different metrics and definitions to describe climate objectives, which is important to discuss the Climate Act's objective to achieve a '*climate resilient, biodiversity rich, environmentally sustainable and climate neutral economy'* by 2050 and what this means for the carbon budgets along the pathway to reach this point (along with sustained climate neutrality beyond 2050).

There is significant discussion in the scientific literature on how the concept of **net zero** is defined and the climate metric or conversion factor (for example GWP_{100} or GWP*) chosen to compare emissions of different gases. The Intergovernmental Panel on Climate Change (IPCC, 2022) definition of net zero emissions is as follows;

> *'Net-zero emissions are achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period. Where multiple greenhouse gases are involved, the quantification of net-zero emissions depends on the climate metric chosen to compare emissions of different gases (such as global warming potential, global temperature change potential, and others, as well as the chosen time horizon).'*

The limitation of GWP_{100} in respect to Short Lived Climate Forcers (SLCFs) such as methane has been recognised in the literature (Wheatley, 2022). While alternatives have been developed including GWP* to provide a more physical basis for balancing long-lived greenhouse gases and SLCFs (IPCC, 2021), no single metric exists that is applicable in every policy context due to the different parameters for greenhouse gases[9] including their infrared absorption and atmospheric lifetime.

GWP_{100}	**GWP***
• Equates emissions using a single scaling factor, such as the 100-year Global Warming Potential (GWP100)	• GWP*, an alternative application where the CO_2-equivalence of short-lived climate pollutant emissions is predominantly determined by changes in their emission rate. • Provides a straightforward means of generating warming-equivalent emissions.
• Conventional application of GWP_{100} has some limitations particularly when methane emissions are stable or declining	• Reports emissions as 'warming-equivalents' that result in similar warming impacts without requiring a like-for-like weighting per emission. • GWP* provides a useful indication of warming.

Table 1 – comparing climate metrics, GWP_{100} and GWP. Source; (Lynch et al., 2020)*

[9] The IPCC definition of greenhouse gases is as follows; '*Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary GHGs in the Earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Besides CO_2, N_2O and CH_4, the Kyoto Protocol deals with the GHGs sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).'*

Some authors (Zickfeld & Herrington, 2015) suggest that non-CO_2 anthropogenic warming is better determined by the present-day emission rate with a small correction for the long-term climate response to the average non-CO_2 forcing over a longer timeframe.

The IPCC's AR6 Synthesis report notes that;

> '*Limiting human-caused global warming to a specific level requires limiting cumulative CO_2 emissions, reaching net zero or net negative CO_2 emissions, along with strong reductions in other GHG emissions'.*

The Synthesis report also notes that reaching **net zero CO_2** emissions is different from reaching **net zero GHG** emissions. In order to meet the 1.5 °C goal under the Paris Agreement with 50% probability, this translates into a specific remaining CO_2 budget of approximately 400–800 $GtCO_2$[10] (Fankhauser et al., 2022), which in turn requires CO_2 emissions to peak before 2030 and fall to net zero by 2050 (i.e. no additional CO_2 emissions unless balanced by removals). The stronger the reductions in non-CO_2 emissions the lower the resulting temperatures are.

This quantification is based on the near-linear relationship between cumulative net anthropogenic CO_2 emissions and CO_2-induced surface warming. A number of studies have attempted to quantify the remaining carbon budget[11] for different probabilities of different global temperature increases. Efforts have also been made to downscale the global carbon budgets to a national level for Ireland[12].

The temperature implications of the net-zero concept when applied to other greenhouse gases are less clear than they are for CO_2 alone, depending on the specific mix of drivers (Fankhauser et al, 2022). This is a particularly important consideration for Ireland, with a mix of CO_2, CH_4 and N_2O emissions which is different in comparison to the European context.

The timing of achievement of net zero for broader GHGs depends on the emissions metric chosen, such as global warming potential over a 100-year period (GWP_{100}), to convert non-CO_2 emissions into CO_2-equivalent. However, for a given emissions pathway, the physical climate response in terms if temperature is independent of the climate metric (IPCC AR6 Synthesis report, 2023). Where net zero is understood to mean net-zero CO_2-equivalent emissions aggregated using the 100-year GWP metric, this cannot be related unambiguously to a specific temperature outcome (Fankhauser et al, 2022).

Methane has a high global warming potential (i.e., the quantum of radiative forcing relative to that of CO_2 scaled to 100 years). This is associated with methane's ability to absorb incoming solar radiation and re-radiate infra-red (i.e., heat) radiation back towards the planetary surface. However, the arbitrary horizon-point of 100 years inflates the impact of the rate of change of atmospheric methane on global temperature change (Allen et al. 2017, Cain, et al. 2019). Thus, it is more appropriate to address methane in terms of changes in flux (methane entering

[10] According to the IPCC AR6 Synthesis report, remaining carbon budgets have been quantified based on the assessed value of TCRE and its uncertainty, estimates of historical warming, climate system feedbacks such as emissions from thawing permafrost, and the global surface temperature change after global anthropogenic CO_2 emissions reach net zero, as well as variations in projected warming from non-CO_2 emissions.

[11] Matthews, Damon, H. et al. (2021). An integrated approach to quantifying uncertainties in the remaining carbon budget. Communications Earth & Environment, 2(1), 1–11. https://doi.org/10.1038/s43247-020-00064-9

[12] Glynn, J., Gargiulo, M., Chiodi, A., Deane, P., Rogan F., Ó Gallachóir, B.,2019. Zero carbon energy system pathways for Ireland consistent with the Paris Agreement. Climate Policy 19:1, 30-42. Available at: https://www.tandfonline.com/doi/pdf/10.1080/14693062.2018.1464893 and https://calculator.climateequityreference.org
https://calculator.climateequityreference.org

and leaving the system at any given time) rather than in terms of stock (i.e., the accumulation of CO_2/N_2O in the atmosphere).

The IPCC defines **climate neutrality** as '*a state in which human activities result in no net effect on the climate system*' (IPCC, 2018). This involves a balance of all anthropogenic greenhouse gas emissions with removals over a specified period and is often referred to as '**net zero**' greenhouse gas emissions, based on the idea that such emissions are comparable given a set of conversion metrics (Wheatley, 2022).

Temperature Neutrality involves a scenario where the national contribution to warming from all sources has peaked. For entities whose only climate impact is CO_2 emissions, net-zero, carbon neutrality, and temperature neutrality amount to the same thing (Wheatley, 2022). Where SLCF emissions are significant, as is the case for Ireland, a net zero or carbon neutral target is difficult to align to a specific outcome in terms of impact on global temperature. In some cases, net zero is used simply to describe emissions trajectories consistent with meeting the goals of the Paris Agreement based on the latest climate science[13]. Some recent scientific opinion favours split gas targets, as have been implemented in New Zealand[14].

The Paris Agreement commits to global temperature stabilisation below a specified global temperature, i.e., well below 2°C but does not specify a target year for achieving this. In comparison, many national policies do not specify a national warming contribution ceiling in terms of temperature but do specify a target year for 'climate neutrality' and/or net-zero (Wheatley, 2022).

This section attempts to consider the differences in the following definitions, based on the latest IPCC reports and recent literature (this can be expanded further in future iterations of this document);

- Net Zero GHG – *'Net-zero emissions are achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period. Where multiple greenhouse gases are involved, the quantification of net-zero emissions depends on the climate metric chosen to compare emissions of different gases (such as global warming potential, global temperature change potential, and others, as well as the chosen time horizon).'*

- Climate neutrality - '*a state in which human activities result in no net effect on the climate system'*

- Temperature Neutrality – This involves a scenario where the national contribution to warming from all sources has peaked. For entities whose only climate impact is CO_2 emissions, net-zero, carbon neutrality, and temperature neutrality amount to the same thing (Wheatley, 2022). Where SLCF emissions are significant, as is the case for Ireland, a net zero or carbon neutral target is difficult to align to a specific outcome in terms of impact on global temperature.

[13] See for example https://sciencebasedtargets.org/.

[14] Allen, M. R., Peters, G. P., Shine, K. P., Azar, C., Balcombe, P., Boucher, O., . . . others (2022). Indicate separate contributions of long-lived and short-lived greenhouse gases in emission targets. npj Climate and Atmospheric Science, 5 (1), 1–4.

4. Scenarios and Pathways for 2050

4.1 Carbon Budgets between 2030 and 2040

For the first programme of Carbon Budgets, scenario modelling was carried out in order to develop different scenarios for emissions reductions and pathways to meet the 51% emissions reduction target by 2030.

The scenarios modelled represent different sharing across sectors with different % reductions across energy (including heat, transport, and electricity) and agriculture with an assumed 51% reduction in the LULUCF sector. An average of these scenarios was taken to inform the carbon budgets.

There is no single model in Ireland that captures in sufficient detail the technical information on mitigation options across all sectors. These models are not integrated and are limited in their time horizon, so proposed research to develop an integrated assessment model for Ireland, mapping integrated pathways for rapidly and deeply decarbonising the energy, land, and food systems out to 2100 will be beneficial to future programmes of carbon budgets. An EPA research project on sustainable integrated pathways for carbon-negative energy, land and food systems (SELFS) is due to commence in Q3 2023, with a final report becoming available in 2027.

For the second programme of carbon budgets, modelling of pathways and effort sharing across sectors will need to be carried out for CB3 (2031-2035) and provisional CB4 (2036-2040), based on the start point in 2030 (which may include a number of scenarios based on projections of compliance with CB1 and CB2) on a pathway to 2050. This will require longer term modelling of scenarios for effort sharing across economy wide sectors in order to consider:

1. The pathway from a number of baseline scenarios in 2030 to 2040, which align with climate neutrality in 2050, accounting for the role of negative emissions i.e., initial ranges for carbon budgets.

2. The relative level of mitigation feasible and potential range across different sectors based on different carbon budgets.

4.2 Overview

The Paris Agreement leaves it to its parties to define their own emissions pathways or nationally determined contributions (NDCs) to global net zero. Regular stocktakes are intended to ensure that national emissions pathways gradually converge to a global net-zero state consistent with long-term temperature goals (Fankhauser et al, 2022).

Modelled scenarios or pathways can reflect what reductions in emissions or actions are required to stay within a certain carbon budget or deliver a certain global temperature. A critical gap in current evidence is the lack of an overall climate neutral pathway for Ireland. Limited studies to date have considered the energy, agriculture and land use sectors separately. Challenges also include the need to look beyond 2050 and consider emissions removals.

Wheatley (2022) has calculated illustrative multi-gas emissions scenarios for Ireland expressed as percentages of 2018 for the years 2025, 2030, 2035, 2050 and 2100 to estimate Ireland's contribution to global warming while reaching temperature neutrality by mid-century, using a range of simple climate models. This analysis takes a 'split-gas' scenario approach where fossil-CO_2 emissions are assumed to be eliminated by 2050 and the effect of alternative methane reduction pathways is considered. All scenarios assume a 51% cut in fossil-CO_2 by 2030 and zero fossil-CO_2 emissions by 2050. Different illustrative scenarios for emissions associated with agriculture include stabilisation of methane emissions at 2018 levels and

reductions of 40% by 2050 with nitrous oxide stabilising at 2018 levels or reducing by 40% by 2050.

A tool has also been developed by McMullin & Price (2020), which provides an open-source model of greenhouse gas emissions scenarios and their warming impacts under a range of pathways for CO_2, Ch_4 and N_2O emissions for Ireland up to 2100[15]. For example, the pathways below are calculated based on a reduction in net CO_2 emissions of 61% by 2030 and 112% by 2050, with reductions in N_2O and CH_4 of 25% by 2030 and 30% by 2050. A number of parameters can be changed in the tool to see the impact on emissions in CO_2 equivalent terms of CO_2-we terms, as shown in the example in Figure 1 below.

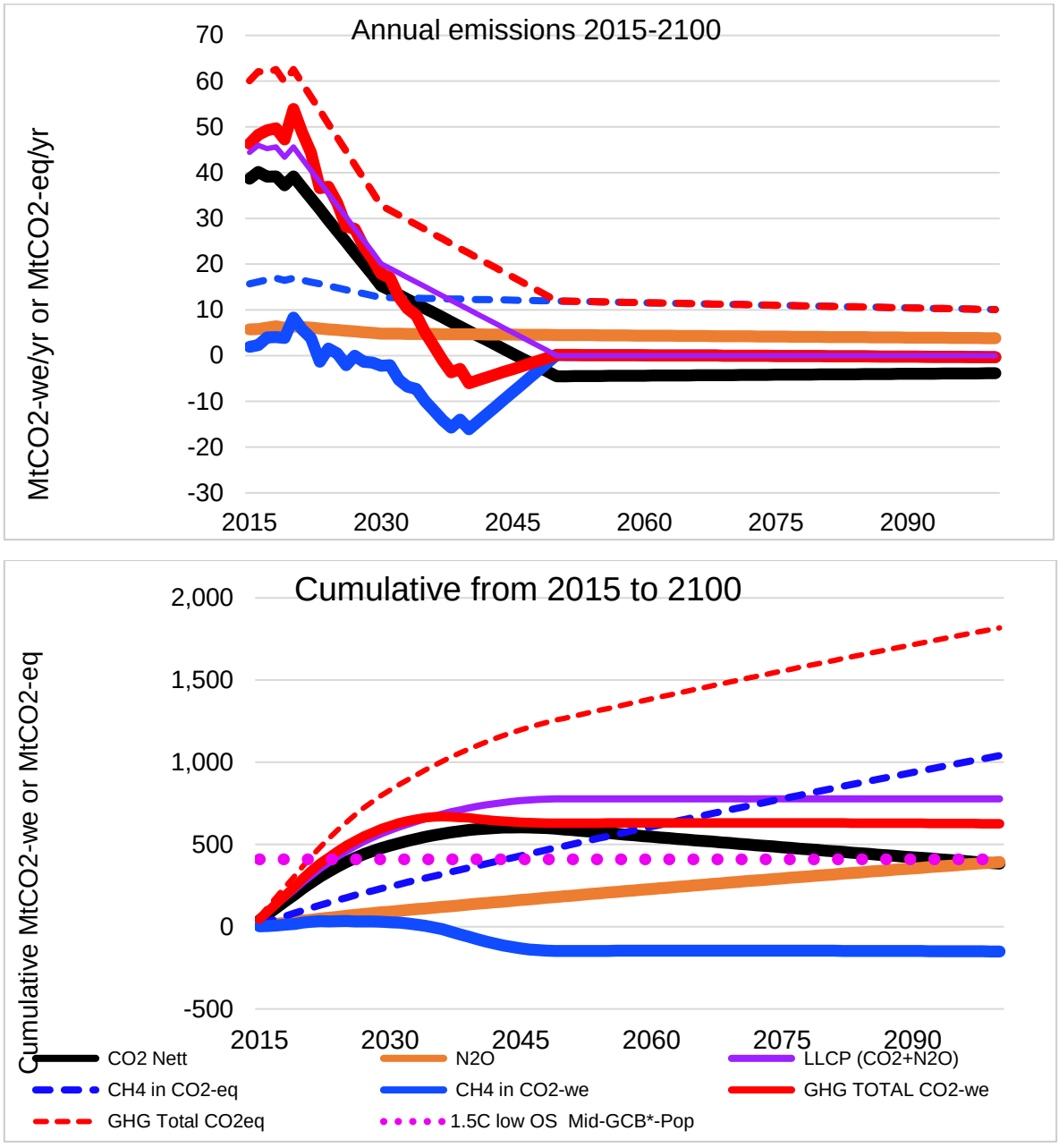


Figure 1, Example of a scenario using the tool developed by McMullin and Price (2020)

[15] The tool can be downloaded here as an Excel file; https://zenodo.org/record/7129352#.ZC1Xb3vMInI. A video is also available explaining how the tool works; https://www.youtube.com/watch?v=QotHiuPuO1E

4.3 Sectoral Emissions

Determining a sector-by-sector pathway to Net Zero is useful for understanding the pace of emissions reduction that can be achieved over time, as well as the choices, trade-offs, implications and constraints involved in the transition within each area of the economy (UK CCC, 2023).

In setting out its advice on the UK's pathway to net zero, the UK CCC built its pathways through detailed sectoral analysis with an assessment of what this might involve for each sectoral source of emissions to have a more detailed understanding of what the choices, constraints and implications are for each sector as well as across the whole economy.

Sectoral analysis can also identify which sectors can achieve net zero emissions by or before 2050, while others will have some residual emissions that require balancing by removals. Existing studies in Ireland have mainly looked at the energy sectors separately or at agriculture and land use.

Sector	**Baseline emissions and 2030 CAP scenario**	**Literature on 2050 Scenarios**
Electricity	• 3 $MtCO_2eq$ by 2030 Annually • 9 GW onshore wind, 8 GW solar, and at least 7 GW of offshore wind by 2030 (with 2 GW earmarked for green hydrogen production) • Phase out of coal and peat in electricity generation.	Literature by Martins & Carton (2023) has argued that considerable acceleration is needed in the decarbonisation of the Ireland's energy sector. In their paper, they investigate the potential role hydrogen can play in Ireland's energy transition, proposing hydrogen as an energy vector and storage medium that may help the country achieve its targets and reduce greenhouse gas emissions. The current state of the Irish energy sector is analysed, and recommendations are made as to how, where and when hydrogen can be integrated into the decarbonisation of Ireland's electricity, heating, and transport. The effective use of technologies on both the demand and the supply sides of the energy system can enhance the decarbonisation process, reduce overall societal costs and deliver broader benefits, such as enhanced security of supply and greater system resilience (Gallachóir et al., 2020). Economic growth can be maintained in Ireland while rapidly decarbonizing the energy system. The social cost of carbon needs to be included as standard in valuation of infrastructure investment planning, and the crucial role of marginal abatement cost curves (MACCs) (Gaur et al., 2022; Glynn et al., 2019; Yue et al., 2021).
Industry	• 4 $MtCO_2eq$ by 2030 Annually • Reduce fossil fuel use from 64% of final consumption (2021) to 45% by 2025 and further by 2030.	N/A

	• Increase total share of heating to carbon neutral to 50-55% by 2025, up to 70-75% by 2030. • Significantly grow the circular economy and bioeconomy	
Built Environment	• 5 $MtCO_2eq$ by 2030 Annually • 500,000 BER B2 dwellings by 2030. • 400,000 existing and 280,000 new heat pumps in dwellings by 2030. • Generation up to 2.5 TWh of district heating by 2030 • Decrease embodied carbon in construction materials produced and used in Ireland by at least 30%.	In SEAI's Heat study of decarbonisation pathways for heating and cooling in Ireland, a number of modelled scenarios met the net zero by 2050 target. This included a high electrification scenario with minimal amounts of bio-derived gases, CCUS and green hydrogen along with high levels of heat networks deployment. The decarbonised gas scenario is weighted towards green hydrogen use, CCUS infrastructure or bio-derived gases, coupled with domestic and commercial fuel switching to green hydrogen or bio-derived gases. The balanced scenario entails a mix of cost-effective deployment of low-carbon technologies (electricity, bio-derived gases, green hydrogen), with a medium level of industrial CCUS, heat networks and efficiency.
Transport	• 6 $MtCO_2eq$ by 2030 Annually • Reduce the total distance driven across all car journeys by 20%. • Walking, cycling and public transport to account for 50% of journeys. • 1 in 3 private cars will be an Electric Vehicle. • 70% of people in rural Ireland will have buses that provide at least 3 trips to the nearby town daily by 2030.	Danielis et al., (2022) paper "decarbonizing transport in Europe", estimates that the biofuel strategy can deliver a GHG reduction of up to 19 MtCO2eq (−3.6%), while the electrification strategy can deliver a GHG reduction up to 45 MtCO2eq (−8.3%). Jointly used, the GHG reduction could reach up to 64 MtCO2eq (−11.9%). Without large-scale negative emissions, significant demand reductions for aviation, shipping, road freight and industry sectors' activities are needed to meet the 1.5–2°C goal. Policy priorities include affordable alternatives to frequent air travel; smooth connectivity between low-carbon travel modes; speed reductions in shipping and reduced demand for transporting fossil fuels; distributed manufacturing and local storage; and tightening standards for material use and product longevity (Sharmina et al., 2021).
Agriculture	• 20 $MtCO_2eq$ by 2030 Annually • Increase uptake of protected urea on grassland farms to 90-100%.	A recent review (Madden et al., 2022) found that emissions can be efficiently lowered if the right initiatives are taken. They argue that more precise emission factors and adaptable inventories are urgently needed. They further reiterate that multi-modelling approaches will give a better understanding of the technology

	• Increase organic farming to up to 450,000 hectares, the area of tillage to up to 400,000 ha. • Expand the indigenous biomethane sector through anaerobic digestion, reaching up to 5.7TWh of biomethane.	pathways required to meet decarbonisation ambitions.
Land Use, Land Use Change, Forestry	• Increase annual afforestation rates to 8,000 hectares per annum from 2023 onwards. • Improve carbon sequestration of 450,000 ha of grasslands on mineral soils and reduce the management intensity of grasslands on 80,000 ha of drained organic soils. • Rehabilitate 77,600 hectares of peatlands.	In a randomized national land management strategies for net-zero study conducted by (Duffy et al., 2022), they generate 850 randomized scenarios of activity combinations for Ireland's AFOLU sector in the year 2050 and evaluate associated greenhouse gas fluxes to the year 2100. Using a GWP_{100} 'net-zero' greenhouse gas definition, 146 scenarios achieve AFOLU climate neutrality and 38 contribute to national neutrality (a substantial AFOLU sink) by 2050. Just one scenario contributes to national climate neutrality to 2100, reflecting future declines in CO_2 removals by new forests (excluding potential downstream mitigation). Active CO_2 removal on destocked land, via organic soil rewetting and ambitious afforestation, could moderate output declines in milk and beef production, reducing international carbon leakage risks.
Other (F-Gases, Waste & Petroleum refining	• 1 $MtCO_2eq$ by 2030 Annually	N/A
Aviation and Maritime		N/A

Table 2 – Sectoral Scenarios for 2050 available in Ireland

The traditional focus of emissions reduction strategies has been in the energy sector, and the scale-up of clean energy remains at the core of decarbonisation. In most other sectors, the transition to zero carbon is still uncertain such as heavy industries, buildings, food and agriculture, aviation, and mining. In most of these sectors, zero-carbon solutions exist, but they are still costly and not yet as established as incumbent technologies and infrastructures (IPCC AR6 Synthesis Report, 2023).

AFOLU mitigation options, when sustainably implemented, can deliver large-scale GHG emission reductions; however, barriers to implementation and trade-offs may result from the impacts of climate change, competing demands on land, conflicts with food security and livelihoods (IPCC AR6 Synthesis Report, 2023).

4.4 Long Term Climate Strategies

Article 15 of the EU Regulation (EU) 2018/1999 of the European Parliament and of the Council on the Governance of the Energy Union and Climate Action requires each Member State to

prepare and submit to the Commission a long-term strategy with a perspective of at least 30 years by 1 January 2020[16].

There is currently no pathway which considers all sectors and their interactions in Ireland for achieving climate neutrality and Ireland has only recently submitted a Long-Term Climate Strategy[17]. This is required to take at least a 30-year perspective in terms of GHG emissions reductions and include a range of emission reduction pathways in each key sector. The current focus of NCAP23 and recent iterations of the Climate Action Plan have focused on targets and pathways to 2030. Ireland's Long-Term Strategy was published on the 28th of April 2023 based on a previous consultation carried out in 2019. The summary of consultation responses notes '*While the 2019 consultation and associated responses remain valid and provide valuable input to the Long-term Strategy for submission to the European Commission, the Department considers it prudent to carry out a further public consultation in light of the important climate policy developments since the introduction of the Climate Action and Low Carbon Development (Amendment) Act 2021.*

As such, the Long-term Strategy that will be submitted to the European Commission will be used as the basis for launching a further public consultation to prepare an updated Long-term Strategy by the end of 2023, as committed to in Ireland's Climate Action Plan 2023 Annex of Actions.' An updated strategy is due to be published and submitted to the European Commission by the end of 2023.

National Energy and Climate Plans (NECPs) are the framework within which EU Member States plan climate and energy objectives to the Commission and Ireland's NECP is being updated as a 2023 action in NCAP23.

The Paris Agreement also invites all Parties to communicate, by 2020, to the UNFCCC, mid-century, long-term low greenhouse gas emission development strategies. The EU submitted its long-term strategy to the United Nations Framework Convention on Climate Change (UNFCCC) in March 2020[18].

An overview of a selection long-term climate strategies submitted across the EU before 2020 is provided in Table 1 below. These were assessed by DG Clima for compliance with requirements under the Regulation. As can be seen from the table, the level of detail varies significantly, and many strategies are significantly out of date as of 2023. Due to the late

[16] The national long-term strategies and the EU's strategy have to cover, with a perspective of at least 30 years:

- Total greenhouse gas emission reductions and enhancements of removals by sinks;
- Emission reductions and enhancements of removals in individual sectors, including electricity, industry, transport, the heating and cooling and buildings sector (residential and tertiary), agriculture, waste and land use, land-use change and forestry (LULUCF);
- Expected progress on transition to a low greenhouse gas emission economy, including greenhouse gas intensity, CO2 intensity of gross domestic product, related estimates of long-term investment, and strategies for related research, development and innovation;
- To the extent feasible, expected socio-economic effect of the decarbonisation measures, including, inter alia; links to other national long-term objectives, planning and other policies and measures, and investment.

[17] Long term strategies submitted by other EU countries can be found here: https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-long-term-strategies_en#:~:text=EU%20long%2Dterm%20strategy,-The%20Commission%20put&text=The%20European%20Council%20endorsed%20in,(UNFCCC)%20in%20March%202020.

[18] The communication to the UNFCCC can be found here: https://unfccc.int/documents/210328 . The in depth analysis supporting the communication can be found here: https://climate.ec.europa.eu/system/files/2018-11/com_2018_733_analysis_in_support_en.pdf

submission of Ireland's Long-Term Strategy an assessment is not available on the European Commission's website.

Country	Overall Goal	Scenarios Considered	Features of 2050
Austria	Climate neutrality by 2050 (which was superseded by a 2040 target). The goal includes all main greenhouse gases. The goal covers all sectors, including national and international aviation. It is not clearly specified if the target includes international maritime Remaining emissions in 2050 can be compensated by natural sinks, import of renewable energy (including hydrogen) and technical sinks (CCU/CCS).	The LTS presents one main scenario and four pathways towards climate neutrality in 2050: Scenario "Transition 2019" – modelled with the same approach as the official WEM and WAM projections under the EU Monitoring Mechanism Regulation. Pathways A, B, C and D – alternative scenarios modelled with a Excel-tool carbon pathway calculator. Show how climate neutrality could be reached with different options.	Share of renewables in gross final energy consumption in 2050:76% to 93%. By 2050, only nearly zero-energy buildings (NZEB) or positive energy buildings will be built. There is no disaggregated information on industrial sectors, transport types, AFOLU expected emissions by sources and by individual GHGs
Denmark	Net-zero emissions by 2050, at latest. The goal does not specify whether it includes all main greenhouse gases. The goal includes all sectors with the exclusion of LULUCF. It does not specify whether it includes international navigation and aviation.	The LTS does not include any scenarios at the national level. Some projections up to 2040 have been developed on the basis of an 'existing and adopted measures' (WEM) policy scenario. The strategy was originally published in August 2019 and a summary was included in Denmark's National Energy and Climate Plan (NECP).	Projections have been completed only as far as 2040 under an existing-measure (WEM) scenario.
France	Carbon neutrality by 2050. According to the communication materials accompanying the French national strategy on reducing GHG emissions, carbon neutrality should be interpreted as climate neutrality. The goal includes all the main greenhouse gases. The goal covers all sectors, with the exclusion of international maritime and aviation.	The LTS presents one reference scenario up to 2050, which is a scenario with additional measures (WAM) for reducing greenhouse gas emissions in line with the objective of achieving a carbon neutrality by 2050. The scenario is the result of a stakeholder engagement process.	Final energy consumption projections to 2050 by sector (i.e. transport, industry, buildings and agriculture) to be almost cut by half compared to today's levels.
Germany	The Federal Climate Change Act, amended in July 2021, defines a new long-term goal for Germany: "By the year 2045, greenhouse gas emissions shall be reduced to the point of net greenhouse gas neutrality. After the year 2050, negative greenhouse gas emissions are to be achieved.' The scope of the goal is not explicitly defined. It excludes international maritime and aviation.	The LTS does not provide modelling scenarios.	The LTS does not provide any likely estimate of final energy consumption or renewable estimates by 2050.

Greece	Moving towards a climate neutral economy by 2050. The goal does not specify whether it includes all main greenhouse gases. It does not specify if it includes LULUCF and international bunkers.	The LTS presents four scenarios up to 2050, two of which correspond to strategies to achieve the 2°C climate target and two scenarios compatible with the 1.5°C climate target: Energy Efficiency and Electrification for 2°C (EE2): 'very ambitious' measures for the electrification of energy uses in all sectors and the improvement of energy efficiency. New Energy Carriers for 2°C" (NC2): energy efficiency and electrification measures (at a lower level than EE2), complemented by 'very ambitious' EU policies to boost hydrogen, biogas, and synthetic methane. Energy Efficiency and Electrification for 1.5°C (EE1.5); as for EE2, but at 'maximum ambition' level. − New Energy Carriers for 1.5°C (NC1.5): as for NC2, but at 'maximum ambition' level.	Share of renewables in gross final energy consumption in 2050: 81.9% to 113.8%. Final energy consumption is estimated for specific sectors: buildings; industry and transport.
Portugal	Carbon neutrality by 2050. The goal does not specify whether it includes all main greenhouse gases. It does not specify if it includes national and international aviation	The LTS presents three alternative macro-economic scenarios by 2050 "Off-track": retains economic structure and current trends as well as the decarbonisation policies already adopted. "Peloton": socio-economic developments and new technologies compatible with carbon neutrality, but not enough to significantly change either the production structures or the population's lifestyles. Modest adoption of circular economy models. Population concentrated in cities. "Yellow Jersey": socio-economic developments compatible with carbon neutrality, with structural change in production chains. More effective adoption of circular economy models. Growth of medium-sized cities.	Share of renewables in gross final energy consumption in 2050: 86% to 88%. Reduction in the energy intensity of passenger and freight transport, respectively, from -81% to -84% and -73% to -75% of -84% and -75%, by 2050 compared to 2015. Reduction of energy intensity in industry by -52% to -64% by 2050, compared to 2015. Reduction of energy intensity of buildings respectively from -7% to -20% and from -42% to -43% by 2050, compared to 2015.
Sweden	Climate neutrality by 2045. The goal includes all main greenhouse gases. The goal covers all sectors, excluding international maritime and aviation.	The LTS does not present the scenarios used to generate projections and targets for the climate neutrality's goal. Annex I states that scenarios were developed by a government's task-force led by	Electricity production from 100% renewable sources by 2040. The largest renewable energy contributions originate from biofuels, followed by hydropower.

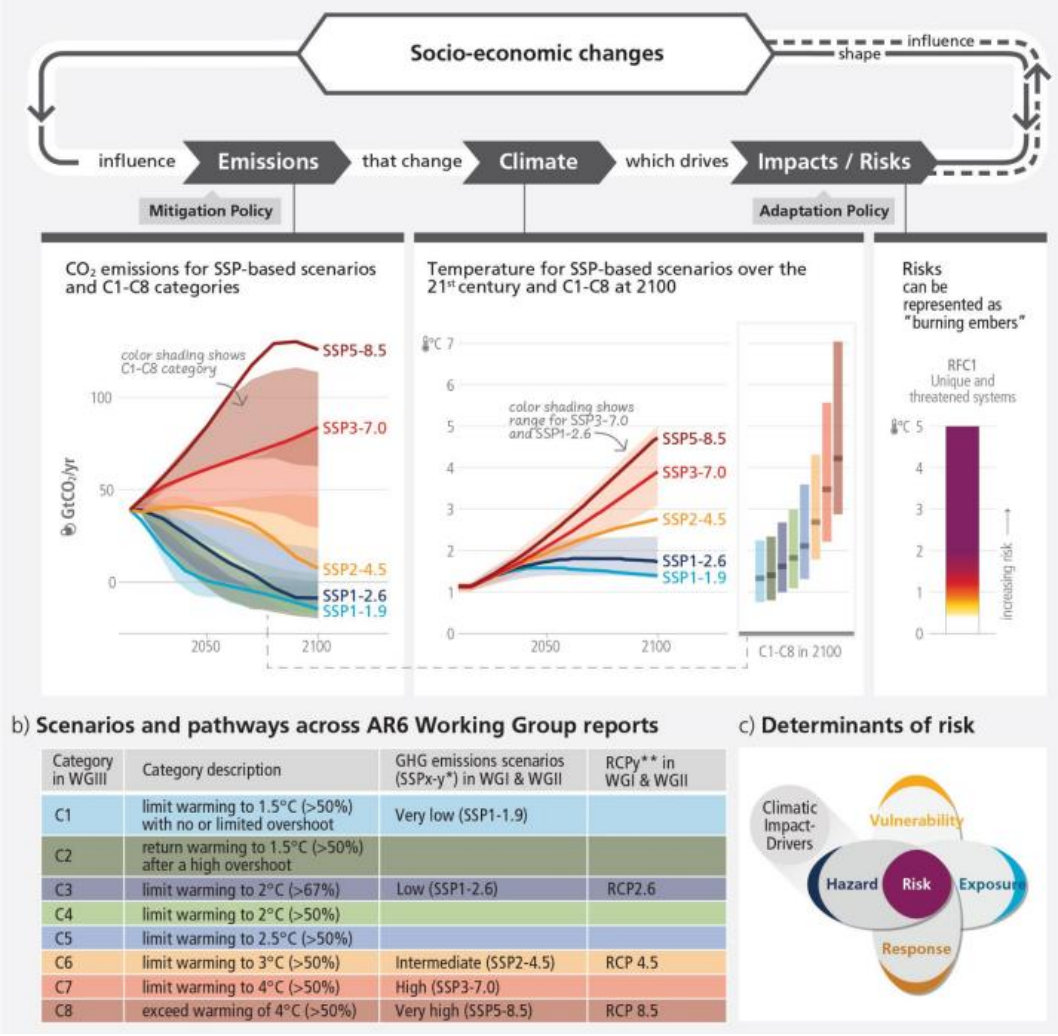
		the Swedish Environmental Protection Agency, involving five national authorities, universities and consultants in energy modelling.	Renewable share in transport with a focus on renewable sustainable fuel.
Slovenia	Climate neutrality by 2050. The goal does not specify whether it includes all main greenhouse gases. The goal covers all sectors, with the exclusion of international maritime and aviation.	The LTS presents two scenarios up to 2050: With existing measures (WEM), which includes planned measures Net-zero scenario, which includes additional measures necessary to meet the net-zero emission target. This scenario is further broken down into two options: i) the nuclear scenario, in which nuclear is the main energy supply; and ii) the synthetic natural gas scenario, in which synthetic natural gas is the dominant energy supply.	Share of renewables in gross final energy consumption in 2050: 60% Indicative sectoral targets: 65% in transport, at least 50% in heating and cooling and at least 80% in electricity generation. Exploitation of RES in district heating and cooling systems will be promoted as a matter of priority. Use of biofuels will be prioritised towards the development, production and use of advanced sustainable biofuels from woody biomass. Focus on hydropower generation and biomass.
Spain	Climate neutrality by 2050. The goal includes all the main greenhouse gases. The goal covers all sectors, excluding international aviation.	The LTS presents two alternative scenarios: The Baseline Scenario is only used as a reference scenario and does not reach climate neutrality by 2050. The Climate Neutrality Scenario reaches Climate Neutrality by 2050. It is a fixed strategy up to 2030. After 2030, the technologies and strategies used to reach climate neutrality in 2050 might change, depending on the specific technological improvements and breakthroughs that could take place in the different sectors of the economy.	Share of renewables in total final energy consumption in 2050: 97% Electricity production from 100% renewable sources by 2050. Renewables in the transport sector: 28% in 2030 and 79% in 2050. Renewables in the 'heating and cooling' sector: 97% in 2050. Primary energy consumption projected to decrease by around 50 % from 2020 to 2050. The use of autonomous and electric vehicles will bring about significant efficiency gains in the transport and mobility sector. The use of heat pumps, energy saving and efficiency in heating and cooling sector are promoted through tax benefits.

Table 3, Section of Long-Term Climate Strategies submitted to the European Commission (Source: European Commission)

4.5 International Scenarios and Pathways

In the most recent assessment from the IPCC, seven pathways were developed from a collection of 1,202 scenarios from a wide range of modelling approaches (IPCC, 2022). These seven pathways condense this very large set of scenarios into a representative range of different mitigation strategies that would be consistent with different warming levels.

These pathways are based on a range of assumptions including mitigation options based on land use changes, socio-economic and macro-economic variables (IPCC AR6 synthesis, 2023). The high and very high GHG emissions scenarios (SSP3-7.0 and SSP5-8.5) have CO_2 emissions that roughly double from current levels by 2100 and 2050. The intermediate GHG emissions scenario (SSP2-4.5) has CO_2 emissions remaining around current levels until the middle of the century. The very low and low GHG emissions scenarios (SSP1-1.9 and SSP1-2.6) have CO_2 emissions declining to net zero around 2050 and 2070 followed by varying levels of net negative CO_2 emissions (IPCC AR6 synthesis, 2023).



Category in WGIII	Category description	GHG emissions scenarios (SSPx-y*) in WGI & WGII	RCPy** in WGI & WGII
C1	limit warming to 1.5°C (>50%) with no or limited overshoot	Very low (SSP1-1.9)	
C2	return warming to 1.5°C (>50%) after a high overshoot		
C3	limit warming to 2°C (>67%)	Low (SSP1-2.6)	RCP2.6
C4	limit warming to 2°C (>50%)		
C5	limit warming to 2.5°C (>50%)		
C6	limit warming to 3°C (>50%)	Intermediate (SSP2-4.5)	RCP 4.5
C7	limit warming to 4°C (>50%)	High (SSP3-7.0)	
C8	exceed warming of 4°C (>50%)	Very high (SSP5-8.5)	RCP 8.5

Figure 2, AR6 integrated assessment framework on future climate impacts and mitigation (Source: IPPC AR6 Synthesis Report)

In its recent advice[19] to the European Commission (EC), the European Scientific Advisory Board (ESAB) noted that drawing on scenario evidence that is as up to date as possible to

[19] https://www.eea.europa.eu/about-us/climate-advisory-board/setting-climate-targets-based-on

quantify transformation scenarios towards net zero greenhouse gas emissions by 2050 is crucial to ensure that technology costs, policies and other trends are up to date.

The ESAB recommended that analysis underpinning the proposal for an EU-wide 2040 climate target and projected indicative greenhouse gas budget for the period 2030-2050 should also consider the implications of different pathways in terms of side effects, co-benefits, resilience and feasibility. Furthermore, in selecting scenarios, scenario analysis should be used carefully and consider non-scenario insights on different mitigation options in addition to combining perspectives from different models and approaches. The advice also notes that scenarios that have an integrated cross-sectoral perspective as well as scenarios that examine individual sectors in greater detail should be collected and analysed.

In modelled pathways considered by the IPCC, the timing of net-zero CO_2 emissions, followed by net-zero GHG emissions, depends on several variables, including the desired climate outcome, the mitigation strategy and the gases covered.

Global net zero CO_2 emissions are reached in the early 2050s in pathways that limit warming to 1.5°C (>50%) with no or limited overshoot, and around the early 2070s in pathways that limit warming to 2°C (>67%) (IPCC AR6 Synthesis Report, 2023). While non-CO_2 GHG emissions are strongly reduced in all pathways that limit warming to 2°C (>67%) or lower, residual emissions of CH_4 and N_2O and F-gases remain at the time of net zero GHG, counterbalanced by net negative CO_2 emissions (IPCC AR6 Synthesis Report, 2023).

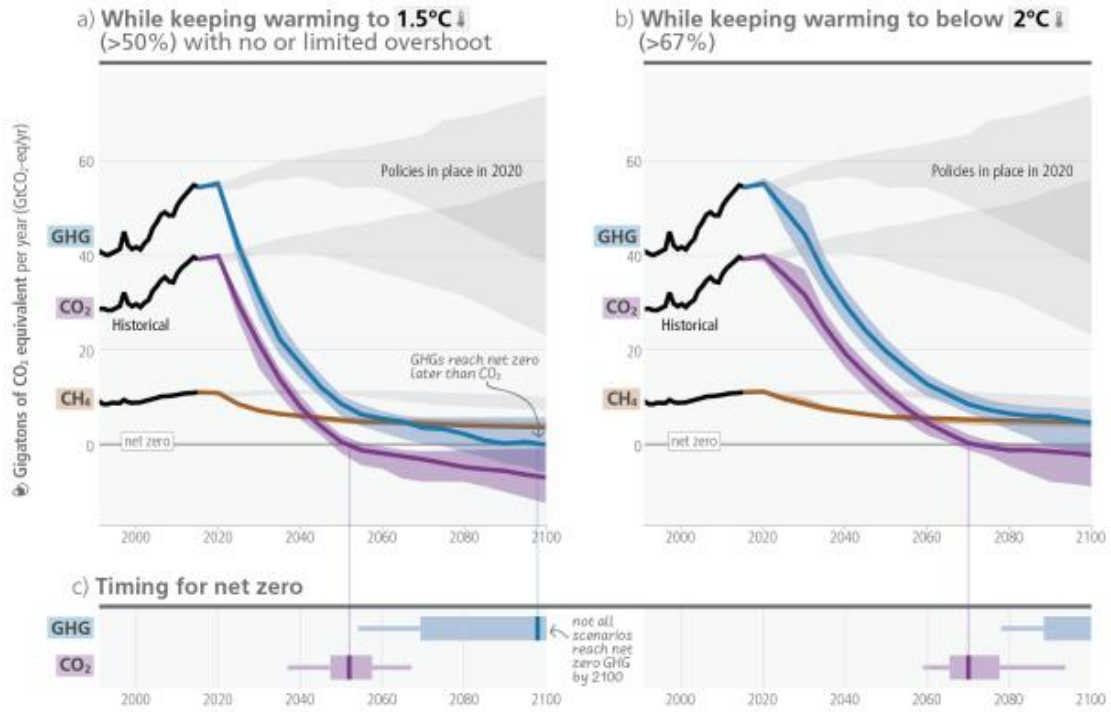


Figure 3: Global modelled pathways that limit warming to 1.5 degrees (>50%) with no or limited overshoot reach net zero CO2 emissions around 2050. Total greenhouse gases (GHG) reach net zero later. (Source: IPCC AR6 Synthesis report)

4.6 Net-Zero & Negative Emissions

Regardless of the pathway to climate neutrality for Ireland in 2050, what happens beyond 2050 is also important. According to the IPCC AR6 Synthesis report, carbon dioxide removal (CDR) will be necessary to achieve net-negative CO_2 emissions to counterbalance hard-to-

abate residual emissions (e.g., some emissions from agriculture, aviation, shipping, and industrial processes).

Carbon dioxide removal will probably be constrained by cost considerations and geopolitical factors, as well as by biological, geological, technological and institutional limitations on our ability to remove carbon from the atmosphere and store it durably and safely (Fankhauser et al. 2022)

Ireland is anticipated to need to implement significant negative emissions which will require deployment of carbon dioxide removal including nature based and technology solutions as well as mitigation within Land Use, Land Use Change and Forestry (LULUCF) in the period to 2050 and beyond.

LULUCF is a key strategic buffer in terms of absorbing atmospheric CO_2. The global terrestrial carbon sink sequesters approximately 2.3 billion tonnes CO_2 per annum and this sink may be enhanced or reduced via land-use and/or land management change. However, at national level, there is considerable uncertainty as to the size of the carbon sink and the rate of influx/efflux of CO_2 into that sink. In general terms, the LULUCF sector is a net sink in the majority of EU states. However, Ireland, the Netherlands, Denmark and Malta are net carbon emitters from LULUCF, due to a lack of afforestation and/or the predominance of managed peat soils.

Land-use and forestry sinks/sources have a high degree of uncertainty (between 59-124%, Duffy et al. 2022). This is due to variability in source/sink strength attributable to ecotype (forest, grassland, cropland) and is further confounded by biotic and abiotic factors such as climate, soil type, aspect and management. The potential effect of inventory uncertainty on climate neutrality needs to be considered as part of the development of carbon budgets.

5. Climate Change Impacts in Ireland in 2050

5.1 Future climate projections

In Ireland, mid-century mean annual temperatures are projected to increase by 1-1.2°C and 1.3-1.6°C under different Representative Concentration Pathways (RCP) i.e., RCP4.5 and RCP8.5 scenarios[20] respectively (Nolan, 2020).

The recently released AR6 synthesis report also reiterates with high confidence that climatic and non-climatic risks will increasingly interact, creating compound and cascading risks that are more complex and difficult to manage. Therefore, framing appropriate policy responses to the climate crisis requires a holistic understanding of the social and economic consequences of the increasing extreme weather events which will be useful in protecting people and especially those most vulnerable and assets in risky locations. Looking beyond 2050 requires a shared vision driven by community-led initiatives that will foster a low-carbon and climate-resilient Ireland (Flood et al., 2023).

5.2 Changes for Ireland

The pursuit and achievement of the national climate objective will need to follow an integrated approach with measures designed and implemented to have positive effects on each of its key elements – climate neutrality, climate resilience, environmental sustainability and biodiversity richness. This will involve significant social, political and economic changes and significant emissions reductions across all sectors. Different pathways and technology transitions will need to be navigated.

The pathways for Ireland will need to take a Just Transition approach by way of supporting equity and fairness in its transition to a climate neutral and resilient economy. This will require integrating the Just Transition principles when developing and implementing climate policy, instruments and regulations across all sectors. The principles as laid out in the National Climate Action Plan 2023 include; an integrated, structured, and evidence-based approach to identify and plan our response to just transition requirements, the right skills to be able to participate in and benefit from the future net zero economy, costs are shared so that the impact is equitable and existing inequalities are not exacerbated and social dialogue to ensure impacted citizens and communities are empowered and are core to the transition process.

With Ireland currently being in both a climate and biodiversity emergency, the pathways will need to follow approaches to mitigation, adaptation and disaster risk reduction that promote nature-based solutions and restore and enhance biodiversity. The conservation and sustainable use of biodiversity going forward will allow us to soak up and store CO_2 emissions, increase resilience to flooding, coastal erosion, droughts and other extreme events and contribute towards improved environmental sustainability in Ireland.

The pathway for Ireland will also need to consider technology readiness, skills and supply chains, supporting infrastructures and a variety of expected changes from an economic, cultural and social perspective along with projected population growth, global impacts and factors.

This will include some common key assumptions such as fossil fuel prices, carbon prices, Gross Domestic Product (GDP) growth, population growth, levels of energy demand and

[20] A Representative Concentration Pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC. The RCPs are consistent with a wide range of possible changes in future anthropogenic (i.e., human) GHG emissions, and aim to represent their atmospheric concentrations.

investment costs. In addition, this will need to consider the emissions across each sector today and in 2030, land use, and opportunities for land-based removals, available infrastructure.

In developing scenarios out to 2050, uncertainty will be greater than in scenarios that have been developed to date, which have focused on 2030. The UK CCC for example tried to address this uncertainty by using a range of scenarios to explore trade-offs and different degrees of optimism around potential solutions.

5.3 Emerging evidence of climate impacts

There is a growing body of literature underpinning future projected impacts and risks from climate change, for instance, the length, frequency, and intensity of heatwaves might increase in large parts of Europe, Asia, and Australia (Warren et al., 2021; Arbuthnott et al., 2023).

A significant sea level rise is projected to have severe effects on coastal communities and assets in Europe including Ireland (McEvoy et al., 2021). AR6 further notes that at sustained warming levels between 2°C and 3°C, the Greenland and West Antarctic ice sheets will be lost almost completely and irreversibly over multiple millennia, potentially causing several metres of sea level rise. Future simulations show that even the most conservative scenario of sea level rise will result in an increase of flooded areas by 51%, indicating that flooding and surge penetration will increase as sea levels rise (Mansur et al., 2022). Different Shared Socioeconomic Pathways (SSP[21]) such as 1-1.9, 2-4.5, 5-8.5 emission scenarios, indicate an increase in global-sea levels of 0.2 ± 0.01 m, 0.5 ± 0.01 m and 1.4 ± 0.1 m, respectively, by 2150 (Park et al., 2023). Therefore, planning for sea level rise is a key part of responding to hazards in a timely and adequate manner and taking into account past sea level changes is crucial for characterizing current trends and assessing future scenarios (Adebisi et al., 2021).

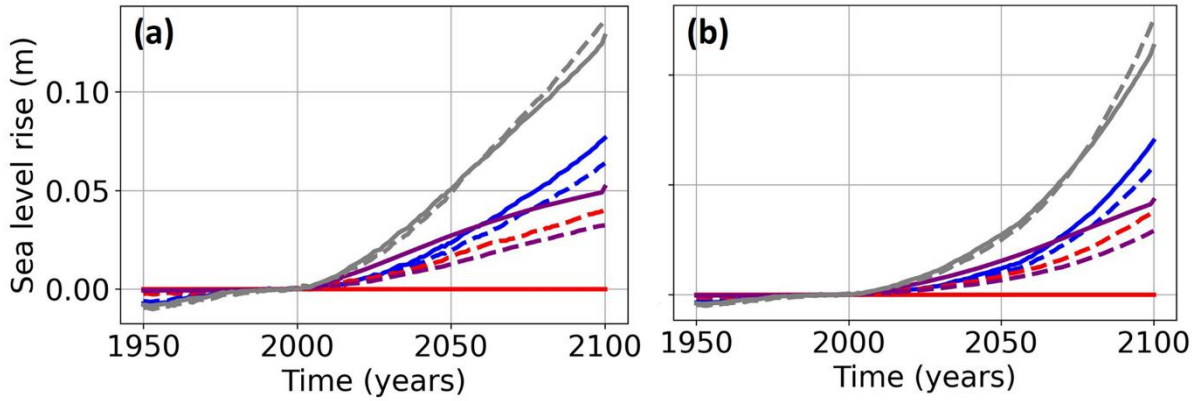


Figure 4: Projected changes up to 2100 relative to 1986-2005 of the dominating barystatic SLR contributions scaled to the IBI domain using spatial fingerprints for the (a) SSP1-2.6 and (b) SSP5-8.5 scenario. Source (Chaigneau et al., 2022)

The likelihood and impacts of abrupt and/or irreversible changes in the climate system, including changes triggered when tipping points are reached, increase with further global warming. The effects of climate change are likely to negatively affect water quality, resource availability, and riverine ecosystems. Under RCP8.5, winter flows are predicted to increase (-3.29 to 59.63%), with large variations anticipated for summer flows (-59.18 to 31.23%), low flows (-49.30 to 22.37%), and flood flows (-19.31 to 116.34%) by the 2080s (Murphy et al., 2023). In the absence of adaptation, these changes are likely to pose a challenge to water management in Ireland.

[21] Shared Socioeconomic Pathways (SSPs) are scenarios of projected socioeconomic global changes up to 2100. They are used to derive greenhouse gas emissions scenarios with different climate policies.

Among the most substantial impacts of climate change on biodiversity are geographical range shifts, habitat loss, food web changes, and disease outbreaks. As warming levels increase, so do the risks of species extinction or irreversible loss of biodiversity in ecosystems. It is more likely that species closely tied to their breeding grounds will be affected by changes in sea surface temperatures because this will affect both habitat availability and breeding behaviours associated with those habitats (Martin et al., 2023). Extreme weather events may alter plant and animal distributions in the future (Mogos et al., 2021), and increasing pressures such as marine renewable energy expansion will also exacerbate these cumulative impacts.

The relationship between climate change and health is complex. Climate change affects multiple dimensions of human well-being in ways that are emerging or invisible to decision-makers (Adger et al., 2022). In particular, coastal cities and Island nations, which are at risk of rising sea levels, experience the direct effects of extreme weather events such as heat waves, droughts, storms, and floods (Kapović Solomun et al., 2022). Increasing temperatures can lead to heat stroke, heat stress, and death, especially in people with pre-existing health conditions, and to cardiovascular, respiratory, and kidney events. In addition, floods and storms can cause traumatic injuries, drowning, and the spread of vector-borne and water-borne infectious diseases (Nicholas et al., 2021). Ireland, as well as many other regions, is expected to experience increasingly intense, frequent, and extreme weather events, which may adversely affect the health and well-being of those most vulnerable and exposed (Farrell et al., 2023).

6. Potential Recommendations and areas for Discussion

- There is no single model in Ireland that captures in sufficient detail the technical information on mitigation options across all sectors. Available models are not integrated and are limited in their time horizon. In addition, there are limited sector specific studies available which consider pathways to 2050 in Ireland. This will be an important consideration in developing the scope of work for a consultancy package in 2023 to inform the next carbon budgets process and also needs to be considered for future programmes of carbon budgets. Note: research to develop new integrated pathways for rapidly and deeply decarbonising the energy, land and food systems out to 2100 is due to commence in Q3 2023, however, the final report will not be available in time for the 2nd carbon budgets programme but this research will be beneficial to future programmes of carbon budgets.
- Ireland's Long Term Climate Strategy should be an important information source to support this work. However, a review of Long-Term Climate Strategies submitted to date shows that many lack sufficient details and are significantly out of date as of 2023. The recently published strategy, currently undergoing public consultation, notes that reaching climate neutrality will mean that Ireland will have no further negative impacts on the climate system by mid-century. It notes *'. To reach this point, Ireland will have to achieve net zero emissions for long-lived greenhouse gases combined with a substantial reduction in methane emissions by 2050.'*
- Scenarios used to determine the starting point in 2030 for the development of CB3 and CB4 should assume achievement of the first and second carbon budgets as a primary assumption, with alternative scenarios developed based on other assumptions. Sections 6D (4) and (5) of the Act consider situations where a surplus from a preceding carbon budget may be carried forward where there is overperformance against a budget and where excess emissions are carried forward where there is underperformance against a budget.

- **This leads to three start points for the Carbon Budgets Working Group to consider; (1) staying within carbon budgets 1 and 2 (2) overperformance against carbon budgets 1 and 2 and (3) underperformance against carbon budgets 1 and 2.**
- The IPCC's AR6 Synthesis report notes that; '*Limiting human-caused global warming to a specific level requires limiting cumulative CO_2 emissions, reaching net zero or net negative CO_2 emissions, along with strong reductions in other GHG emissions'.*
- Section 3(1) pf the Act sets out the national climate objective; *'The State shall, so as to reduce the extent of further global warming, pursue and achieve, by no later than the end of the year 2050, the transition to a climate resilient, biodiversity rich, environmentally sustainable and climate neutral economy'.* **It may be appropriate for scenarios based on climate neutrality, understood in the context of their temperature impact, to be developed for the purposes of the next carbon budgets process and assessed against the temperature goals of the Paris Agreement. Analysis of the impact of an emissions trajectory towards net zero greenhouse gas emissions in 2050 should also be carried out.**
- This leads to at least two scenarios; (1) based on an emissions trajectory consistent with specific temperature outcomes (2) based on an emissions trajectory towards net zero greenhouse gas emissions in 2050.

Building blocks for scenarios for CB3 and CB4			
Start point in 2030	(1) staying within carbon budgets 1 and 2	(2) overperformance against carbon budgets 1 and 2 and	(3) underperformance against carbon budgets 1 and 2
Target for 2050		(1) based on an emissions trajectory consistent with specific temperature outcomes	(2) based on an emissions trajectory towards net zero greenhouse gas emissions in 2050.

- According to the IPCC AR6 Synthesis report, carbon dioxide removal (CDR) will be necessary to achieve net-negative CO_2 emissions to counterbalance hard-to-abate residual emissions (e.g., some emissions from agriculture, aviation, shipping, and industrial processes). Further work is required to understand the potential for negative emissions in the Irish context. The templates developed for the EU Reference Scenario may be useful for reference to this work[22].

[22] https://energy.ec.europa.eu/data-and-analysis/energy-modelling/policy-scenarios-delivering-european-green-deal_en

References

Adebisi, N., Balogun, A. L., Min, T. H., & Tella, A. (2021). Advances in estimating Sea Level Rise: A review of tide gauge, satellite altimetry and spatial data science approaches. *Ocean and Coastal Management*, *208*(January), 105632. https://doi.org/10.1016/j.ocecoaman.2021.105632

Adger, W. N., Barnett, J., Heath, S., & Jarillo, S. (2022). Climate change affects multiple dimensions of well-being through impacts, information and policy responses. *Nature Human Behaviour*, *6*(11), 1465–1473. https://doi.org/10.1038/s41562-022-01467-8

Arbuthnott, K., Maria Vicedo-Cabrera, A., & Gasparrini, A. (2023). *Temporal variation in impacts of heat exposure on human health* (Y. Guo & S. B. T.-H. E. and H. H. in the C. of C. C. Li (eds.); pp. 243–291). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-12-819080-7.00007-0

Chaigneau, A. A., Reffray, G., Voldoire, A., & Melet, A. (2022). IBI-CCS: a regional high-resolution model to simulate sea level in western Europe. *Geoscientific Model Development*, *15*(5), 2035–2062. https://doi.org/10.5194/gmd-15-2035-2022

Danielis, R., Scorrano, M., & Giansoldati, M. (2022). Decarbonising transport in Europe: Trends, goals, policies and passenger car scenarios. *Research in Transportation Economics*, *91*, 101068. https://doi.org/https://doi.org/10.1016/j.retrec.2021.101068

Duffy, C., Prudhomme, R., Duffy, B., Gibbons, J., Iannetta, P. P. M., O'Donoghue, C., Ryan, M., & Styles, D. (2022). Randomized national land management strategies for net-zero emissions. *Nature Sustainability*, *5*(11), 973–980. https://doi.org/10.1038/s41893-022-00946-0

ESAB. (2022). *The ESAB's call for scenario data contributions*. https://www.eea.europa.eu/about-us/climate-advisory-board/call-for-scenario-data-contributions

Fankhauser, S., Smith, S. M., Allen, M., Axelsson, K., Hale, T., Hepburn, C., Kendall, J. M., Khosla, R., Lezaun, J., Mitchell-Larson, E., Obersteiner, M., Rajamani, L., Rickaby, R., Seddon, N., & Wetzer, T. (2022). The meaning of net zero and how to get it right. *Nature Climate Change*, *12*(1), 15–21. https://doi.org/10.1038/s41558-021-01245-w

Farrell, E. J., Smith, G., Hagan, A. M. O., & Tissier, M. Le. (2023). *Building Coastal and Marine Resilience in Ireland. Environmental Protection Agency Report* (Issue 429).

Flood, S., Rogan, F., Revez, A., McGookin, C., O'Dwyer, B., Harris, C., Dunphy, N., Byrne, E., Gallachóir, B. Ó., Bolger, P., Boyle, E., Glynn, J., Barry, J., Ellis, G., & Mullally, G. (2023). Imagining climate resilient futures: A layered Delphi panel approach. *Futures*, *147*(February 2022), 103100. https://doi.org/10.1016/j.futures.2023.103100

Gallachóir, A. B. Ó., Deane, P., Glynn, J., & Rogan, F. (2020). *The Role of Energy Technology in Climate Mitigation in Ireland : Irish Times Phase 3* (Issue 326).

García-León, D., Casanueva, A., Standardi, G., Burgstall, A., Flouris, A. D., & Nybo, L. (2021). Current and projected regional economic impacts of heatwaves in Europe. *Nature Communications*, *12*(1), 1–10. https://doi.org/10.1038/s41467-021-26050-z

Gaur, A., Balyk, O., Glynn, J., Curtis, J., & Daly, H. (2022). Low energy demand scenario for feasible deep decarbonisation : Whole energy systems modelling for Ireland. *Renewable and Sustainable Energy Transition*, *2*(May), 100024. https://doi.org/10.1016/j.rset.2022.100024

Glynn, J., Gargiulo, M., Chiodi, A., Deane, P., Rogan, F., & Ó Gallachóir, B. (2019). Zero

carbon energy system pathways for Ireland consistent with the Paris Agreement. *Climate Policy*, *19*(1), 30–42. https://doi.org/10.1080/14693062.2018.1464893

IPCC. (2022). IPCC, 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In *Climate Change 2022: The Physical Science Basis.* https://doi.org/10.1017/9781009325844.Front

IPCC. (2023). Summary for Policymakers Sixth Assessment Report (AR6) SYR. *Implementing a US Carbon Tax: Challenges and Debates*, xxiii–xxxiii. https://doi.org/10.4324/9781315071961-11

Kapović Solomun, M., Ferreira, C. S. S., Zupanc, V., Ristić, R., Drobnjak, A., & Kalantari, Z. (2022). Flood legislation and land policy framework of EU and non-EU countries in Southern Europe. *Wiley Interdisciplinary Reviews: Water*, *9*(1), 1–14. https://doi.org/10.1002/wat2.1566

Lynch, J., Cain, M., Pierrehumbert, R., & Allen, M. (2020). Demonstrating GWP: A means of reporting warming-equivalent emissions that captures the contrasting impacts of short- A nd long-lived climate pollutants. *Environmental Research Letters*, *15*(4). https://doi.org/10.1088/1748-9326/ab6d7e

Madden, S. M., Ryan, A., & Walsh, P. (2022). Exploratory Study on Modelling Agricultural Carbon Emissions in Ireland. *Agriculture (Switzerland)*, *12*(1), 1–12. https://doi.org/10.3390/agriculture12010034

Mansur, M., Hopkins, J., & Chen, Q. (2022). “Delft3D model runs”, in Data, model setup and simulation output from “Estuarine response to storm surge and sea level rise associated with channel deepening: A flood vulnerability assessment of southwest Louisiana, USA.” *DesignSafe-CI*, *0123456789*. https://doi.org/10.1007/s11069-023-05841-1

Martin, E., Banga, R., & Taylor, N. L. (2023). Climate change impacts on marine mammals around the UK and Ireland. *MCCIP Science Review*, 2.

Martins, K., & Carton, J. G. (2023). Prospective roles for green hydrogen as part of Ireland’s decarbonisation strategy. *Results in Engineering*, *18*(June 2022), 101030. https://doi.org/10.1016/j.rineng.2023.101030

McEvoy, S., Haasnoot, M., & Biesbroek, R. (2021). How are European countries planning for sea level rise? *Ocean and Coastal Management*, *203*, 105512. https://doi.org/10.1016/j.ocecoaman.2020.105512

McMullin, B., & Price, P. (2020). Synthesis of Literature and Preliminary Modelling Relevant to Society-wide Scenarios for Effective Climate Change Mitigation in Ireland. In *Environmental Protection Agency, Ireland. https://www. epa. ie/researchandeducation/research/researchpublications/researchreports/Research_ Report_352. pdf* (Issue 35).

Mogos, R. I., Negescu–Oancea, M. D., Burlacu, S., & Troaca, V. A. (2021). Climate Change and Health Protection in European Union. *European Journal of Sustainable Development*, *10*(3), 97. https://doi.org/10.14207/ejsd.2021.v10n3p97

Murphy, C., Kettle, A., Meresa, H., Golian, S., Bruen, M., O’Loughlin, F., & Mellander, P.-E. (2023). Climate Change Impacts on Irish River Flows: High Resolution Scenarios and Comparison with CORDEX and CMIP6 Ensembles. *Water Resources Management*. https://doi.org/10.1007/s11269-023-03458-4

Nicholas, P. K., Breakey, S., Tagliareni, M. E., Simmonds, K., & Sabo, K. K. (2021). Climate

Change and Population Health: Incorporating Stages of Nursing's Political Development. *Nursing Outlook*, *69*(1), 65–73. https://doi.org/10.1016/j.outlook.2020.08.001

Nolan, P. (2020). *High-Resolution Climate Projections for Ireland – a Multi-Model Ensemble Approach | ICHEC., Environmental Protection Agency Report* (Issue 339). https://www.ichec.ie/partnerships/state-supported/high-resolution-climate-projections-for-Ireland

Park, J. Y., Schloesser, F., Timmermann, A., Choudhury, D., Lee, J. Y., & Nellikkattil, A. B. (2023). Future sea-level projections with a coupled atmosphere-ocean-ice-sheet model. *Nature Communications*, *14*(1), 636. https://doi.org/10.1038/s41467-023-36051-9

Sharmina, M., Edelenbosch, O. Y., Wilson, C., Freeman, R., Gernaat, D. E. H. J., Larkin, A., Littleton, E. W., Traut, M., Vuuren, D. P. Van, Vaughan, N. E., Wood, R., & Quéré, C. Le. (2021). *Decarbonising the critical sectors of aviation , shipping , road freight and industry to limit warming to 1 . 5 – 2 ° C*. https://doi.org/10.1080/14693062.2020.1831430

UK CCC. (2023). *Climate Change Committee Insights : Determining a pathway to Net Zero Contents*. *January*.

Warren, R., Price, J., & Jenkins, R. (2021). *Climate change and terrestrial biodiversity* (T. M. B. T.-T. I. of C. C. Letcher (ed.); pp. 85–114). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-12-822373-4.00025-2

Wheatley, J. (2022). "Temperature Neutrality and Irish Methane Policy." *Climate Policy*, *13*(1), 104–116. https://doi.org/10.1080/14693062.2023.2191921

Zickfeld, K., & Herrington, T. (2015). The time lag between a carbon dioxide emission and maximum warming increases with the size of the emission. *Environmental Research Letters*, *10*(3). https://doi.org/10.1088/1748-9326/10/3/031001

Appendix 1: Previous Council Positions

The Council has raised this topic in a number of previous annual reviews, with some examples outlined below.

2022 Annual Review: *'Timely delivery of measures, particularly those identified as high-impact measures, is essential if Ireland is to meet national targets. For example, there are continued delays with the finalisation of a Long-Term Climate Strategy.'*

2021 Annual Review: *'When considering national policy goals to 2050, Ireland is significantly off-track from paths that deliver long-term transition to climate neutrality. While progress is crucial across all sectors, it is particularly urgent in the LULUCF (Land Use, Land Use Change and Forestry) sector. Given the timescales of LULUCF, actions in coming years are key to realise 2050 ambitions'.*

'Transition and transformation are delivered by long-term strategy and analysis, implemented by action in the short term, as per IPCC conclusions in the AR5 synthesis report. The IPCC have reaffirmed that this strategic process can deliver win-win outcomes and assist in managing trade-offs and conflicts. This is crucial if national transition is to be achieved in a cost effective, fair and sustainable manner. Ireland would therefore benefit from developing a range of strategic policy scenarios, addressing current gaps in knowledge on possible and preferable pathways to 2050.'

'The lack of a Long-Term Strategy to 2050 is a critical gap in Ireland's policy approach, with respect to the ability to achieve the National Climate Objective to 2050, in a cost-effective manner. The increase in emissions noted in the EPA projections after 2030, and then ending in 2040, are an illustration of challenges that arise when climate action policy is framed primarily by the short to medium-term. Furthermore, the 2021 IPCC AR6 WGI report makes clear that emissions will need to reach net zero by mid-century and then be net negative on a sustained basis to meet the ambitions set forth in the Paris Agreement. This policy gap leaves Ireland behind its peers, raising concerns about the ability to achieve long-term targets. It is noted that the Department of the Environment, Climate and Communications initiated a public consultation on Ireland's Long-term Strategy on Greenhouse Gas Emissions Reduction in November and December 2019. However, a Long-Term Strategy has not been published.

'National strategic response can be greatly enhanced by the exploration of multiple scenarios, responding to uncertainty and the needs of long-term strategy. A scenario approach can include defining social, cultural, political, and institutional drivers. Scenarios of alternative developments also allow consideration of the implications of transformative shifts, in systems, practices, and technologies, such as in settlement and mobility, or agriculture and land use, and in key themes, such as consumption, inequality and biodiversity.'

2020 Annual Review: *'Ireland lacks a framework that sets out a shared understanding of zero-carbon or climate neutrality goals to guide us towards the 2050 objective of net zero emissions. This needs to be established at an EU level but Ireland could usefully inform the debate. The long-term strategy must be consistent with meeting EU targets and requirements.*

A definition of carbon neutrality would enable long-term strategic planning in the Agriculture and Land Use sector. Agreeing a definition is a priority to support strategic development of the sector consistent with long-term goals. National policy considers neutrality in the context of Agriculture and Land Use; however, the EU Green Deal and proposed EU Climate Law expands this to all sectors and all greenhouse gases. Definition of neutrality should consider this policy context.'

'Based on these criteria, and until a formal definition is adopted at national or international level, the Council will use the following working definition of carbon neutrality:

Carbon neutrality is achieved when the net sum of emissions and removals of greenhouse gases associated with all activities within the economy makes no further additional physical impact on global warming[23].

This definition can be modified to consider carbon neutrality in the narrower context of Agriculture and Land Use, as framed from the current national policy position. However, other sectors are anticipated to need removals to balance unavoidable residual emissions in the context of a net zero emissions target by 2050.'

[23] As set out in the introduction this has been updated through the 2021 amendment to the Climate Action and Low Carbon Development Act which defines a 'climate neutral economy' as a sustainable economy and society where greenhouse gas emissions are balanced or exceeded by the removal of greenhouse gases. Section 3(1) sets out the national climate objective; '*The State shall, so as to reduce the extent of further global warming, pursue and achieve, by no later than the end of the year 2050, the transition to a climate resilient, biodiversity rich, environmentally sustainable and climate neutral economy'*.

Appendix 2: Relevant NCAP23 Actions

NCAP 2023 sets a number of targets relevant to this thematic area. Chapter 5 of NCAP 2023 also sets out the ambition and high-level pathways for each sector under the sectoral emissions ceilings.

Action #	NCAP Action	Completion Date	Current Status
CN/23/1	Finalise Ireland's Long-term Climate Strategy in line with the requirements in the Climate Act 2021	Q4 2023	This is currently being adjusted to align with NCAP 2023.
RE/23/4	Publish Ireland's Five-year Assessment Report on Climate Change. This will include: 1 – Science: Ireland in a changing world. 2 – Achieving climate neutrality by 2050. 3 – Being prepared for Ireland's future climate. 4 – Realising the benefits of transition and Transformation, and a synthesis report.	Q4 2023	First and second order drafts for each volume have been prepared with a number of publication dates provisionally scheduled in mid to late 2023.
GV/23/5	Develop a standardised, evidence-based approach for assessing the climate impacts of policy proposals	Q4 2023	TBC
GV/23/6	Ensure Ireland's Long-term Climate Strategy is fully aligned with the Climate Action Plan and national and EU legislative requirements.	Q4 2023	This is currently being adjusted to align with NCAP 2023.

Table x: Relevant NCAP23 Actions

Appendix 3: Changes for Ireland

The table below provides an initial overview of parameters which might be considered in the development of scenarios for Ireland between now and 2050, based on the UK CCC methodology, questions raised in DECCs' initial consultation on a long-term strategy for Ireland and requirements for the preparation of long-term strategies. This will be developed further with the Carbon Budgets Working Group.

Parameter	Considerations to 2050
Economy Wide	
Carbon Price	A varying carbon tax that increases by €7.50 per annum and €100 per tonne by 2030 in all scenarios is used in the 2021 EPA projections. Post 2030, a linear trajectory is assumed between the 2030 value and the EU Reference scenario 2050 price which reaches 150 €/tCO_2 (2015 money) by 2050. Any updates to these and assumptions should be considered by the WG.
GDP	The macroeconomic components of EU GDP are projected to record only marginal changes by 2050 in their shares in the current EU Reference Scenario.
Fossil fuel prices	In the 2021 EPA projections, fossil fuel prices are used from the BEIS Fossil Fuel Price Assumption 2019 (last updated on 6 February 2020). Data available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/863717/beis-2019-fossil-fuel-price-assumptions.pdf EU Reference Scenario prices are also used.
Population	According to EUROSTAT, the EU population is projected to decline over the (very) long term. However, there are wide differences in national population trends, with population growing in 11 Member States and dropping in the others. In Ireland the population is forecast to grow to approximately 5.5 million by 2030, however the CSO intends to publish updated national population and labour force projections in Q2 2024.
Projected GHG emissions and removals	
Energy Demand	According to the IEA roadmap to net zero for the global energy sector, global energy demand is about 8% smaller than today in 2050, but serving an economy that is more than twice as big with a population with 2 billion more people. More efficient use of energy, resource efficiency and behavioural changes combine to offset increases in demand for energy (IEA, 2022).
Economic	
Investment costs	
Questions to address	• Aspects related to macro-economic and social development, health risks and benefits and environmental protection which should be considered? • What financial instruments could complement a decarbonised economy by 2050? • What financial instruments could best lead us towards a climate neutral and resilient economy by 2050?
Sectoral	
What should our electricity fuel mix look like by 2050?	According to the IEA, by 2050, instead of fossil fuels, the energy sector is based largely on renewable energy. Two-thirds of total energy supply in 2050 is from wind, solar, bioenergy,

	geothermal and hydro energy. Modelling undertaken for the carbon budgets also presents a number of scenarios for 2050; https://tim-carbon-budgets-2021.netlify.app/results/power-sector
Questions to address (based on initial long term strategy consultation)	• What advanced technologies, across all sectors, could support a move to net-zero or negative emissions by 2050? • What resources will help manage intermittency on the grid (e.g., long duration storage, zero-emissions fuel)? • What is the future of the national gas grid in a net-zero emissions pathway? • How can emissions from large industry, e.g., cement and alumina, be reduced, including options beyond fuel substitution? • How can Ireland retrofit almost all buildings by 2050, including options for heating fuels and what buildings will be most challenging to decarbonise? • How do we ensure that building and infrastructure development supports compact urban development, which is regionally balanced and sustainably designed to reduce GHG and enhance sustainable quality of life? • What are the most cost-effective solutions for reducing emissions from heavy duty and long-distance vehicles? • How can Ireland, as a small island economy, reduce emissions from aviation and navigation, including demand reduction and stimulating supply of sustainable fuels? • What are the most important issues to consider in developing a long-term strategy to 2050 in order to ensure a just transition? • What should transport in our cities and rural areas look like by 2050?

Note on Ireland's Long-term Strategy on Greenhouse Gas Emissions Reductions

Background

Article 15 of the EU Regulation (EU) 2018/1999 of the European Parliament and of the Council on the Governance of the Energy Union and Climate Action requires each Member State to prepare and submit to the Commission a long-term strategy with a perspective of at least 30 years by 1 January 2020.

Ireland's Long-term Strategy for Greenhouse Gas Emissions Reductions was published on the 28th of April 2023 based on a public consultation carried out in 2019. A summary of consultation responses is also published with the strategy.

A further consultation on the strategy was opened on the 19th of May and is open until the 30th of June. The consultation is being undertaken given significant developments in climate policy since 2019 and will input to the preparation of an updated strategy by the end of 2023 as set out in the 2023 Climate Action Plan. The Consultation notes '*The updated Strategy will conform to the requirements for preparing a long-term climate strategy as set out under both national and EU law; and will be brought to Government for approval with a view to publishing and submitting it, as an updated version, to the European Commission by the end of 2023.'*

Points in relation to 2050 Target

The Secretariat's working paper on a Vision for 2050 was prepared prior to publication of the Strategy and initially discussed at the April Climate Change Advisory Council meeting but has been updated to reflect its publication and will be a key input to considerations of scenario development for the carbon budgets.

The Strategy notes that reaching climate neutrality will mean that Ireland will have no further negative impacts on the climate system by mid-century, stating that '*The Strategy is consistent with achieving net zero emissions for long-lived greenhouse gases (CO_2 and N_2O) and a significant reduction in methane emissions by 2050, thus establishing a climate neutral economy.'* It further notes; *'Achieving climate neutrality in Ireland will mean that the country will have no further negative impacts on the climate system by mid-century. To reach this point, Ireland will have to achieve net zero emissions for long-lived greenhouse gases combined with a substantial reduction in methane emissions by 2050.'*

Consultation Questions

The recently launched public consultation considers the following questions;

1) Following on from the 2019 consultation, is there anything new or incremental you think should be included in Ireland's Long-term Strategy?

2) Does the current long-term strategy identify realistic emission reduction pathways beyond 2030, or are there alternative or complementary pathways worthy of further consideration?

3) Noting that the transition to climate neutrality requires systemic change and that it is critical to consider the factors that may contribute to or hinder progress of such a transition, are there enabling conditions to support the transition that you think require greater focus, if so, what are they?

4) Are there any other comments or observations that you wish to make regarding Ireland's Long-term Strategy?