Carbon Budgets Working Group

Outputs Report

CLIMATE CHANGE ADVISORY COUNCIL

Carbon Budgets Working Group Outputs Report

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George Hussey

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Meabh Gallagher

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Kieran Craven

Philip O'Brien

Contents

Abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
AR6	Sixth Assessment Report
BECCS	bioenergy with carbon capture and storage
BEV	battery electric vehicle
CAP	Climate Action Plan
CAP23	Climate Action Plan 2023
CB1, 2, 3, 4	Carbon Budget 1, 2, 3, 4
CB Proposal	Carbon Budget Proposal
CBWG	Carbon Budgets Working Group
CCAC	Climate Change Advisory Council
CCS	carbon capture and storage
CDR	carbon dioxide removal
CSO	Central Statistics Office
DECC	Department of the Environment, Climate and Communications
DHLGH	Department of Housing, Local Government and Heritage
EBI	Economic Breeding Index
EPA	Environmental Protection Agency
EPMG	Energy Policy and Modelling Group
ESABCC	European Scientific Advisory Board on Climate Change
ESRI	Economic and Social Research Institute
ETS	Emissions Trading System
FAPRI	Food and Agricultural Policy Research Institute
FERS	Forest, Environmental Research & Services
FFI	fossil fuel and industry
GDP	gross domestic product
GHG	greenhouse gas

GOBLIN	General Overview for a Back-casting approach of Livestock Intensification and land use
GWP	global warming potential
GPW_{100}	average global warming potential over 100 years
GVA	gross value added
HGV	heavy goods vehicle
I3E	Ireland Environment, Energy and Economy (model)
IPCC	Intergovernmental Panel on Climate Change
LED	low energy demand
LGV	large goods vehicle
LULUCF	Land Use, Land Use Change and Forestry
MACC	marginal abatement cost curve
MoU	memorandum of understanding
Mt CO_2 eq	megatonnes of carbon dioxide equivalent
NEMF	National Energy Modelling Framework
NEP	National Energy Projections
NESC	National Economic and Social Council
NTA	National Transport Authority
P1, 2	Pathway 1, 2
S1, 2, 3	Scenario 1, 2, 3
SEAI	Sustainable Energy Authority of Ireland
TIM	TIMES-Ireland Model
UCC	University College Cork
UCD	University College Dublin
UNFCCC	United Nations Framework Convention on Climate Change
WAM	with additional measures
WEM	with existing measures

Executive summary

The Climate Change Advisory Council is an independent, statutory body. The core function of the Council is to provide independent advice to Government on climate change policy, with regard to how best to address both reducing greenhouse gas emissions and adapting to climate change.

The Carbon Budgets Working Group (CBWG) was established by the Council to support the development of Carbon Budget Proposals for Carbon Budget 3 (CB3) (2031–2035) and a provisional Carbon Budget 4 (CB4) (2036–2040). The CBWG was tasked with assisting the Council in the development of an evidence base for Carbon Budget Proposals. The working group held meetings from March 2023 to September 2024. The membership included relevant experts in modelling of energy, agriculture and land use, with additional expertise in economics, macroeconomics, biodiversity, philosophy and climate justice, socioeconomics and the Just Transition, carbon dioxide removal, and emissions inventories and projections.

Three core models were each used to perform three modelling iterations from September 2023 to August 2024 to provide greenhouse gas emission scenarios to at least 2050 to inform the Carbon Budget Proposal for CB3 and provisional CB4. The energy system was modelled using the TIMES-Ireland Model (TIM) from University College Cork, agriculture was modelled using Teagasc's FAPRI-Ireland model, and both agriculture and land use were modelled using the GOBLIN model and FERS Carbon Budgets Model by the University of Galway (**Section 4.2**). The models were refined between iterations based on CBWG expert input and guidance provided by the Council to the modelling teams. The warming impact of 1,196 scenarios developed by the CBWG was modelled using simple climate models assessing both the magnitude of warming and the likelihood of achieving temperature neutrality by 2050 under different global emissions scenarios (**Section 4.3**).

Additional models (National Energy Modelling Framework, National Transport Authority's model (**Section 4.4**)) tested the assumptions and outputs of the core models, economic and macroeconomic assessments (including the Central Bank of Ireland's semi-structural model) were conducted on selected scenarios (**Section 4.5**), and expert input from the working group refined the modelling and output processes (**Sections 4.6**–**Sections 4.11**).

This report provides an overview of the activities of the CBWG, synthesising the outputs and providing links to relevant output documents that assisted the Council in its deliberations for proposing CB3 (2031–2035) and a provisional CB4 (2036–2040).

1. Introduction

This report provides an overview of the outputs of the Carbon Budgets Working Group (CBWG) to assist the Climate Change Advisory Council (the Council or CCAC) in its Carbon Budget (CB) Proposal for Carbon Budget 3 (CB3) (2031–2035) and provisional Carbon Budget 4 (CB4) (2036–2040). It synthesises the outputs to assist the Council in its CB Proposal to the Minister of the Environment, Climate and Communications (the Minister), providing links to relevant output documents from the working group.

1.1. The Climate Change Advisory Council and carbon budgets

The Council is an independent, statutory body established under the Climate Action and Low Carbon Development Act 2015 (the Act), as amended. The core function of the Council is to provide independent advice to Government on climate change policy, regarding how best to address both reducing greenhouse gas (GHG) emissions and adapting to impacts.

The National Climate Objective, as outlined in the Act, is that the State shall transition to a climate-resilient, biodiversity-rich, environmentally sustainable and climate-neutral economy. Section 6A of the Act requires the Council to propose a carbon budget, consistent with furthering the achievement of the National Climate Objective, which shall be finalised by the Minister and approved by the Government for the period of 5 years commencing on 1 January 2021 and ending on 31 December 2025 and for each subsequent period of 5 years.

1.2. Background

1.2.1. First carbon budget programme

The Act mandated the Council to propose carbon budgets for CB1 (2021–2025), CB2 (2026–2030) and provisional CB3 (2031–2035), constituting the first carbon budget programme. Under the legislation, the proposed carbon budgets were required to provide for a 51% reduction in the total amount of GHG emissions, using the GWP_{100} (average global warming potential over 100 years) metric, by 2030, relative to 2018.

To propose carbon budgets for the first carbon budget programme, a Carbon Budgets Committee, comprising a panel of experts, was established by the Council in 2021. Meetings were held through 2021, and a CB Proposal for CB1 (2021–2025) and CB2 (2026–2030) was made (295 and 200 megatonnes of carbon dioxide equivalent (Mt CO_2 eq), respectively; see **Table 1** and **Figure 1**), including a provisional CB3 (2031–2035) of 151 Mt CO_2 eq). A technical report[1] outlining the methodology and rationale for the budgets was produced, and the carbon budgets were formally agreed by the Council in October 2021.[2]

1 Climate Change Advisory Council (2021). Carbon Budget Technical Report. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/Technical%20report%20on%20carbon%20budgets%2025.10.2021.pdf

2 Climate Change Advisory Council (2021). Climate Change Advisory Council Meeting – Minutes 25.10.2021. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/documents/governance/Signed%20Climate%20Change%20Advisory%20Council%20Minutes%2025.10.2021.pdf

Table 1: The Climate Change Advisory Council's CB Proposal for CB1, CB2 and provisional CB3 for the first carbon budget programme (all gases)

	CB1 (2021–2025)	CB2 (2026–2030)	Provisional CB3 (2031–2035)
Carbon budget (Mt CO_2eq)	295	200	151
Annual average percentage change in emissions	–4.8%	–8.3%	–3.5%

The figures are consistent with emissions in 2018 of 68.3 Mt CO_2 eq reducing to 33.5 Mt CO_2 eq in 2030, thus allowing compliance with the 51% emissions reduction target.

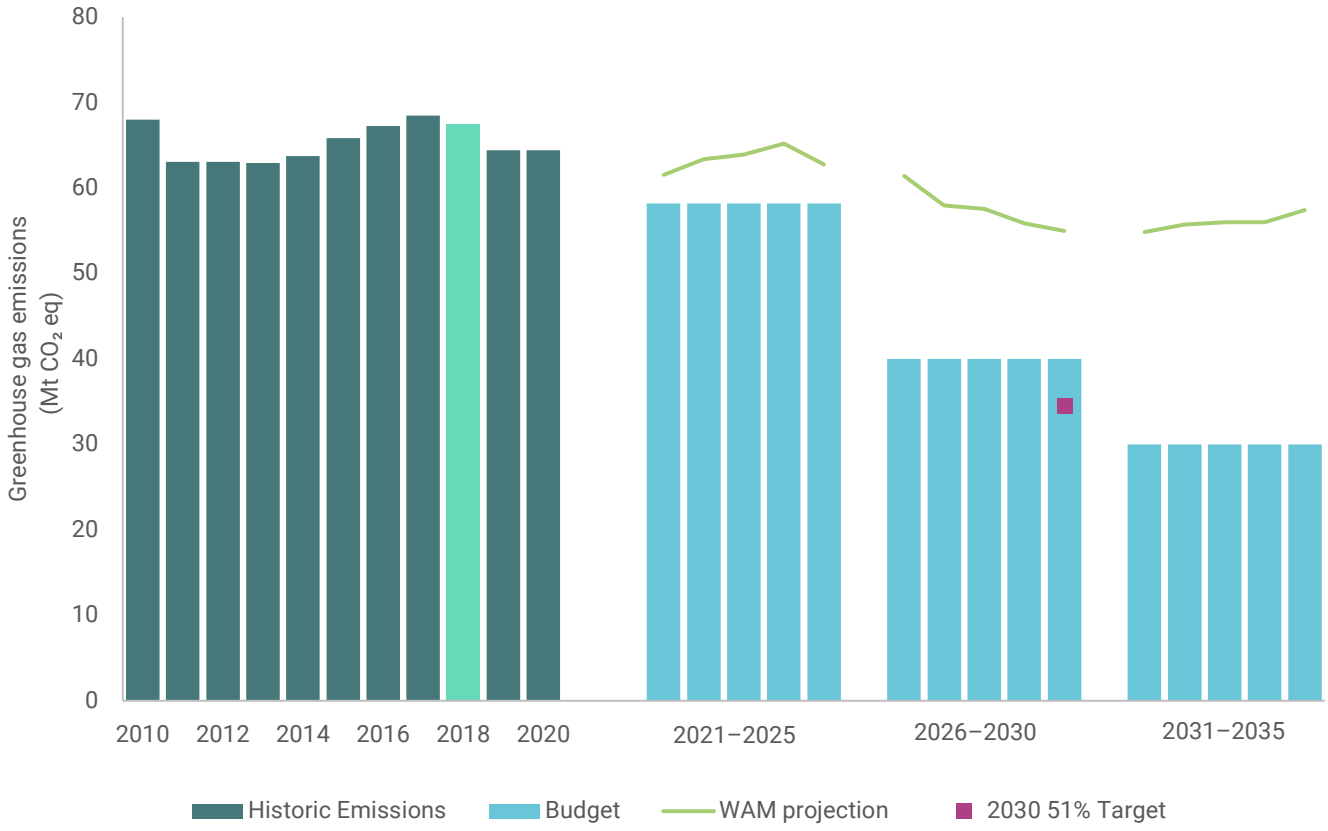

Figure 1: The proposed carbon budgets in the context of recent historical emissions and the Environmental Protection Agency's 'with additional measures' (WAM) projections of emissions based on implementation of Climate Action Plan 2019, including Land Use, Land Use Change and Forestry sector, excluding international aviation and navigation and the annualised average emissions associated with the proposed carbon budgets. Source: CCAC, 2021.[3] Reproduced from the Carbon Budget Technical Report from the first carbon budget programme.

3 Climate Change Advisory Council (2021). Carbon Budget Technical Report. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/Technical%20report%20on%20carbon%20budgets%2025.10.2021.pdf

The CB Proposal for CB1 (2021–2025), CB2 (2026–2030) and provisional CB3 (2031–2035) was approved by the Government on 22 February 2022. The budgets were laid before the Houses of the Oireachtas on 24 February 2022. The carbon budgets were approved by both Houses of the Oireachtas in April 2022.[4]

Sectoral emissions ceilings refer to the total amount of permitted GHG emissions that each sector of the economy can produce during a specific period. Section 6C of the Act provides for the preparation of sectoral emissions ceilings, which set out the maximum amount of GHG emissions that are permitted in different sectors of the Irish economy. Following approval of the carbon budgets, Ireland's sectoral emissions ceilings were agreed by Government in July 2022, with the Summary Report published in September 2022.[5]

1.2.2. Carbon budgets modelling workshop

To prepare for the CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040), the Council convened an online workshop in October 2022. This workshop provided an opportunity for experts and interested parties to discuss experiences from the 2021 CB Proposal for CB1 (2021–2025), CB2 (2026–2030) and provisional CB3 (2031–2035), and to facilitate conversations about planning the analytical process to inform the Council's development of a CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040). The aim of this workshop was to inform the work of the Council and provide insights on the evidence required and analytical tools available for the proposal. The objectives of this workshop were as follows:

- Consider and review the evidence required and the analytical tools available for the CB Proposal for CB3 and provisional CB4.
- Build capacity and knowledge in relation to a macroeconomic assessment of the impacts of the transition.
- Provide a forum for discussing integration, networking and/or looser 'coupling' of models with relevant stakeholders.

There were more than 60 registered attendees, including members of the Council, Secretariat and previous Carbon Budgets Committee, liaison officers under the Memorandum of Understanding (MoU) between the Council and Government departments and agencies,[6] members of the Department of the Taoiseach's Research and Modelling Group, policy makers, representatives of key departments and of other relevant organisations and communities and researchers. A report[7] arising from this

4 Government of Ireland (2022). Carbon Budgets 2022. [online] https://www.gov.ie/pdf/?file=https://assets.gov.ie/222805/697ec730-a09f-4216-a54a-6a5cd0b358df.pdf#page=null

5 Department of the Environment, Climate and Communications (2022). Sectoral Emission Ceilings. [online] https://www.gov.ie/en/publication/76864-sectoral-emissions-ceilings/

6 Climate Change Advisory Council (2022). Memorandum of Understanding between the Irish Climate Change Advisory Council and All Relevant Government Departments and Agencies. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/documents/memorandumsofunderstanding/2022%20Signed%20MoU%20between%20Government%20Departments%20and%20CCAC.pdf

7 Climate Change Advisory Council (2022). Carbon Budgets Modelling Workshop Report. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/documents/carbonbudgetworkshop2022/Carbon%20Budgets%20Modelling%20Workshop%20Report.pdf

workshop was prepared by the Secretariat for the information of the Council. The output from this workshop was used to produce a methodology and work programme for the CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040).

1.3. Carbon Budget Proposal for CB3 and provisional CB4

This second CB Proposal consists of CB3 (2031–2035) and provisional CB4 (2036–2040). Under Section 6A of the Act, not less than 12 months prior to the expiry of the first carbon budget in a carbon budget programme (i.e. before the end of Q4 2024) the Council shall prepare and submit to the Minister:

- a proposed carbon budget in respect of the budget period following the third budget period in the carbon budget programme (i.e. CB4 2036–2040),
- proposed amendments, if any, to the provisional carbon budget (i.e. CB3 2031–2035).

The Minister may revise CB2 (2026–2030) under Section 6D of the Act, but a revision of this budget was not conducted during the preparation phase for the Council's proposal.

1.3.1. Establishment of the Carbon Budgets Working Group

The Council agreed at its meeting in September 2022 to establish a CBWG to support Council's second CB Proposal. The CBWG was tasked with assisting and advising the Council in the development of a methodology and evidence base for this proposal, to provide modelling and analytical support for the development of carbon budgets. The CBWG held 18 regular meetings and one workshop from March 2023 to September 2024. Overall responsibility for taking the final decision on the CB Proposals and submission to Government remained with the Council.

1.3.2. Terms of reference of the working group

The terms of reference for the CBWG were agreed at the December 2022 Council meeting and are published on the Council's website.[8] The CBWG provided the Council with key findings, recommendations and outputs for consideration in the context of the Council's role in submitting a CB Proposal to Government for CB3 (2031–2035) and provisional CB4 (2036–2040). The scope of the working group also included further consideration of CB2 (2026–2030) in the context of any potential revision of carbon budgets, as provided for under Section 6D of the Act, but it was not revised by the Minister during the lifetime of the working group. The CBWG focused on analysis and modelling support for the CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040), in line with the criteria specified in the Act and the methodology for this programme, as developed by the Secretariat and approved by Council. This included the data, assumptions and modelling scenarios to be considered in the development of economy-wide carbon budgets and the process for iteration between modelling results. Meetings of the CBWG were held approximately once a month.

8 Climate Change Advisory Council (2022). Terms of Reference of Carbon Budgets Working Group. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/documents/governance/Carbon%20Budgets%20Working%20Group%20Terms%20of%20Reference_Final.pdf

1.3.3. Membership of the working group

The membership of the CBWG was decided and appointed by the Council (see **Table 2**) with regard to the range of qualifications, expertise and experience that the Council considered useful for the proper and effective performance of the functions of the group. This included a requirement for sufficient membership with access to and experience of appropriate models and the expertise to provide a sufficient evidence base for the Council's CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040).

Table 2: Members of the CBWG

Role	Name	Institute (area of expertise)
Chair	George Hussey	Climate Change Advisory Council Secretariat Manager
Members	Stephen Treacy/Dr James Murphy	Environmental Protection Agency (national emissions inventories and projections)
	Dr Kevin Hanrahan/Trevor Donnellan	Teagasc (FAPRI-Ireland model)
	Prof. Hannah Daly/Prof. Brian Ó Gallachóir	University College Cork (TIMES-Ireland Model)
	Dr David Styles/Dr Colm Duffy	University of Galway (GOBLIN model)
	Jim Scheer/Emma Lynch	Sustainable Energy Authority of Ireland (National Energy Modelling Framework)
	Dr Kelly C. De Bruin/Dr Mert Yakut	Economic and Social Research Institute (I3E model)
	Dr Niall McInerney	Central Bank (COSMO-based semi-structural model)
	Dr Jeanne Moore/Niamh Garvey	National Economic and Social Council (socioeconomics and Just Transition)
	Dr Kian Mintz-Woo	University College Cork (climate justice)
	Dr Oliver Geden	German Institute for International and Security Affairs (EU and international climate policy)
	Prof. John Fitzgerald	Trinity College Dublin (economics and macroeconomics)
	Prof. Yvonne Buckley	Trinity College Dublin (biodiversity) – resigned in March 2024 due to her appointment to the Council
	Dr James Moran/Dr Eamon Haughey	Atlantic Technological University (biodiversity) – appointed in April 2024 following the resignation of Yvonne Buckley

Council and Secretariat members were invited to attend all CBWG meetings as observers, and meetings were attended by them on an ad hoc basis. The Secretariat chaired the CBWG and had responsibility for supporting the running of meetings and also for liaising between the working group and the Council.

1.3.4. Memorandum of understanding

Modelling capacity for the CBWG was requested by the Council through the MoU between the Council and all relevant Government departments and agencies.[9] Initial letters notifying recipients of capacity required were sent out in March 2023 to the Department of the Environment, Climate and Communications (DECC), Teagasc, the Sustainable Energy Authority of Ireland (SEAI) and the Economic and Social Research Institute (ESRI).

Modelling capacity was requested be made available between Q3 2023 and Q3 2024 to support the modelling of pathways for CB3 (2031–2035) and provisional CB4 (2036–2040). In June 2023, core modelling capacity for the CBWG was requested from DECC under its existing contracts with modelling groups to support the work of the Climate Action Modelling Group. Capacity from University College Cork's (UCC's) TIMES-Ireland Model (TIM) was requested under climate and energy modelling services contracts and capacity from the University of Galway's General Overview for a Back-casting approach of Livestock Intensification and land use (GOBLIN) model under the Agriculture and Land Use, Land Use Change and Forestry (LULUCF) modelling services contract. Core modelling capacity was also requested from Teagasc for its Food and Agricultural Policy Research Institute (FAPRI)-Ireland model. Additional modelling support capacity was requested from ESRI for the Ireland Environment, Energy and Economy (I3E) model, and SEAI for the National Energy Modelling Framework (NEMF). These models and their relevance to the CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040) are outlined in the CBWG methodology.[10] In May 2024, expert review and input from the National Transport Authority (NTA) modelling team was also requested and provided through the MoU.

9 Climate Change Advisory Council (2022). Memorandum of Understanding between the Irish Climate Change Advisory Council and All Relevant Government Departments and Agencies.

10 Carbon Budget Programme 2 Methodology v1.3. [online] https://www.climatecouncil.ie/carbonbudgets/

2. Carbon budgets methodology and work plan

2.1. Methodology and Council guidance for the Carbon Budgets Working Group

The Act (2021) requires the Council to take account of scientific advice when proposing carbon budgets that help to achieve the National Climate Objective and ensure Ireland's compliance with EU legislation and targets.

The Council provided initial guidance to the working group through the agreed terms of reference of the group and the development of the Council's Carbon Budget Programme 2 Methodology,[11] approved at the Council meeting in December 2022. The aim of this methodology, which is further outlined in **Section 3.1.1**, was to inform the work of the CBWG in terms of the preparation of scenarios for 2030 to 2040 that align with climate neutrality in 2050 and to account for the role of negative emissions. Many of the inputs and parameters for development of carbon budgets were determined through the Act and Regulations (S.I. No. 531/2021[12]) and are outlined in the methodology.

The Council's Vision for 2050 working paper[13] also helped frame key considerations for the working group and is detailed further in **Section 3.2.1**. Scenarios based on climate neutrality, understood in the context of their temperature impact, were developed, and assessed against the temperature goals of the Paris Agreement. Analysis of the impact of an emissions trajectory towards climate neutrality in 2050 was also conducted and is outlined in **Section 4**.

For the duration of the CBWG, the Secretariat updated the Council on the progress of the working group at Council meetings. Additional briefings were also provided by the Secretariat to the Council following the modelling workshop and first and second iterations of modelling (see **Section 2**). Further guidance from the Council was conveyed to the CBWG by the Secretariat following these briefings to refine subsequent model iterations.

2.2. Work plan for the Carbon Budget Proposal for CB3 and provisional CB4

The work plan for the CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040) was developed to align with the methodology[14] and updated as required throughout the programme. Inputs, parameters and pathway development for the work plan are outlined in the methodology document. **Figure 2** illustrates the final schedule of the work plan, with **Figure 3** illustrating the schedule of thematic discussion topics, as presented to the CBWG following agreement.

11 CCAC Carbon Budget Programme 2 Methodology v1.3. [online] https://www.climatecouncil.ie/carbonbudgets/

12 Government of Ireland (2021). Climate Action and Low Carbon Development Act 2015 (Greenhouse Gas Emissions) Regulations 2021; S.I. No. 531/2021. [online] https://www.irishstatutebook.ie/eli/2021/si/531/made/en/print?q=531/2021

13 Vision for 2050 Secretariat Paper. [online] https://www.climatecouncil.ie/carbonbudgets/

14 CCAC Carbon Budget Programme 2 Methodology v1.3. [online] https://www.climatecouncil.ie/carbonbudgets/

Item	Description	2023									2024										
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	**Modelling/analysis iteration 1**																					
1.0	Scoping of modelling work																					
1.1	Agree inputs, parameters and assumptions																					
1.2	Core pathways development and modelling																					
1.3	Paris Test assessment																					
1.4	Additional modelling and testing of results																					
1.5	Post hoc analysis																					
2	**Modelling/analysis iteration 2**																					
2.1	Agree inputs, parameters and assumptions																					
2.2	Core pathways development and modelling																					
2.3	Paris Test assessment																					
2.4	Additional modelling and testing of results																					
2.5	Post hoc analysis																					
3	**Modelling/analysis iteration 3**																					
3.1	Agree inputs, parameters and assumptions																					
3.2	Core pathways development and modelling																					
3.3	Paris Test assessment																					
3.4	Additional modelling and testing of results																					
3.5	Post hoc analysis																					
D	**CBWG key deliverables**																					
D.1	Modelling/analysis iteration 1 results																					
D.2	Modelling/analysis iteration 2 results																					
D.3	Modelling/analysis iteration 3 results																					
D.4	CBWG outputs report																					
C	**CCAC deliverables**																					
C.1	CB Proposals																					

Figure 2: Schedule of the carbon budgets work plan from April 2023 to December 2024. The three iterations of modelling and analysis are outlined, with the first model run commencing October 2023 and the final model run completed in September 2024. Key deliverables from CBWG inputting to separate Council CB Proposals by end Q4 2024 are also included.

Item	Description	2023								2024								
		Apr	May	Jun	Jul	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
T	**Thematic discussions**																	
T.1	Socioeconomic considerations																	
T.2	Vision for 2050																	
T.3	Macroeconomics																	
T.4	Climate justice/ethics																	
T.5	Methane																	
T.6	Population projections																	
T.7	Just Transition																	
T.8	GHG projections																	
T.9	Negative emissions																	
T.10	Biodiversity																	
T.11	Agriculture and land use																	
T.12	COP28 – global stocktake																	
T.13	Energy and power systems																	
T.14	Aviation and maritime emissions																	
T.15	Economic assessment																	
T.16	EU 2040 climate target																	
T.17	International approaches to carbon budgeting																	

Figure 3: Final schedule of thematic discussion topics from March 2023 to September 2024.

3. Working group inputs: guidance, briefings, reports and submissions

Documents were considered by the CBWG to assist the Council in its CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040). Guidance was provided by the Council to the CBWG, with briefings provided by the Secretariat and members of the working group on specific themes considered of relevance. Reports were delivered from organisations external to the CBWG that had been invited to present relevant material to the CBWG during the programme. Submissions included all other material from either internal or external sources that was shared with the CBWG.

3.1. Council guidance

Council guidance consisted of documents approved by Council and provided to the CBWG. They include the methodology for the CB Proposal, the Vision for 2050 and specific guidance provided to the modelling teams during the modelling process.

3.1.1. Methodology for the Carbon Budget Proposal for CB3 and provisional CB4

The methodology[15] for the CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040) was discussed and approved by Council at its meeting in December 2022.[16] As set out in the terms of reference for the CBWG,[17] the Council specified 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 methodology was submitted to the CBWG in its first meeting in March 2023 (see **Appendix 1, Meeting 1**) and discussed at early meetings. It was amended based on CBWG feedback and submitted to the working group in June 2023 (see **Appendix 1, Meeting 4**).

Many of the inputs and parameters for the development of carbon budgets were determined through the Act and (Greenhouse Gas Emissions) Regulations (S.I. No. 531/2021). The aim of the methodology report was to inform the work of the CBWG in terms of the preparation of several scenarios for 2030–2040 that align with climate neutrality in 2050, accounting for the role of negative emissions. The Council's Vision for 2050 working paper[18] also helped frame key considerations for the development of a CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040).

15 CCAC Carbon Budget Programme 2 Methodology v1.3. [online] https://www.climatecouncil.ie/carbonbudgets/

16 Climate Change Advisory Council (2022). Climate Change Advisory Council Meeting – Minutes 15.12.2022. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/documents/governance/Signed%20Minutes%2015.12.2022.pdf

17 Climate Change Advisory Council (2022). Terms of Reference of Carbon Budgets Working Group. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/documents/governance/Carbon%20Budgets%20Working%20Group%20Terms%20of%20Reference_Final.pdf

18 Vision for 2050 Secretariat Paper. [online] https://www.climatecouncil.ie/carbonbudgets/

The base year for emissions to be considered under the Act is the 'total amount of annual GHG emissions reported for the year ending on 31 December 2018'.[19] 'A carbon budget, consistent with furthering the achievement of the National Climate Objective, shall be proposed by the Advisory Council…', with the National Climate Objective as defined in the Act as a 'climate resilient, biodiversity rich, environmentally sustainable and climate neutral economy'. The CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040) accounted for a trajectory towards a climate-neutral economy by 2050.

The modelling of carbon budget scenarios was calibrated to and informed by data from the Environmental Protection Agency (EPA) inventory and projections, and the Act requires the use of the 'latest Inventories, Projections and Best Practice Reporting of Emissions and Removals'. The national inventory undergoes continual updates and revisions to take account of improved scientific understanding and improved activity data. Refinements and revisions to the inventory are ongoing and reduce the uncertainty associated with the inventory. The CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040) accounted for refinements and revisions to the inventory. In addition, ongoing monitoring of compliance with the first carbon budget and sectoral emissions ceilings was an important consideration in developing CB3, as this will be relevant to how any under- or overperformance is accounted for in subsequent budgets.

The Act requires the Council to take account of 'relevant scientific advice, including with regard to the distinct characteristics of biogenic methane' when proposing carbon budgets. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) updated understanding of the global carbon budget and the need for net zero emissions of long-lived gases (e.g. CO_2 and nitrous oxide) and for a strong, rapid and sustained reduction in methane emissions. However, the approach specified in the Act and Regulations does not require separate budgets for methane or other GHGs.

Ireland's compliance with developing EU legislation and targets was also monitored as part of this CB Proposal. The European Climate Law (Regulation (EU) 2021/1119) sets out a binding objective of climate neutrality in the EU by 2050 in pursuit of the long-term temperature goal set out in the Paris Agreement to hold 'the increase in the global average temperature to well below 2°C above pre-industrial levels' and pursue efforts 'to limit the temperature increase to 1.5°C above pre-industrial levels'. The European Climate Law also provides for the establishment of the European Scientific Advisory Board on Climate Change (ESABCC), which will provide independent scientific advice and produce reports on EU measures, climate targets and indicative GHG emission budgets and their coherence with the European Climate Law. To meet the objective of achieving climate neutrality by 2050, the European Climate Law requires the EU to adopt an intermediate GHG target for 2040 accompanied by a projected indicative EU GHG emission budget for 2030–2050, which considers the advice of the ESABCC.

The Act states that 'The Advisory Council shall — (a) carry out its functions under this section in a manner – (i) that is consistent with the ultimate objective specified in Article 2 of the United Nations Framework Convention on Climate Change done at New York on 9 May 1992 and the matters specified in subparagraphs (i) and (ii) of section 3(3)(a)'. Given the bottom-up nature of nationally determined contributions as defined in the Paris Agreement, there is no top-down allocation of mitigation effort – instead, each country must determine what it considers its fair share of domestic action and international action to be. The consistency of the carbon budgets with the Paris Agreement was assessed to propose national budgets that were in line with equity principles.

19 Government of Ireland (2021). Climate Action and Low Carbon Development Act 2015 Revised. [online] https://revisedacts.lawreform.ie/eli/2015/act/46/revised/en/html

To limit global warming to a given temperature level, the total amount of GHGs that can be emitted to the atmosphere is also limited, leading to a global carbon budget while staying within a certain global temperature target. An assessment of the remaining global carbon budget is an important input to the initial context for setting and monitoring carbon budgets in Ireland and for the broad assessment of consistency with the Paris Agreement. The IPCC's AR6 Working Group I report updates the remaining global carbon budget estimates from its Fifth Assessment Report, noting that several factors such as estimates of historical warming, future emissions from thawing permafrost, variations in projected non-CO_2 warming and the global surface temperature change after the cessation of CO_2 emissions affect the exact value of carbon budgets. The Indicators of Global Climate Change project has provided updated knowledge on some of these variables since the publication of AR6, indicating average observed warming of 1.19°C for the decade 2014–2023, and a remaining global carbon budget for 1.5°C of 200 Gt CO_2 e from 2024.[20]

The ESABCC provided scientific advice for the determination of an EU-wide 2040 climate target and a GHG emissions budget for 2030–2050.[21] The ESABCC recommended keeping the EU's GHG emissions budget (i.e. cumulative emissions) for 2030–2050 within a limit of 11–14 Gt CO_2 e, with emission reductions of 90–95% by 2040 required to keep within that budget.[22]

Several countries have set carbon budgets related to the cumulative amount of emissions from specified GHGs that can be permitted over a certain period to keep within a certain temperature range. These include the UK, France and New Zealand, and the CCAC has carried out work to understand the different approaches to carbon budgets and governance in other jurisdictions and the modelling approaches used in each case to propose carbon budgets. Emissions from international aviation and maritime navigation are reported as 'memo items' in the national emissions inventory. This means they are not counted as part of Ireland's national total emissions but are reported by Ireland to the United Nations Framework Convention on Climate Change (UNFCCC) and EU for information purposes. International aviation and maritime emissions are excluded from Ireland's legislated carbon budgets.[23] The CBWG considered these emissions based on a briefing from the Secretariat (see **Section 3.2.7**).

In discussions of the methodology within the CBWG, issues regarding the implications of population projections and biodiversity assessments on carbon budgets were raised. In September 2023, presentations were given by the Central Statistics Office (CSO), ESRI and the Department of Housing, Local Government and Heritage (DHLGH) on methodologies and applications of population projections (see **Appendix 1, Meeting 6**). It was noted that the publication timings on upcoming population projections were not compatible for inclusion in modelled scenarios in this carbon budget proposal. As a result, recently updated population projections could not be included and can be fully considered only in the next set of EPA projections. The latest projections are for 5.7 million people in

20 Forster, P. et al. (2024) Indicators of global climate change 2023: annual update of key indicators of the state of the climate system and human influence. *Earth System Science Data*, 16, 2625–2658. [online] https://doi.org/10.5194/essd-16-2625-2024

21 European Scientific Advisory Board on Climate Change (2023). Scientific Advice for the Determination of an EU-wide 2040 Climate Target and a Greenhouse Gas Budget for 2030–2050. [online] https://climate-advisory-board.europa.eu/reports-and-publications/scientific-advice-for-the-determination-of-an-eu-wide-2040

22 European Scientific Advisory Board on Climate Change (2023).

23 Government of Ireland (2021). Climate Action and Low Carbon Development Act 2015 (Greenhouse Gas Emissions) Regulations 2021; S.I. No. 531/2021.

2030,[24] while the EPA currently has only 5.2 million in its projections. The CSO had already recorded 5.4 million in April 2024.[25]

Regarding biodiversity, the importance of achieving a 'biodiversity-rich' society within the National Climate Objective was noted by Yvonne Buckley in a presentation to the CBWG in November 2023 (see **Appendix 1, Meeting 8**). The interconnected issues of climate change and biodiversity loss were noted. The complexity of biodiversity assessments in carbon budgets was outlined, along with the acute limitations in Ireland regarding existing research capacity and understanding of the impacts of biodiversity considerations and mitigation options for carbon budget scenarios, including understanding of conflicts over land use and the vision for post 2050. The lack of an appropriate assessment framework was noted as potentially limiting advice regarding the role of biodiversity and the consequences of biodiversity loss across carbon budget scenarios.

3.1.2. Modelling guidance

The Secretariat conveyed the first iteration of carbon budget modelling and temperature analysis to the Council in January and February 2024. Similarly, the second iteration of modelling and temperature analysis was conveyed in July 2024. Following the delivery of results from the first and second iterations of core modelling, the Council provided further guidance to the modelling teams to refine the modelling process. This guidance was delivered to the modelling teams in February and July 2024 (see **Appendix 1, Meeting 11** and **Meeting 16**).

Following the first iteration of modelling, the guidance points from the Council to the core modelling groups included the need to widen the scope of modelling for the second iteration, consideration of the European Commission's 2040 proposal for emissions reductions and the options to address the emissions gap for waste and fluorinated gases. There was also a request for modelling teams to provide a short descriptive narrative to accompany the scenarios for the second iteration of modelling. Specific modelling requests were provided to individual modelling teams: TIM was requested to explore additional carbon budgets; FAPRI-Ireland was to extend to 2050 and additional levels of emissions reductions in agriculture were to be modelled; and GOBLIN was to incorporate new 2024 inventory emissions data and to explore additional levels of emissions reductions in agriculture.

Following the second iteration, the modelling teams were requested to incorporate recent inventory refinements and informed that CB3 (2031–2035) and provisional CB4 (2036–2040) should assume compliance with CB1 (2021–2025) and CB2 (2026–2030). All three core modelling teams were requested to carry out a sensitivity analysis accounting for carbon budget exceedance in line with the latest EPA projections to provide further details on the implications of not meeting CB1 (2021–2025) and CB2 (2026–2030). Co-ordination of assumptions or a commentary on the overlap of assumptions where applicable was requested. In addition, more detail regarding the rewetting and peatland assumptions under the GOBLIN scenarios and the implications for imported biomass and international biodiversity under the TIM scenarios were requested. For temperature analysis, further clarification on the warming impact analysis and implications for climate neutrality was requested.

24 Central Statistics Office (2024). Population and Labour Force Projections 2023–2057. [online] https://www.cso.ie/en/releasesandpublications/ep/p-plfp/populationandlabourforceprojections2023-2057/

25 Central Statistics Office (2024). Population and Migration Estimates, April 2024. [online] https://www.cso.ie/en/releasesandpublications/ep/p-pme/populationandmigrationestimatesapril2024/keyfindings/

3.2. Briefing notes

Briefings were provided to the CBWG to inform the process. These were provided by the Secretariat and members of the working group.

3.2.1. Vision for 2050

The Vision for 2050 was discussed and approved by the Council at its April 2023 meeting.[26] The Secretariat presented a discussion paper to provide background information and analysis for a Council discussion on the long-term climate objective under the Act, prior to a discussion with the CBWG. At that meeting, the Council noted that the draft Long-term Strategy on Greenhouse Gas Emissions Reduction had been submitted to the European Commission. The Council subsequently wrote to the Government to provide advice on further development of the draft strategy in June 2023,[27] noting its importance as a strategic statement for guiding policy and investment decisions and highlighting that it is vital that the Long-term Strategy sets out the urgency of accelerated action across all sectors of Ireland's economy and society. The Long-term Strategy on Greenhouse Gas Emissions Reduction 2024[28] was subsequently published in August 2024.

Prior to publication of the Long-term Strategy by the Government, the Vision for 2050 working paper was submitted to the CBWG in May 2023 and discussed by the group (see **Appendix 1, Meeting 3**). The briefing note assessed the current literature and evidence base, looking at what climate neutrality might mean for Ireland in 2050, including the definition of climate neutrality. It reviewed the availability of pathways from an integrated cross-sectoral perspective along with sector-specific scenarios, where available, at Irish, EU and IPCC levels. It also provided context for a broader discussion on what 2050 might look like for Ireland and the technological, societal and economic changes that could be observed at that point, along with potential impacts by 2050 from climate change under several temperature scenarios. 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.

The latest physical science assessment by the IPCC highlights that limiting global warming to a specific level requires global cumulative CO_2 emissions to be kept within a global CO_2 emissions budget (or a 'global carbon budget') together with deep reductions in other GHG emissions.[29] This will

26 Climate Change Advisory Council (2023). Climate Change Advisory Council Meeting – Minutes 27.04.2023. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/documents/governance/Signed%20Minutes%2027.04.2023.pdf

27 Climate Change Advisory Council (2023). Letter to Minister Ryan of 19 June 2023. [online] https://www.climatecouncil.ie/councilpublications/councilcorrespondenceandadvice/Response%20to%20Minister%20Ryan%20on%20LTS%2019.06.2023.pdf

28 Government of Ireland (2024). Ireland's Long-Term Strategy on Greenhouse Gas Emissions Reduction. [online] https://www.gov.ie/en/publication/e4e81-long-term-strategy-on-greenhouse-gas-emissions-reductions/

29 Pörtner, H.-O. et al. (2022). Technical summary, in Climate Change 2022: Impacts, Adaptation and Vulnerability. Intergovernmental Panel on Climate Change, pp. 37–118. [online] https://doi.org/10.1017/9781009325844.002

require rapid, deep and, in most cases, immediate GHG emissions reductions in all sectors.[30] There are a variety of pathways that might be taken to achieve a climate-neutral economy in Ireland, which will require distinct policy choices and understanding of their implications.

The Long-term Strategy on Greenhouse Gas Emissions Reduction for Ireland notes that reaching climate neutrality will mean that Ireland will have no further negative impacts on the climate system by mid-century. 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 Carbon Budget Technical Report,[31] the stabilisation of GHG concentrations in the atmosphere and the establishment of a climate-neutral economy requires that emissions of long-lived GHGs such as CO_2 and nitrous oxide must reduce to net zero, and strong, rapid and sustained reductions in methane emissions are required by 2050.

In February 2024, the European Commission presented its assessment for a 2040 climate target for the EU, recommending reducing the EU's net GHG emissions by 90% by 2040 relative to 1990.[32] The EU aims to be climate neutral by 2050 – an economy with net zero GHG emissions – a legally binding target under the European Climate Law.[33]

Therefore, for the CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040), scenarios based on climate neutrality, understood in the context of their temperature impact, should be developed and assessed against the temperature goals of the Paris Agreement. Analysis of the impact of an emissions trajectory towards net zero GHG emissions in 2050 should also be carried out. Potential start points and end targets for modelling scenarios for CB3 and provisional CB4 are outlined in **Table 3**. Scenarios used to determine the starting point in 2030 for the development of CB3 and provisional CB4 should assume achievement of the first and second carbon budgets as a primary assumption, with alternative scenarios developed based on other assumptions.

30 Intergovernmental Panel on Climate Change (2023). Summary for Policymakers, in Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. [online] https://www.ipcc.ch/report/ar6/syr/summary-for-policymakers/

31 Climate Change Advisory Council (2021). Carbon Budget Technical Report. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/Technical%20report%20on%20carbon%20budgets%2025.10.2021.pdf

32 European Commission (2024). 2040 climate target. [online] https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2040-climate-target_en

33 European Commission (2021). European Climate Law. [online] https://climate.ec.europa.eu/eu-action/european-climate-law_en

Table 3: Proposed building blocks for CB3 and provisional CB4. Source: Vision for 2050 working paper

Consideration	Outcome 1	Outcome 2	Outcome 3
Start point in 2030	Staying within CB1 and CB2	Overperformance against CB1 and CB2	Underperformance against CB1 and CB2
Target for 2050	Based on an emissions trajectory consistent with specific temperature outcomes	Based on an emissions trajectory towards net zero GHG emissions in 2050	–

3.2.2. Secretariat note on the Long-term Strategy on Greenhouse Gas Emissions Reduction

A short briefing note on Ireland's Long-term Strategy on Greenhouse Gas Emissions Reduction,[34] compiled by the Secretariat, was submitted to the CBWG in May 2023. Relevant EU regulations and Ireland's Long-term Strategy on Greenhouse Gas Emissions Reduction[35] were outlined, along with relevance for the Council's Vision for 2050 working paper.

3.2.3. Secretariat note on methane

A briefing note on methane[36] compiled by the Secretariat was submitted to the CBWG in July 2023. This outlined the requirement in the Act for Council to consider 'relevant scientific advice, including with regard to the distinct characteristics of biogenic methane' in its deliberations on carbon budgets.

An overview on the physical characteristics of methane as a GHG was provided, along with the generation of biogenic methane. Ireland's historical annual emissions were presented along with differences between emissions patterns in Ireland and globally. The limitations of using the GWP_{100} metric in respect of short-lived climate forcers such as methane were noted, along with the mandating of this metric for EU and UN processes. A brief overview of selected international approaches to methane accounting was presented along with scientific advice in relation to biogenic methane, including outputs of global integrated assessment models.

3.2.4. Secretariat note on agriculture and land use

A briefing note on agriculture and land use[37] compiled by the Secretariat was submitted to the CBWG in November 2023.

34 CCAC Secretariat Note on Long-Term Strategy on Greenhouse Gas Emissions Reduction: Meeting 3. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

35 Government of Ireland (2024). Ireland's Long-Term Strategy on Greenhouse Gas Emissions Reduction. [online] https://assets.gov.ie/297131/ad1847e4-b9d7-4643-a01b-04ce9586e121.pdf

36 CCAC Secretariat Note on Methane: Meeting 4. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

37 CCAC Secretariat Note on Agriculture and Land Use: Meeting 8. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

The UNFCCC explicitly acknowledges the risk of adverse impacts on food production in the context of climate change itself and the potential risk of mitigation actions themselves to reduce production capacity.

This paper considered the status and trends within agriculture in Ireland with a summary of key statistics describing the agriculture sector including social, environmental and economic indicators and analyses. Insight was provided into the priority mitigation options identified in the Teagasc marginal abatement cost curve (MACC) with background to the topical issue of changes to the Nitrate Action Programme. The status of national systems to support the reporting of emissions and removals associated with LULUCF was presented with insights from the Land Use Review Phase 1. Key features of EU regulations and accounting rules governing LULUCF in the period to 2030 and the outlook for further development in EU policy on LULUCF considering proposals under the European Green Deal were also considered. However, this paper did not consider other EU legislative initiatives, such as the Nature Restoration Law (Regulation (EU) 2024/1991), which would be likely to further refine national land use policies.

3.2.5. Note on Irish carbon budgets: some moral considerations

A report written by working group member Kian Mintz-Woo from UCC on the moral considerations of Irish carbon budgets was circulated to the working group and presented for discussion at the CBWG meeting in December 2023.

The report discusses several assumptions built into the CCAC's temperature assessment from a moral philosophical point of view to understand how Irish carbon budgets are viewed from this standpoint. The report introduces a philosophical methodology, after which it considers climate temperature targets, reference years and equity principles of two types: those based in distributional justice and those based on climate ethics burden-sharing framings. The report finds that the assumptions adopted from the Paris Test, while broadly being defensible and consistent with positions defended in the philosophical literature, are conservative in the sense of being favourable to Ireland. It concludes that carbon budgets generated from these assumptions can be defensible, but should be thought of as upper bounds, and that inclusion of more equity and justice considerations would be likely to revise them downwards.

3.2.6. NESC Secretariat note on Just Transition

At the September 2023 CBWG meeting, Jeanne Moore and Niamh Garvey presented insights from the recent National Economic and Social Council (NESC) report on Just Transition in agriculture and land use[38] to the CBWG. The presentation and the discussion that followed focused on the recommendations for agriculture and land use at that time. In April 2024, Jeanne Moore and Niamh Garvey prepared a note that was circulated to the CBWG. The note was aimed as a prompt for a second discussion by the CBWG on Just Transition and the carbon budget process. At the April CBWG meeting Jeanne Moore and Niamh Garvey provided a presentation on the note for discussion by the CBWG.

The note focused on what bringing a Just Transition lens to the carbon budget process might be in practice. It highlighted several areas arising from NESC's previous work of note for discussion. The

38 National Economic and Social Council (2023). Just Transition in Agriculture and Land Use. [online] https://www.nesc.ie/publications/exploring-a-just-transition-in-agriculture-and-land-use/

note referenced NESC's work on Just Transition, which has informed policy developments in this area. It highlighted the critical role of a Just Transition approach as part of a low-carbon transition – one that is fair, equitable and inclusive both in process and in outcomes.[39]

The opening sections of the note set the context and NESC's approach. This assisted the discussion and helped prepare the key questions for the working group. The note included the concept of Just Transition as still evolving and broadening in scope in how it is discussed and applied and not without contestation. Some brief reflections on this context were outlined. A principles-based approach for considering a Just Transition was outlined for the carbon budget process, and how these principles are used in Ireland. The final section set out key questions to prompt discussion by the working group.

3.2.7. Secretariat note on aviation and maritime emissions

A briefing note on aviation and maritime emissions[40] compiled by the Secretariat was submitted to the CBWG in June 2024.

The note provided an overview of aviation and maritime emissions for Ireland and presented drivers of demand and overall international trends for discussion within the CBWG. It also provided an overview of relevant international, EU and national legislation covering both sectors and current policies and measures to address these emissions.

3.3. Reports

3.3.1. Carbon Budget Technical Report

The *Carbon Budget Technical Report*[41] from the CCAC was submitted to the CBWG in March 2023. This report describes the deliberations, reasoning and evidence behind the Council's carbon budget proposals for the first carbon budget programme. Under the legislation, the proposed carbon budgets must provide for a reduction of 51% in the total amount of those GHG emissions specified by the regulations by 2030, relative to 2018.

The 51% target applies to GHG emissions attributable to industrial, agricultural, energy, land use and other anthropogenic activities in the State. This target does not include emissions from international aviation or shipping. The 51% target is the primary constraint on carbon budgets over the course of the first two budget periods ending on 31 December 2030, relative to 2018. The provisional CB3 (2031–2035) proposed continues the trajectory towards climate neutrality by 2050.

The proposed carbon budgets were built on the latest science, including from the IPCC AR6 Working Group I, and were calculated using data from the latest EPA inventories and projections and are consistent with best practice on international reporting.

39 National Economic and Social Council (2020). Addressing Employment Vulnerability as Part of a Just Transition in Ireland. [online] https://www.nesc.ie/publications/addressing-employment-vulnerability-as-part-of-a-just-transition-in-ireland-2/

40 CCAC Secretariat Note on Aviation and Maritime: Meeting 15. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

41 Climate Change Advisory Council (2021). Carbon Budget Technical Report. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/Technical%20report%20on%20carbon%20budgets%2025.10.2021.pdf

To calculate the first two carbon budgets, the 51% target was used to calculate the required level for total emissions in 2030. Modelling by UCC, Teagasc and the University of Limerick informed the calculation by the Council of the carbon budgets. The amount of emissions was aggregated for each scenario to give an economy-wide total for the scenario in each budget period. The total emissions from each economy-wide scenario[42] reaching the 51% emissions reduction target by 2030 were then averaged to give the final carbon budget amounts.

The Council proposed the carbon budgets of 295 and 200 Mt CO_2 eq for CB1 (2021–2025) and CB2 (2026–2030) respectively, and 151 Mt CO_2 eq for the provisional CB3 (2031–2035).

3.3.2. Carbon budgeting in selected countries

A report commissioned by the CCAC reviews carbon budgeting and target-setting approaches in other jurisdictions.[43] It was presented to the CBWG by its author, Sadhbh O'Neil, on 19 October 2023 (see **Appendix 1, Meeting 7**). The report reviews and describes the different methodological approaches employed in Ireland, the UK, New Zealand, the Netherlands, France, Finland, Denmark and the EU. Aspects including baseline years, carbon budgets versus net zero target setting, the treatment of non-CO_2 gases, LULUCF, and aviation and maritime emissions, and understandings of fair shares and climate justice are included.

The report shows that, across the jurisdictions studied, factors of legislation differ, including baseline years, climate targets and application of carbon budgets versus target setting. It also outlines factors to be considered for carbon budgets, including methodological choices, non-CO_2 gases, equity considerations, impacts on policy and temperature analysis. In Ireland the baseline year for the second carbon budget programme under the Act is the 'total amount of annual GHG emissions reported for 2018'.[44] In one of the jurisdictions considered, the Danish 2020 Climate Act sets a target to reduce Denmark's emissions by 70% in 2030 compared with 1990 and reach climate neutrality by 2050 at the latest (see **Table 4**). The Danish Act sets a rolling 5-year target 10 years in advance.[45] Like the Danish approach, the Dutch Act does not commit to a carbon budgeting process; rather, it sets a target of a 49% emissions reduction by 2030 and a 95% reduction by 2050 against a 1990 baseline.[46] The UK Climate Act sets an emissions reduction target of 100% (updated in 2019 from previously 80%) by the year 2050 compared with a base year of 1990.[47] Similarly to Ireland, the UK Act requires the Government to implement 5-year emissions budgets or 'carbon budgets' (which cover all six main GHGs).

42 Two modelled scenarios (late action and early action) were omitted from this calculation due to feasibility concerns.

43 O'Neill, S. (2023). Working Paper No. 25 Carbon Budgeting in Selected Countries. [online] https://www.climatecouncil.ie/councilpublications/councilworkingpaperseries/FINAL%20WP%2025%20Carbon%20Budgeting%20in%20Selected%20Countries.pdf

44 Government of Ireland (2021). Climate Action and Low Carbon Development (Amendment) Act 2021. [online] https://www.irishstatutebook.ie/eli/2021/act/32/enacted/en/print#sec9

45 Danish Ministry of Climate, Energy and Utilities (2020). Climate Act. [online] https://www.en.kefm.dk/Media/1/B/Climate%20Act_Denmark%20-%20WEBTILGÆNGELIG-A.pdf

46 Government of the Netherlands (2022). Klimaatwet. [online] https://wetten.overheid.nl/BWBR0042394/2022-03-02/0

47 Government of the United Kingdom (2019). The Climate Change Act 2008 (2050 Target Amendment) Order 2019. [online] https://www.legislation.gov.uk/ukdsi/2019/9780111187654

Table 4: Comparison of policy on reducing GHG emissions in selected countries: baseline year, carbon budgets versus target setting and net zero targets

Country	Base year	Carbon budgets or target setting	National policy and legislation climate target
UK	1990	5-year budgets, 12 years in advance	2050
Finland	1990	Targets	2035
France	1990	5-year budgets, set 10–12 years in advance	2050
Netherlands	1990	Targets	95% by 2050
New Zealand	2017 for methane 1990	5-year budgets, 12 years in advance	2050 (10% methane by 2030)
Ireland	2018	5-year budgets, 12 years in advance	2050 at the latest
Denmark	1990	Targets	70% by 2030 Net zero by 2050
EU	1990	Targets	Net zero by 2050 90% reduction by 2040

The treatment of non-CO_2 gases is discussed in the context of different global warming potential (GWP) measures[48] including GWP_{100} and GWP*.[49] The GWP_{100} measure is the internationally accepted standard for converting all gases to one standardised measure and is most used by countries for their emissions accounting, as agreed at international level. In Ireland, S.I. 531/2021, Climate Action and Low Carbon Development Act 2015 (Greenhouse Gas Emissions) Regulations 2021, was adopted on 12 October 2021. This requires that, for carbon budgets, relevant GHG emissions are to be considered on the basis of GWP_{100}. Similarly to Ireland, the UK's climate change legislation states that all sectors and GHG emissions should be included in one target employing the GWP_{100} measure.[50] In contrast, New Zealand's Climate Act sets separate targets for CO_2 and biogenic methane.[51]

The treatment of LULUCF gases is a key consideration for carbon budget and target-setting methodological approaches. Other jurisdictions consider the LULUCF sector as either a future sink or

48 Global warming potential (GWP) is a term used to describe the relative potency, molecule for molecule, of a greenhouse gas, taking account of how long it remains active in the atmosphere. The GWPs currently used are those calculated over 100 years. Carbon dioxide is taken as the gas of reference and given a 100-year GWP of 1. (Glossary: Global-warming potential (GWP) – Eurostat Statistics Explained).

49 GWP* is a method that relates emission rate changes of short-lived gases such as methane to emissions of CO_2. It can approximate the temperature implications of emission time series.

50 Fankhauser, S. et al. (2018) 10 years of the UK Climate Change Act. Grantham Research Institute on Climate Change and the Environment. [online] https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2018/03/10-Years-of-the-UK-Climate-Change-Act_Fankhauser-et-al.pdf

51 Taylor, P. (2023). New Zealand's net zero carbon legislation: obfuscation and missed opportunities to move beyond the dominance of national self-Interest, in The Routledge Handbook of Applied Climate Change Ethics (Brown, D. et al., eds), pp. 331–342.

a source and include it in carbon budgets. In Ireland the Act requires Ireland to include LULUCF when calculating its national carbon budget. In contrast, the treatment of aviation and shipping emissions is largely not considered when developing carbon budgets or target setting across other jurisdictions. While the UNFCCC accounting rules do not require the inclusion of international bunker fuels in a country's territorial emissions inventory, they are an important area for policy frameworks to consider. Denmark is highlighted as a good example, in that it is actively engaged with mitigation planning for the reduction in national aviation and shipping emissions.[52,53] In the UK, emissions from aviation and shipping sectors are not included in the first five carbon budgets,[54] but they will be included in the sixth carbon budget (2033–2037).[55] In Ireland, carbon budgets do not consider aviation and maritime emissions as these are excluded by the regulation (S.I. No. 531/2021).[56]

Ireland's Act sets out 'the requirement for a just transition to a climate neutral economy which endeavours, in so far as is practicable, to — (i) maximise employment opportunities, and (ii) support persons and communities that may be negatively affected by the transition'.[57] Hence, the Government must consider Just Transition when drawing up climate policies and plans. However, the report states that it is not a requirement under the Act to consider Just Transition when producing carbon budgets. Just Transition considerations are not included within climate laws across most other jurisdictions, with these considerations featuring more often in practice within the climate policy frameworks and political dialogues.

Overall, the report notes that Ireland's climate law and carbon budgeting framework rank highly among countries with robust climate laws that include science-based targets, accountability mechanisms in the policy cycle and opportunities for public participation. It makes note of lessons that can be learned from other jurisdictions.

3.3.3. SEAI Decarbonised Electricity System Study report

SEAI presented the results of its Decarbonised Electricity System Study to the CBWG in April and June 2024 (see **Appendix 1, Meeting 13** and **Meeting 15**). A draft report[58] was submitted to the working group, along with additional notes.

52 Government of Denmark (2019). The Climate Partnership for Aviation. [online] https://climatepartnerships2030.com/the-climate-partnerships/aviation/

53 Government of Denmark (2019). The Climate Partnership for Blue Denmark. [online] https://climatepartnerships2030.com/the-climate-partnerships/blue-denmark/

54 Climate Change Committee (2008). Building a Low-Carbon Economy – the UK's Contribution to tackling Climate Change. [online] https://www.theccc.org.uk/publication/building-a-low-carbon-economy-the-uks-contribution-to-tackling-climate-change-2/

55 Department for Business, Energy and Industrial Strategy (2021). UK enshrines new target in law to slash emissions by 78% by 2035, 20 April 2021. [online] https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035

56 Government of Ireland (2021). Climate Action and Low Carbon Development Act 2015 (Greenhouse Gas Emissions) Regulations 2021; S.I. No. 531/2021.

57 Government of Ireland (2021). Climate Action and Low Carbon Development (Amendment) Act 2021.

58 SEAI presented provisional results of this expert elicitation to the CBWG in April and June 2024. A final Decarbonised Electricity System Study report documenting the methodology and results of the surveys will be published by SEAI in late 2024.

3.3.3.1. Report on forecasts of plausible rates of generation technology deployment 2024–2040

SEAI undertook an expert elicitation to validate critical assumptions of model solutions for the carbon budget process. A working group with representation from EirGrid, ESB Networks, DECC, the Commission for Regulation of Utilities and SEAI guided the process.

SEAI identified onshore wind, offshore wind, solar photovoltaic power, thermal plant combusting hydrogen and carbon capture and storage (CCS) as the technologies that primarily support the mitigating effort in the power sector up to 2040. The study was designed to establish a plausible interval for cumulative installed capacity for each generation of technology up to 2040 by pooling expert opinion. Thirty experts participated in the study, drawn from State agencies, industry, electricity and gas system operators, and universities across Ireland and the UK. Participants provided forecasts, which were pooled.

The draft report[59] found significant uncertainties in the deployment of mature and new generation technologies in Ireland. The experts were not optimistic regarding the achievement of 2030 targets for renewable generation capacity. The expert pooled opinion deemed any deployment of bioenergy with carbon capture and storage (BECCS) or gas CCS before 2040 very unlikely.

The draft report found that the gap between plausible technology deployment rates and carbon budget requirements may be large. A comparison between deployment rates required for carbon budget solutions and the result of the expert elicitation on deployment rates was recommended.

3.3.3.2. SEAI note on value of expert elicitations

A note was developed by the SEAI and submitted to the CBWG in June 2024.[60] It explained that an expert elicitation is an exercise in forecasting. It is a method for establishing the likelihood of certain outcomes by asking experts for a range of estimates. In the case of long-term climate mitigation scenarios for the power sector, expert elicitations can forecast the likelihood that power generation technologies will be deployed (how much and by when). The methodology of the expert elicitation for the Decarbonised Electricity System Study report was outlined.

The expert elicitation results informed additional scenarios produced with the SEAI NEMF to supplement those produced for the EPA's 2023–2050 GHG emissions projections. The difference between the SEAI forecasts for current carbon budget solutions and the first iteration of modelling were highlighted.

59 SEAI presented provisional results of this expert elicitation to the CBWG in April and June 2024. A final Decarbonised Electricity System Study report documenting the methodology and results of the surveys will be published by SEAI in late 2024.

60 SEAI (2024). The Value of Using Expert Elicitations to Informing Decarbonisation Pathways and Target Setting: Meeting 15. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

3.3.3.3. SEAI note on renewables deployment rates

This note[61] was prepared by Frontier Economics and SEAI in February 2024 in advance of the expert elicitation on plausible deployment scenarios and rates of renewables. It provided accompanying information on factors that may influence the deployment in Ireland of offshore wind, onshore wind and solar photovoltaic installations.

3.3.3.4. SEAI note on power sector technology deployment rates

This note[62] was prepared by SEAI in April 2024 in advance of the expert elicitation on plausible deployment scenarios for hydrogen and ammonia power generation and generation with CCS. It provided accompanying information on factors that may influence the deployment of these technologies in Ireland.

3.3.4. Assessment of biodiversity considerations in the carbon budgets process

A report commissioned by the CCAC assessed key biodiversity considerations in the carbon budgets process.[63] The report was submitted to the CBWG in July 2024 with a presentation from the authors (see **Appendix 1, Meeting 16**).

The report outlines that climate change and biodiversity loss are interconnected global crises and must be addressed together. Climate change exacerbates biodiversity loss, and the loss of biodiversity weakens ecosystems' resilience to climate change, reducing their ability to provide the ecosystem services essential for the economy, society, and human health and well-being. Ireland's contribution to global environmental crises is significantly influenced by its import and export activities. The country's reliance on imported energy and goods, combined with national patterns of resource consumption, waste production and energy demand, plays a critical role. In addition, agricultural exports, particularly beef and dairy, contribute to GHG emissions and likely deforestation (where supported by imported feed), further exacerbating these challenges.

By law, Ireland is required to achieve climate neutrality and a 'biodiversity-rich' state by 2050 under the National Climate Objective. However, policies to address these two crises are not fully aligned across sectors, and the impacts of climate mitigation measures to reduce carbon emissions on biodiversity are not assessed systematically. The annual carbon budgeting process for Ireland considers biodiversity impacts using an ad hoc process that does not systematically address the spatial context of biodiversity. To achieve the ambitious carbon budget targets, land and sea use will need to change, and this will have implications for the spatial distribution of biodiversity and how ecosystems function to deliver ecosystem services. This working paper addresses the need to

61 SEAI (2024). Briefing Note: SEAI Expert Elicitation on Plausible Deployment Rates of Variable Renewable Generation Technologies in Ireland, 2025–2040: Meeting 15. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

62 SEAI (2024). Briefing Note: SEAI Expert Elicitation on Plausible Rates of Hydrogen, Ammonia and CCS in the Irish Power Sector, 2025–2040: Meeting 15. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

63 Molloy, A. et al. (2024). Working Paper No. 33 Assessment of Biodiversity Considerations in the Carbon Budgets Process. [online] https://www.climatecouncil.ie/councilpublications/councilworkingpaperseries/WP33%20Biodiversity%20for%20web.pdf

consider biodiversity impacts in the carbon budget process and make recommendations on how to incorporate biodiversity into this process.

Two online workshops were held with a working group with expertise in the carbon budgets process and the Land Use, Energy, Biodiversity, Forestry and high nature value Agriculture sectors. A webinar on biodiversity and carbon budgets was held with input from six international experts from Finland and New Zealand. Recommendations from both workshops and the webinar, along with reviews of published literature, were used to complete the final working paper.

The report provided a provisional, expert-informed analysis of trade-offs, synergies and lose–lose scenarios for climate and biodiversity actions in different land use/land cover categories that can be used to assess risks and identify mitigation strategies. The report concluded that, to achieve emission reduction targets while protecting biodiversity, Ireland will need to reach compromises involving demand management and resource use. Key recommendations identified through the study included the following:

- Statutory obligations for biodiversity protection and restoration must be implemented, with co-benefits for the protection of carbon stocks, reduction of GHG emissions and carbon removals through biological sequestration quantified. Policies that deal with land use should be aligned to achieve climate and biodiversity obligations.
- A national land use strategy should be developed that explicitly considers climate actions, biodiversity protection and restoration as land uses, and the land use strategy needs to align with climate and biodiversity obligations. The national land use strategy must be underpinned by regularly updated spatial data sources and include a spatial planning framework.
- Changes in land use practices are needed in the Forestry, Agriculture and Energy sectors to achieve climate and biodiversity benefits through nature-friendly forestry and farming practices and the appropriate siting of renewable energy infrastructures. In addition, systemic change is needed for individuals, businesses, industry and society to reduce energy and resource consumption and to minimise waste.
- Definitions of 'climate neutrality' and 'biodiversity rich' are needed for the development of appropriate land use strategies and to better account for biodiversity and biodiversity change.
- Increased knowledge generation and sharing are needed to resolve key uncertainties, assess the impacts of actions and policies, and continually update climate and biodiversity actions in response to data.
- International impacts of climate and biodiversity action need to be assessed to avoid 'off-shoring' climate and biodiversity impacts. Ireland should not contribute to biodiversity and carbon decline here or elsewhere through resource exports or imports.

Addressing climate change and biodiversity loss requires integrated policies that consider their interconnected impacts. To achieve Ireland's carbon budget targets and climate neutrality, along with a 'biodiversity-rich' state, biodiversity needs to be incorporated into the carbon budget process using a spatial framework, and biodiversity and climate action policies need to be aligned. The recommendations offered a framework to align biodiversity and climate change goals.

3.4. Submissions

The following documents were submitted to the CBWG for consideration during the preparation of the CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040).

- Mintz-Woo, K. (2023). Compensation duties. In: Pellegrino, G., Di Paola, M. (eds) Handbook of Philosophy of Climate Change. Handbooks in Philosophy. Springer, Cham. https://doi.org/10.1007/978-3-030-16960-2_54-1
  - Submitted to the CBWG following a presentation by Kian Mintz-Woo on methane in Irish carbon budgets in July 2023 (see **Appendix 1, Meeting 5**).
  - This chapter discusses several principles discussed on how to divide climate duties – the polluter pays principle, the beneficiary pays principle, the ability to pay principle and, a new one, the polluter pays then receives principle.
- Barret, A. and Curtis, J. (2024). The National Development Plan in 2023: Priorities and Capacity. ESRI Survey and Statistical Report Series Number 12.
  - Submitted to the CBWG following a presentation by John Fitzgerald on preparing for the macroeconomic assessment of the carbon budget process in January 2024 (see **Appendix 1, Meeting 10**).
  - This report looks at the need for public investment and the constraints on investment, as well as cross-cutting issues regarding the National Development Plan.
- Pisani-Ferry, J. and Mahfouz, S. (2023). The Economic Implications of Climate Action: A Report to the French Prime-Minister. *République Français Report*.
  - Submitted to the CBWG following a presentation by John Fitzgerald on preparing for the macroeconomic assessment of carbon budget process in January 2024 (see **Appendix 1, Meeting 10**). This is the English version of the report published in May 2023 under the title *Les incidences économiques de l'action pour le climat*. The report built on an interim report published in November 2022 and entitled *L'action climatique: un enjeu macroéconomique*.
- Guillemette, Y. and Chateau, J. (2023). Long-term Scenarios: Incorporating the Energy Transition. OECD Economic Policy Paper No 33.
  - Submitted to the CBWG following a presentation by John Fitzgerald on preparing for the macroeconomic assessment of the carbon budget process in January 2024 (see **Appendix 1, Meeting 10**).
  - This paper describes the latest update of the Organisation for Economic Co-operation and Development's long-term scenarios, which are done every 2–3 years to quantify some of the most important long-term macroeconomic trends and policy challenges facing the global economy.

- Meinshausen, M. and Nicholls, Z. (2022). GWP* is a model, not a metric. *Environmental Research Letters*, 17, 041002.
  - Submitted to the CBWG by the author following a presentation by the author on determining carbon budgets in February 2024 (see **Appendix 1, Meeting 11**).
  - This paper illustrates that GWP* can exhibit the wrong sign in terms of the climate effects of a single year of emissions, and that aggregate emissions based on GWP* feature variability that could undermine the stability of any legal framework.
- Rogelj, J. and Lamboll, R.D. (2024). Substantial reductions in non-CO_2 greenhouse gas emissions reductions implied by IPCC estimates of the remaining carbon budget. *Communications Earth & Environment*, 5(35).
  - Submitted to the CBWG by the author following a presentation by the author on methane and climate neutrality in March 2024 (see **Appendix 1, Meeting 12**).
  - This paper outlines non-CO_2 emissions assumptions that underlie the latest remaining carbon budget estimates by the IPCC and quantifies the implications of the world pursuing alternative higher or lower emissions scenarios. It argues that pursuing inadequate methane emission reductions causes remaining carbon budgets compatible with the Paris Agreement temperature limits to be exhausted today.
- Jackson, A. and Kelleher, O. (2023). Ireland's second-generation climate act: still playing the laggard during the climate crisis?' *Irish Jurist*, 283, 283–321.
  - Submitted to the Secretariat by the authors and shared with the CBWG in June 2024.
  - This article examines Irish climate lawmaking with reference to Irish climate legislation and its implementation. The article argues that the law and its implementation have lagged seriously behind the required response to the crises faced, measured against the demands of climate science and climate justice.

4. Working group outputs: pathway development and sectoral analysis under a range of carbon budgets

For this CB Proposal, modelling of emission pathways was required for CB3 (2031–2035) and provisional CB4 (2036–2040), based on a start point assuming compliance with CB1 (2021–2025) and CB2 (2026–2030) in 2030 and a pathway to climate neutrality in 2050. Eighteen meetings of the working group were held between March 2023 and September 2024 (see **Appendix 1**), and a workshop was held in September 2023 to refine parameters of modelling for the second programme (see **Section 4.1**).

Three iterations of three core models were completed between September 2023 and August 2024 (see **Section 4.2**). Temperature analysis of the GHG emissions for the scenarios produced from these core models was conducted using simple climate models (see **Section 4.3**). Additional support modelling was completed to test the assumptions and results of these core models (see **Section 4.4**). Members of the CBWG were available to comment on aspects of the carbon budget programme and all modelled scenarios for the CB Proposal (see **Sections 4.5–4.11**). Following completion of the work of the CBWG in September 2024, working group members were each requested to submit final reports summarising their inputs to assist the Council in their deliberations on the next carbon budget proposal. These reports, referenced within this document, are published on the Council's website. Executive summaries written by the members were used to compile **Sections 4.2–4.10**.

4.1. Carbon budgets workshop outcome report

The CBWG convened a workshop for members of the working group and those directly involved in the modelling process on 13 September 2023. The workshop provided an opportunity for the group to discuss the analytical process for the CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040). The objective of this workshop was to develop a shared understanding of model inputs and expected outputs for the first iteration of modelling. The main outcomes from the workshop are summarised in the following paragraphs.[64]

For 2030 start points, it was identified that modelling could commence from positions consistent with achieving CB1 and CB2, or positions underperforming or overperforming against these carbon budgets:

- Staying within CB1 (2021–2025) and CB2 (2026–2030). The achievement of the sectoral emissions ceilings was assumed to be the basis for staying within CB1 and CB2, with two sub-scenarios developed for the treatment of unallocated emissions savings for CB2: (a) assigned to the Energy sector and (b) assigned on a pro rata basis based on emissions.
- Underperformance against CB1 (2021–2025) and CB2 (2026–2030). The 2023 with existing measures (WEM) scenario was proposed as a possible 2030 starting point. Modelling teams were requested to use both, if possible, and there was an openness to using either scenario as long as it was made explicit in the results.

64 CBWG (2024). Carbon Budgets Working Group Workshop Outcome Report: Meeting 7. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

- Overperformance against CB1 (2021–2025) and CB2 (2026–2030). It was agreed not to pursue the 5% overperformance scenario analysis at this time for the first iteration of modelling, with the potential to revisit it in subsequent modelling iterations.

For 2050 targets, the primary aim of the initial modelling for the first iteration was to provide a baseline for subsequent analysis and modelling iterations. The initial scenarios were to be compiled and assessed against targets for specific temperature outcomes, climate neutrality and net zero emissions in 2050 for subsequent modelling iterations once results were available.

For scenario development, the refinement of parameters for subsequent modelling iterations was to be revisited when initial results were available following the first iteration of results. It was agreed that scenario results from the TIM, NEMF, FAPRI-Ireland and GOBLIN models would be made available for the December CBWG meeting, and it was proposed that temperature assessment would be conducted following receipt of the initial modelling results and presented when available.

Competing land use requirement points raised in discussion were to be revisited at subsequent meetings following the availability of initial modelling results.

4.2. Pathway development and modelling

Pathways were developed in line with the second carbon budget programme methodology and agreed carbon budgets work plan, and with consideration for the Council's Vision for 2050 working paper. Formal requests for modelling capacity were made to relevant organisations under the MoU between the CCAC and all relevant Government departments and agencies,[65] with capacity requested between Q3 2023 and Q3 2024 to support modelling of pathways for CB3 (2031–2035) and provisional CB4 (2036–2040).

Scoping of modelling work was conducted within the working group. A workshop was held prior to the establishment of the working group,[66] and again with the working group in September 2023, to develop the analytical process for the CB Proposal and a shared understanding of model inputs and expected outputs for the first iteration of modelling.[67] The initial modelling considered a start point in 2030 on a pathway to climate neutrality in 2050. All scenarios are assumed to meet the steep GHG reductions in the period to 2030, as mandated under the sectoral emissions ceilings. Following this, the Council provided guidance to the working group to expand the range of scenarios modelled for the second and third iterations.

The services of three core modelling groups from UCC (TIM), Teagasc (FAPRI-Ireland) and the University of Galway (GOBLIN) were applied to assist with developing an evidence base for the CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040). This included the provision of

65 Climate Change Advisory Council (2022). Memorandum of Understanding between the Irish Climate Change Advisory Council and All Relevant Government Departments and Agencies. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

66 Climate Change Advisory Council (2022). Carbon Budgets Modelling Workshop Report. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

67 CBWG (2024). Carbon Budgets Working Group Workshop Outcome Report: Meeting 7. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

modelling and analytical support. Additional modelling support was requested from SEAI, ESRI, the Central Bank of Ireland and NTA.

While the models do not explicitly model important implications of climate action, including the Just Transition, biodiversity impacts, climate justice and consequences for investment, the macroeconomy, energy bills and energy security modelled scenarios can provide a quantitative basis for developing analyses on these aspects of climate action. Three iterations of modelling were completed, with engagement with other modelling teams for this CB Proposal and CBWG members, and feedback and guidance from the Council between the iterations.

The Secretariat presented ongoing updates on the progress of the CBWG to the Council at each Council meeting. An update report[68] was provided to the Council in December 2023, with the results of the first iteration of modelling presented by the Secretariat to the Council in January 2024, and temperature analysis presented in February 2024. Modelling results and temperature analysis from the second iteration of modelling were presented by the Secretariat to the Council in July 2024 (**Table 5**). Modelling results and temperature analysis from the third iteration of modelling were presented by the Secretariat to the Council in September 2024. A legend of the scenarios run by the three core models can be found in **Appendix 5**.

Table 5: Overview of the scenarios run by the three core models as part of each iteration of modelling

Iteration (date)	Number of TIM scenarios	Number of FAPRI-Ireland scenarios	Number of GOBLIN scenarios
First iteration (December 2023)	4	3	25
Second iteration (May 2024)	8	3	15
Third iteration (August 2024)	27	9	13

4.2.1. Energy modelling

UCC's Energy Policy and Modelling Group (EPMG) applied TIM, which is a model developed from the Irish-TIMES Model to better inform increased national climate mitigation ambition.[69]

An overview presentation on TIM was given to the CBWG on 31 May 2023. A subsequent presentation on the inputs and outputs of TIM was delivered during the modelling workshop on 13 September 2023. The results from the first iteration of modelling were presented on 15 December 2023. The modellers discussed with the Council on 14 February 2024 and presented the results from the

68 CCAC (2023). 6.1 Update on Carbon Budgets Working Group DIS. [online] https://www.climatecouncil.ie/aboutthecouncil/transparency/councildocuments/2023/

69 Balyk, O. et al. (2022). TIM: Modelling pathways to meet Ireland's long-term energy system challenges with the TIMES-Ireland Model (v1.0). *Geoscientific Model Development*, 15, 4991–5019. [online] https://doi.org/10.5194/gmd-15-4991-2022

second iteration of modelling on 23 May 2024. Third and final iteration results were presented to the working group on 29 August 2024.

Three iterations of TIM were completed for this CB Proposal. Over the three iterations, 27 scenarios were modelled and these are outlined in **Table 6**–**Table 8**.

Core scenario narratives were submitted to the working group following the second iteration of modelling in May 2024. The final report from the TIM team sets out 27 scenarios for possible pathways for Ireland's energy system in the period to 2050 under varying levels of climate ambition. The main focus was on the decade following 2030, to inform the Council's consideration of CB3 and provisional CB4. The scenarios outline the necessary investments, mitigation measures and choices to be made across the Energy, Electricity, Transport, Heating and Industry sectors, under carbon budgets of different stringency.

Table 6: TIM scenarios modelled over the first iteration

Scenario name	End year	Carbon budget	Energy demand/sensitivity case
300 Mt BAU	2050	300	Business as usual energy demand
300 Mt LED	2050	300	Low energy demand
400 Mt BAU	2050	400	Business as usual energy demand
400 Mt LED	2050	400	Low energy demand

Table 7: TIM scenarios modelled over the second iteration

Scenario name	End year	Carbon budget	Energy demand/sensitivity case
250 Mt BAU	2050	250	Business as usual energy demand
250 Mt LED	2050	250	Low energy demand
300 Mt BAU	2050	300	Business as usual energy demand
300 Mt LED	2050	300	Low energy demand
350 Mt BAU	2050	350	Business as usual energy demand
350 Mt LED	2050	350	Low energy demand
400 Mt BAU	2050	400	Business as usual energy demand
450 Mt BAU	2050	450	Business as usual energy demand

Table 8: TIM scenarios modelled over the third iteration

Scenario name	End year	Carbon budget	Energy demand/sensitivity case
250 Mt BAU	2050	250	Business as usual energy demand
250 Mt LED	2050	250	Low energy demand
250 Mt WAM	2050	250	WAM
250 Mt WEM	2050	250	WEM
250 Mt Low Bio	2050	250	Low bioenergy demand
250 Mt High Solar PV	2050	250	High solar PV capacity
300 Mt BAU	2050	300	Business as usual energy demand
300 Mt LED	2050	300	Low energy demand
300 Mt WAM	2050	300	WAM
300 Mt WEM	2050	300	WEM
300 Mt Low Bio	2050	300	Low bioenergy demand
300 Mt High Solar PV	2050	300	High solar PV capacity
350 Mt BAU	2050	350	Business as usual energy demand
350 Mt LED	2050	350	Low energy demand
350 Mt WAM	2050	350	WAM
350 Mt WEM	2050	350	WEM
350 Mt Low Bio	2050	350	Low bioenergy demand
350 Mt High Solar PV	2050	350	High solar PV capacity
400 Mt BAU	2050	400	Business as usual energy demand
400 Mt LED	2050	400	Low energy demand
400 Mt WAM	2050	400	WAM
400 Mt WEM	2050	400	WEM
400 Mt Low Bio	2050	400	Low bioenergy demand
400 Mt High Solar PV	2050	400	High solar PV capacity
450 Mt BAU	2050	450	Business as usual energy demand
450 Mt WAM	2050	450	WAM
450 Mt WEM	2050	450	WEM

PV, photovoltaic; WAM, with additional measures; WEM, with existing measures.

4.2.1.1. Overview of modelling results

Ireland's energy system must achieve net zero emissions well before 2050 to meet carbon budgets consistent with the Paris Agreement commitment, requiring accelerated cuts in GHG emissions in the Power, Buildings, Industry and Transport sectors. Delays in implementing mitigation measures will increase costs and make it harder to meet carbon budgets, highlighting the urgency of immediate action to avoid locking in fossil fuel use and relying on uncertain carbon removals.

Global demand for fossil fuels has not yet peaked, putting the world on track to significantly breach the temperature goals set out in the Paris Agreement. Temperatures will continue to rise until GHG emissions reach net zero. Ireland, which contributes disproportionately to global heating, has established a legal framework and detailed implementation plan to reduce GHG emissions significantly by 2030. Although the energy transition is gathering pace, current mitigation measures are not on track to meet legally binding carbon budgets. This projected overshoot poses a major risk and represents a lost opportunity. The urgency of limiting cumulative emissions — and hence global warming — calls for the development of long-term strategies that extend beyond 2030.

The researchers' report[70] outlines multiple scenarios for Ireland's energy system from now until 2050, under varying levels of climate ambition. It focuses primarily on the decade after 2030 to inform the CCAC's assessment of CB3 and provisional CB4. Developed iteratively by the UCC's EPMG in 2023–2024 as part of the CBWG (appointed by the CCAC), the scenarios present the necessary investments, mitigation measures and choices across the Energy, Electricity, Transport, Heating and Industry sectors, under carbon budgets of different stringency and with varying assumptions about near-term decarbonisation and future energy demands.

4.2.1.2. Key findings

- Net zero is critical, but cumulative CO_2 emissions determine total global warming. Ireland's climate ambition should be framed around cumulative carbon budgets, as the pathway and timing to net zero are crucial to limit dangerous temperature rise. Emissions from Ireland's energy system need to reach net zero, or close to zero, well before 2050 and turn negative thereafter. For example, the most ambitious scenarios show a need for Ireland to reach net zero by around 2035 and also to deliver significant reductions in non-CO_2 emissions. If emissions overshoot the committed carbon budgets to 2030 (as projected), the remaining budget post-2030 will be negligible, even under moderate levels of ambition.
- All scenarios require deeper emissions cuts in the period to 2030, and to 2040, than currently planned. An immediate acceleration of mitigation measures is necessary. Delayed action will increase costs, lead to negative trade-offs (e.g. land use) and make long-term targets less feasible.
- Costs and benefits:
    - The most ambitious carbon budget modelled (250 Mt) can be achieved with a modest increase in total annualised expenditure relative to a '*no mitigation*' scenario — only 0.3% of

70 Daly, H. et al. (2024). Pathways for Ireland's Energy System to 2050: Modelling analysis to support the Climate Change Advisory Council on the second carbon budget programme. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

gross domestic product (GDP) in 2020. This is due to long-term savings from reduced fossil fuel imports.

- Current policy scenarios (with additional measures (WAM) and WEM) are more costly than several of the modelled carbon budget scenarios because they do not phase out fossil fuels in favour of cheaper low-emitting alternatives.

- A near-complete phase-out of fossil fuels is required by 2040 for the Power, Buildings and Transport sectors. The phase-out of peat, coal and oil is particularly urgent. There is nearly no remaining carbon budget for new investments in fossil fuels, including internal combustion engine vehicles, and natural gas demand declines significantly, requiring a plan to decommission its infrastructure.
- Electrification of the Transport, Heat and Industry sectors is a key mitigation lever, alongside decarbonising electricity supply. While this transition requires substantial upfront investment, it is cost-effective in the long run due to the falling costs of renewables and batteries and the broader societal, health and economic benefits.
- Delivering the scenarios relies on strong political, societal and institutional capacity. Most of the required technologies are mature and affordable: time, not technology, is the primary constraint. Significant operational and market innovations, such as in energy storage and grid management, will be needed.
- Final energy demand reduction is essential for meeting ambitious carbon budgets. Reducing energy demand through compact urban development, modal shift in transport and shifting support to less carbon-intensive economic activities are an important complement to technology transitions. These changes will require substantial State investment and policy support.
- The Buildings and Transport sectors need to be almost fully decarbonised by the mid-2030s. This requires a rapid phase-out of oil- and gas-based heating systems and internal combustion engine vehicles by 2025, which is not aligned with current market trends.
- Carbon dioxide removal (CDR) will be necessary for most scenarios, especially under ambitious mitigation targets or if early carbon budgets are overshot. CDR technologies such as BECCS bring risks, including high costs, technology uncertainties and conflicts with land use and biodiversity. Pursuing strategies that minimise reliance on CDR through strong early mitigation is essential.
- Ireland may need to adopt negative carbon budgets due to potential overshoot of its current carbon budgets and the likelihood that the 1.5°C threshold will be exceeded soon. Any overshoot must be compensated in future budget periods, leaving limited flexibility and necessitating net negative targets.
- The European Commission has recommended that the EU cut GHG emissions by 90% by 2040 relative to 1990 levels. While Ireland's exact target is yet to be defined, the scenarios in this report provide a benchmark against a range of potential 2040 targets.
- The scenarios were developed using the peer-reviewed open-source TIM. Detailed results for all scenarios can be explored and downloaded on a web portal: https://epmg.netlify.app/TIM-Carbon-Budget-August_2024/about?scen1=mitigation_cb2024-250mt&scen2=null&diff=false

Table 9: Selected main Agriculture, Forestry and Other Land Use sector scenarios modelled for the first iteration of results

Scenario	Cattle	Rewetting (ha)	Anaerobic digestion grassland (ha)	2025–2050 new forest (ha)	2030–2050 afforestation rate (ha/year)	Forestry mix (C:BL)	Afforestation soils	Milk (kt/year)	Beef (kt/year)	Protein (% change vs 2022)	End year
0	Current	227,222	NA	200,000	8,000	50:50	25% OM	8,790	652	3%	2050
1	MACC+	305,043	NA	200,000	8,000	50:50	25% OM	9,940	643	12%	2050
2	MACC–	305,043	NA	200,000	8,000	50:50	25% OM	9,200	532	0%	2050
3	Dairy – protein	305,043	NA	200,000	8,000	50:50	25% OM	9,930	416	0%	2050
4	30% reduction	305,043	NA	200,000	8,000	50:50	25% OM	6,150	456	–28%	2050
7	MACC–	305,043	NA	200,000	8,000	70:30	Mineral	9,200	532	0%	2050
12	MACC–	305,043	200,000	0	0	NA	NA	9,200	532	0%	2050
22	MACC–	305,043	200,000	546,932	25,347	70:30	Mineral	9,200	532	0%	2050
23	Dairy – protein	305,043	200,000	992,825	47,641	70:30	Mineral	9,930	416	0%	2050
24	30% reduction	305,043	200,000	950,502	45,525	70:30	Mineral	6,150	456	–28%	2050

C:BL, ratio of conifer to broadleaf species mix; MACC–, lower animal numbers; MACC+, higher animal numbers; NA, not applicable; OM, organo-mineral.

4.2.2. Land use modelling

Researchers from the University of Galway and Forest, Environmental Research & Services (FERS) modelled land use and land use change to 2100 using the GOBLIN, FERS Carbon Budget Model and LCAD anaerobic digestion models.[71]

An overview presentation on the GOBLIN model was given to the CBWG on 31 May 2023. A subsequent presentation on the inputs and outputs of GOBLIN was delivered during the modelling workshop on 13 September 2023. The results from the first iteration of modelling were presented on 15 December 2023. The modellers discussed with the Council on 14 February 2024 and presented the results from the second iteration of modelling on 23 May 2024. Third and final iteration results were presented to the working group on 29 August 2024.

Three iterations of modelling were completed for this CB Proposal. Multiple scenarios were modelled over the three iterations and refined to 13 scenarios for the final iteration, and these are outlined in **Table 9**–**Table 11**.

Table 10: Agriculture, Forestry and Other Land Use sector scenarios modelled for the second iteration of results

Scenario	Emissions reductions by 2050 compared with 2020	Forestry mix (C:BL)	Forestry soil type	Afforestation rate 2030–2080 (kha/year)	End year
1a	−30%	50:50	15% on organo-mineral soils	8	2100
1b	−40%	50:50	15% on organo-mineral soils	8	2100
1c	−45%	50:50	15% on organo-mineral soils	8	2100
1d	−50%	50:50	15% on organo-mineral soils	8	2100
1e	−60%	50:50	15% on organo-mineral soils	8	2100
2a	−30%	50:50	15% on organo-mineral soils	25	2100
2b	−40%	50:50	15% on organo-mineral soils	25	2100
2c	−45%	50:50	15% on organo-mineral soils	25	2100
2d	−50%	50:50	15% on organo-mineral soils	25	2100
2e	−60%	50:50	15% on organo-mineral soils	25	2100
3a	−30%	70:30	100% on mineral soils	25	2100
3b	−40%	70:30	100% on mineral soils	25	2100
3c	−45%	70:30	100% on mineral soils	25	2100
3d	−50%	70:30	100% on mineral soils	25	2100
3e	−60%	70:30	100% on mineral soils	25	2100

C:BL, ratio of conifer to broadleaf species mix.

71 Styles, D. et al. (2024). GOBLIN Scenarios to Support Ireland's Carbon Budgets 3 and 4. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

Table 11: Agriculture, Forestry and Other Land Use sector scenarios modelled for the third iteration of results

Scenario	Agriculture emissions	Forestry mix (C:BL)	Forestry soil type	Afforestation rate (kha/year)	End year
1a	−35%	50:50	15% organo-mineral	8	2100
1b	−40%	50:50	15% organo-mineral	8	2100
1d	−52%	50:50	15% organo-mineral	8	2100
1e	−60%	50:50	15% organo-mineral	8	2100
2a	−35%	50:50	15% organo-mineral	25	2100
2b	−40%	50:50	15% organo-mineral	25	2100
2d	−52%	50:50	15% organo-mineral	25	2100
2e	−60%	50:50	15% organo-mineral	25	2100
3a	−35%	70:30	100% mineral	25	2100
3b	−40%	70:30	100% mineral	25	2100
3d	−52%	70:30	100% mineral	25	2100
3e	−60%	70:30	100% mineral	25	2100
4d	−52%	70:30	100% mineral	17.5	2100

C:BL, ratio of conifer to broadleaf species mix.

Core scenario narratives were submitted to the working group following the second iteration of modelling in May 2024. The final report from the GOBLIN team sets out 13 scenarios for possible pathways for Ireland's land use in the period to 2050 (and extended to 2100) under varying levels of climate ambition. The scenarios outline the emissions associated with modelled mitigation measures and considerations to be included across the Agriculture and Land Use sectors.

4.2.2.1. Overview of modelling results

GHG emissions trajectories for the Agriculture, Forestry and Other Land Use (AFOLU) sector were modelled to 2100 using the GOBLIN, FERS Carbon Budget Model and LCAD anaerobic digestion models. Thirteen scenarios were derived to represent maintenance of bovine protein (sum of protein in milk and beef) production at 2020 levels, about 440 kt annually (with the exception of 'e' scenarios that reduced protein output by 19% to achieve a 60% GHG reduction for the Agriculture sector by 2050). These scenarios were predicated on a strong pivot away from suckler beef towards milk and dairy beef production, and 'sustainable intensification' of agricultural production to maximise animal productivity and technical abatement of GHG emissions, while approximately halving the area of grassland required to maintain livestock (up to 48% fewer cattle required).

Ambitious rewetting of 90% of drained organic soils under grassland and exploited peat bogs modestly reduced 'other land use' GHG emissions from 7.5 Mt CO_2 eq in 2020 to 4.3 Mt CO_2 eq in 2050 (CO_2 emissions reductions are offset by increased methane emissions and a diminishing mineral soil carbon sink as grassland improvement effects drop out of future GHG accounting).

Sustained annual afforestation rates of 8–25 kha from 2030 to 2080 combined with carbon-enhancing forest management generated a carbon sink of 2.3–7.4 Mt CO_2 eq in new forests by 2050, somewhat offset by net emissions of about 2 Mt CO_2 eq in pre-existing forests by 2050. The higher rates of afforestation are technically feasible based on areas of mineral soils spared from agriculture, but require further investigation regarding various exclusion criteria currently applied in forest licensing. Harvested wood products and BECCS contributed up to 1.3 and 2.0 Mt CO_2 eq negative emissions by 2050. However, the BECCS results are highly speculative, based on the assumption that 48% of all biogenic CO_2 from biomethane, harvested wood side streams and end-of-life wood products going to bioenergy is captured and stored by 2050. Further analysis is required to understand the economy-wide magnitude and allocation of negative emissions from BECCS, and available end-of-life wood streams, to avoid double counting across sectors. Nonetheless, results for 2100 indicate a very large technical potential for negative emissions from harvested wood products, up to 7.3 Mt CO_2 eq annually, that warrants further careful analysis.

No scenarios achieved a net zero emission balance (GWP_{100} all gases) in 2050, although three scenarios achieved a net zero balance in the mid-2060s. Meanwhile, nine scenarios achieved a GWP_{100} CO_2 and nitrous oxide balance (excluding methane) by 2050, including scenario 4d with a 50% reduction in agricultural emissions and a sustained annual afforestation rate of 17.5 kha post 2030. This scenario could represent a reasonably robust 'climate neutrality' landing zone for Ireland's AFOLU sector, based on a split gas target that recognises the powerful but short-lived warming effect of methane emissions. Extreme caution is urged when applying novel methods to separate methane from the long-lived GHGs, owing to value judgements that could unintentionally (i) undermine economic development and food security across less economically developed countries with low methane emissions at present and (ii) further delay ramping up the afforestation carbon sink essential for robust climate action in the AFOLU sector. This is particularly the case if a reducing rate of national methane pollution loading (from a very high per capita baseline) is equated to a national 'cooling' effect, or negative emissions, as with the temperature neutrality approach in an Irish context.

2050 scenarios were used to derive emissions trajectories through the CB3 and provisional CB4 (2031–2040) periods. It was assumed that Climate Action Plan (CAP) targets were met in 2030 for the Agriculture sector, for organic soils under grass and for peatlands. Derived 5-year agriculture carbon budgets ranged from 68 Mt CO_2 eq ('e' scenarios for the CB4 period, 2036–2040) to 82.4 Mt CO_2 eq ('a' scenarios for the CB3 period, 2031–2035). Cumulative CO_2 (only) emissions represented a minor contribution of just 2 Mt CO_2 in each budget period, with little variation across scenarios.

All scenarios imply a strong consolidation of livestock rearing across fewer highly efficient farms. Even after 134 kha of grassland are diverted to support the 5.7 TWh biomethane strategy target, and 204–576 kha are converted to forestry by 2050, up to 2 million ha of land become available for various forms of diversification – inter alia high nature value grassland, natural regeneration ('rewilding') or production of (low-input) bioeconomy feedstocks. Elucidation of Just Transitions in line with these scenarios will require wider foresight analysis that includes future-oriented socioeconomic assessment and consideration of new business models to support carbon farming, payment for ecosystem services and cascading bio-based value chains. Incorporation of these aspects appears beyond the scope of current economic models, leaving a major evidence gap for strategic AFOLU policy.

4.2.3. Agriculture sector modelling

Teagasc modelled scenarios for agricultural GHG emissions in Ireland using the FAPRI-Ireland model and Teagasc MACC model (2023).[72] Normally these models adopt a medium-term (10-year) horizon, but, following a request from the Council, projections from this model were extended to 2050. Extending the normal time horizon of the FAPRI-Ireland model brings additional uncertainties.

An overview presentation on the FAPRI-Ireland model was given to the CBWG on 31 May 2023. A subsequent presentation on the inputs and outputs of the FAPRI-Ireland model was delivered during the modelling workshop on 13 September 2023. The results from the first iteration of modelling were presented on 15 December 2023. The modellers discussed with the Council on 14 February 2024 and presented the results from the second iteration of modelling on 23 May 2024. Third and final iteration results were presented to the working group on 29 August 2024.

Three iterations of the FAPRI-Ireland model were completed for this CB Proposal. Over the three iterations, 15 scenarios were modelled, with varying agricultural activity and mitigation measures. These scenarios are outlined in **Table 12**–**Table 14**.

Table 12: FAPRI-Ireland scenarios modelled over the first iteration

Scenario	Agricultural activity	MACC technology adoption rates	End year
S1_P1	Base case	Ambitious	2030
S2_P1	Low activity	Ambitious	2030
S3_P1	High activity	Ambitious	2030
S1_P2	Base case	Very ambitious	2030
S2_P2	Low activity	Very ambitious	2030
S3_P2	High activity	Very ambitious	2030

See Section 4.2.3.2 for a detailed description of the scenarios (S1, S2, S3) and pathways (P1, P2).

Table 13: FAPRI-Ireland scenarios modelled over the second iteration

Scenario	Agricultural activity	MACC technology adoption rates	End year
S1	Base case	None	2050
S2	Low activity	None	2050
S3	High activity	None	2050

See Section 4.2.3.2 for a detailed description of the scenarios (S1, S2, S3) and pathways (P1, P2).

72 Teagasc (2024). Modelling Irish Agricultural GHG Emissions and Mitigation to 2050: Scenarios for the Carbon Budgets Working Group. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

Table 14: FAPRI-Ireland scenarios modelled over the third iteration

Scenario	Agricultural activity	MACC technology adoption rates	End year
S1P1	Base case	Ambitious	2050
S2P1	Low activity	Ambitious	2050
S3P1	High activity	Ambitious	2050
S1P2	Base case	Very ambitious	2050
S2P2	Low activity	Very ambitious	2050
S3P2	High activity	Very ambitious	2050

See Section 4.2.3.2 for a detailed description of the scenarios (S1, S2, S3) and pathways (P1, P2).

The final report from the FAPRI team sets out nine scenarios for possible pathways for Ireland's Agriculture sector in the period to 2050 under varying levels of MACC mitigation measure implementation. The scenarios outline the emission pathways associated with modelled agricultural scenarios.

4.2.3.1. Context of modelling work

The report outlines scenarios for agricultural GHG emissions in Ireland using the FAPRI-Ireland model and Teagasc MACC model (2023) to assist the CCAC in planning future carbon budgets.[73] Ireland has committed to a 51% reduction in GHG emissions by 2030 and achieving net climate neutrality by 2050. The Climate Action and Low Carbon Development (Amendment) Act 2021 set a national GHG emissions reduction target, and, under the Act, the Government allocated sectoral emissions ceilings and associated sectoral targets. Agriculture was set a 2030 target of reducing GHG emissions by 25% relative to 2018 emissions.[74] This is a highly ambitious target requiring high and rapid uptake of abatement options.[75]

Agricultural GHGs primarily come from methane (enteric fermentation and manure management) and nitrous oxide (fertiliser and manure application), with CO_2 emissions also representing a minor source.

73 Teagasc (2024). Modelling Irish Agricultural GHG Emissions and Mitigation to 2050: Scenarios for the Carbon Budgets Working Group. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

74 Department of the Environment, Climate and Communications (2022). Sectoral Emissions Ceilings. [online] https://www.gov.ie/en/publication/76864-sectoral-emissions-ceilings/

75 Hanrahan, K. et al. (2021). Teagasc note on carbon budgets. Paper prepared for the Carbon Budget Committee of the Climate Change Advisory Council, 29 September 2021. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/documents/cbcbackgroundpapers/Teagasc%20note%20on%20carbon%20budgets_September_29_2021.pdf

The key factors influencing the level of agricultural GHG emissions in Ireland are:

- the level of economic activity in the sector and its composition,
- the adoption of GHG mitigation measures.

Agricultural GHG emissions in Ireland are mainly the result of bovine agriculture. The future level of GHGs from the sector is difficult to anticipate, reflecting uncertainties around the future size of the bovine population and the dairy to beef cow ratio, which affects the number of different types of bovines in the herd. Underlying this uncertainty about the level of economic activity in the Agriculture sector and its composition is fundamental uncertainty relating to the economic drivers of international agricultural input and output prices over a medium- to long-term horizon. Further areas of uncertainty relate to future decisions relating to agricultural policy, trade policy and environmental policy, all of which are determined at the supranational level. Added to these known uncertainties will be unanticipated events, so-called unknown unknowns.

The projections to 2050 for agricultural activity levels in this report are conditional on the projected evolution of economic aggregates such as GDP per capita, inflation and the input and output prices to which farmers respond. It is important to emphasise that the projections under each of the three scenarios are not predictions or forecasts. The projections are based on a set of differing assumptions concerning future policy conditions that will affect bovine and general agriculture in Ireland. The fundamental uncertainty about the future evolution of these economic signals should be recognised when interpreting these projections and associated levels of GHG emissions.

The scenarios modelled using the FAPRI-Ireland model and the Teagasc MACC model, summarised in the associated report,[76] do not provide model-based insights on the impact of agricultural activities on other environmental issues, such as water quality and biodiversity, which both require spatially explicit modelling. It should be noted, however, that the measures to reduce nitrogen fertiliser use and change fertiliser type will have associated benefits in reducing nitrogen loss to water and ammonia loss to air. It is important to recall these modelling limitations when considering how the future adoption of mitigation technologies or agricultural activity levels may affect other indicators of interest.

4.2.3.2. Approach

The modelling work therefore has examined potential future GHG emissions under three agricultural activity scenarios (S1, S2, S3) with different cow numbers, land use and input usage, alongside two GHG mitigation pathways: P1 (ambitious adoption) and P2 (very ambitious adoption). The scenarios use the most up-to-date EPA national inventory, which reduced agricultural emissions in 2018 from 23.2 Mt CO_2 eq to 22.5 Mt CO_2 eq.[77] Due to the uncertainties already set out, these scenarios cannot be interpreted as predictions of the future. The scenarios are elements in an exercise requested by the CCAC's CBWG to help understand the scale of action that is likely to be required to mitigate future agricultural GHG emissions:

76 Teagasc (2024). Modelling Irish Agricultural GHG Emissions and Mitigation to 2050: Scenarios for the Carbon Budgets Working Group. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

77 Environmental Protection Agency (2024). Ireland's National Inventory Report 2024. [online] https://www.epa.ie/publications/monitoring--assessment/climate-change/air-emissions/Ireland%27s-NIR-2024_cov.pdf

- **S1 (base case):** In this scenario, by 2050, dairy cow numbers rise by 14%, increasing total milk production by 38% relative to 2022 due to higher milk yields. Total cattle inventories decrease by 7%, while beef production declines by 11%. Fertiliser use is projected to rise by 10%, and cropland area shrinks by 16% as grassland farming, especially dairying, becomes more profitable. Sheep numbers drop by 25%, while pig and poultry production grow by 25% and 30%, respectively.

  Under scenario S1, gross value added (GVA, a measure of income arising in the sector) is projected to grow in nominal terms, but the projected annual rate of growth over the period 2023–2050 is less than the projected rate of general inflation – in real terms, sectoral incomes are projected to decline.

- **S2 (lower agricultural activity):** With reduced economic incentives for dairy and beef in this scenario, by 2050 total cattle inventories drop by 22% relative to 2022, driven by an 84% decline in beef cow numbers. Dairy cow numbers rise by 7%, and, with higher milk yields, milk production increases by 28%, but beef production falls 26%. Fertiliser use decreases by 12%, cropland contracts by 14% and sheep numbers drop by 25%. Pig and poultry production grow by 25% and 35%, respectively.

  Under scenario S2, with lower levels of agricultural activity, due to the projected strong contraction in the beef (suckler) cow herd, GVA in nominal terms is projected to grow but at a rate of only 0.9% per annum between 2023 and 2050. With general inflation of circa 2% per annum forecast, real sectoral income is projected to contract strongly under scenario S2.

- **S3 (higher agricultural activity):** Higher milk prices and support for beef farmers lead to a 22% increase in dairy cow numbers by 2050, relative to 2022, and a slower decline in beef cow numbers, compared with the other two scenarios. Total cattle inventories grow by 1%, milk production rises by 47% and beef production drops by less than 5%, a smaller decrease than in S1 and S2. Fertiliser use rises by 22%, cropland area contracts by 24% and sheep numbers decline by 25%. Pig and poultry production grow by 24% and 34%, respectively.

  Under scenario S3, higher agricultural activity levels are associated with growth in GVA of slightly more than 2% for the period 2023–2050. With annual rates of price inflation of close to the same level forecast for the period to 2050, sectoral income in real terms is projected to grow marginally over the period to 2050.

In the absence of GHG mitigation, these three scenarios produce a range of agricultural GHG emissions of 20.23–25.12 Mt CO_2 eq by 2050.

Two mitigation adoption pathways were assessed:

- **P1:** An ambitious adoption rate following the 2023 Teagasc MACC.
- **P2:** Very ambitious adoption rates, with many measures extended close to the maximum potential rate, to 2050.

Established practices such as fertiliser formulation follow a linear adoption rate, while newer measures such as feed additives follow a more gradual adoption curve.

4.2.3.3. Results

Mitigation results in CO_2 equivalents to 2050:

- **P1:** Emissions are reduced to 17.52 Mt CO_2 eq (S1), 14.94 Mt CO_2 eq (S2) and 19.19 Mt CO_2 eq (S3), relative to a base level of 22.5 Mt CO_2 eq in 2018.
- **P2:** Larger emission reductions are delivered, at 13.96 Mt CO_2 eq (S1), 11.75 Mt CO_2 eq (S2) and 15.38 Mt CO_2 eq (S3), relative to a base level of 22.5 Mt CO_2 eq in 2018.

The study indicates that only in scenarios where the highly ambitious (P2) pathway was adopted and agricultural activity remains stable (S1) or declines (S2) can Ireland come close to remaining within the 2021–2030 allocated agricultural sectoral emissions ceiling – equivalent to reducing agricultural emissions to 16.88 Mt CO_2 eq by 2030.

Mitigation results in CO_2 equivalents by 2050 relative to 2018:

- **S1:** Emissions decrease by 22% (P1) and 38% (P2).
- **S2:** Emissions decrease by 34% (P1) and 48% (P2).
- **S3:** Emissions decrease by 15% (P1) and 32% (P2).

Mitigation results by individual gases by 2050 relative to 2018:

- **S1:** Methane emissions decrease by 15–31% and nitrous oxide emissions drop by 55–72%.
- **S2:** Methane emissions decrease by 27–42%, while nitrous oxide emissions fall by 64–77%.
- **S3:** Methane emissions decrease by 7–24%, while nitrous oxide emissions fall by 49–68%.

Across all scenarios, reductions in nitrous oxide emissions are projected to occur primarily by 2030, while reductions in methane emissions are achieved more gradually over the period to 2050.

4.2.3.4. Key takeaways for policy makers

- Significant emission reductions require very ambitious mitigation efforts. Achieving substantial reductions in agricultural GHG emissions by 2050 necessitates very ambitious adoption of mitigation measures (P2). High levels of uptake would allow the Agriculture sector to contribute significantly to Ireland's national climate goals, including the 25% reduction target for agriculture by 2030 and further reductions by 2050, with potential reductions in agricultural emissions of between 38% and 48% by 2050, relative to 2018.
- Agricultural activity levels affect GHG mitigation potential. Scenarios where agricultural activity is stable or reduced (S1 and S2) yield the largest GHG emissions reductions relative to the 2018 level, particularly when coupled with very ambitious mitigation measures (P2). S3, which involves higher agricultural activity, achieves lower reductions in GHG emissions, highlighting the challenge of balancing agricultural productivity with emissions reduction.
- Lower (higher) agricultural activity levels are associated with lower (higher) rates of growth in nominal Agriculture sector income. Under all scenarios modelled, nominal GVA in agriculture (a measure of sectoral income) grows, but at rates that are projected to be less than expected rates of general inflation.

- Lower (higher) agricultural activity levels across scenarios S1, S2 and S3 are reflected in lower (higher) levels of milk, beef and other agricultural output. Across all scenarios modelled, beef production contracts and milk production expands. Developments in agricultural output levels will have consequences for output, employment and income arising in upstream and downstream industries.
- Reducing methane emissions is technologically challenging. While significant reductions in nitrous oxide emissions are feasible due to well-developed mitigation measures, reducing methane emissions poses greater technological challenges and is more costly. Methane mitigation technologies, such as feed additives and manure management, are less efficacious than nitrous oxide mitigation and are slower to deploy. While feed additives are commercially available, they are utilised for housed bovines principally fed on total mixed ration diets. The deployment of feed additives during the grazing period is an immature technology at present, with variable and highly uncertain results depending on the additive used.
- Cumulative GHG emissions exceed sectoral ceilings without very ambitious mitigation measure adoption. Without very ambitious mitigation efforts (P2), agricultural emissions are likely to exceed the sectoral emissions ceilings allocated for 2021–2030. This highlights the need for rapid and extensive implementation of GHG mitigation technologies.
- No single measure delivers a substantial share of the GHG emissions reductions. A wide range of GHG mitigation measures contribute to reducing emissions, with no single measure providing a dominant share of the mitigation potential. Key contributors include reducing the age of cattle finishing, feed additives, fertiliser reformulation and improved breeding practices, such as applying the dairy Economic Breeding Index (EBI).
- Methane reductions are associated with higher costs. Methane mitigation measures, particularly feed additives, are among the most costly, while some reduction measures, such as reducing the age of cattle finishing and applying the dairy EBI, result in considerable cost savings. It can be expected that economic considerations will play a significant role in determining the feasibility of achieving widespread methane mitigation, and Government and industry support for farmers will be required to achieve very ambitious rates of adoption of mitigation measures.
- Increased CO_2 emissions result from certain mitigation measures. Some mitigation strategies, such as liming and fertiliser reformulation, result in increased CO_2 emissions, partially offsetting reductions in other gases. This indicates the need for holistic consideration of trade-offs between emissions of different gases.
- Achievement of long-term agricultural GHG emissions reduction targets will require consistent and very ambitious mitigation efforts. If ambitious mitigation measures are continuously adopted, agricultural emissions could decrease by between 15% and 48% by 2050, depending on the combination of agricultural activity scenario (S1, S2, S3) and abatement adoption pathway (P1 or P2). The P2 abatement adoption pathway represents a degree of mitigation measure uptake that is at or near the maximum biophysical potential for a range of measures, including feed additives, fertiliser formulation and manure management options. Delivering such emissions reductions would be a significant step towards achieving both the 2030 sectoral target and the 2050 goal of climate neutrality.
- Policy and incentives are key to achieving GHG emissions reductions. There is a need to rapidly deploy the mitigation measures highlighted in the analysis. The very high rates of adoption for

many measures, some with in excess of 70% uptake, can be achieved only through targeted policies and incentives. Advisory and extension services will guide farmers and landowners on the path to reducing GHG emissions by 2030 and to achieving further reductions in GHG emissions over the period to 2050.

- Viable and acceptable farm diversification options are important. In all mitigation scenarios modelled, the diversification measures were important contributors to reducing GHG emissions. Government and industry support for such alternative land uses will be critical in achieving the projected impact of these measures on Agriculture sector GHG emissions.
- There is a need for continuing research and development in emissions mitigation technologies to identify new practices to reduce agricultural and land use emissions. Research is also needed to further refine agricultural and land use inventories to reduce uncertainty and provide inventory ready mitigation measures available for adoption by farmers.

4.3. Warming impact of modelled pathways

To help determine the consistency of national emission scenarios with national climate objectives, research into the warming impact of scenarios was commissioned by the CCAC Secretariat. Dr Joseph Wheatley from the Energy Institute and School of Economics from University College Dublin (UCD) was commissioned for a period of 11 months from December 2023 to October 2024 to develop a Simple Climate Model framework to assist the CBWG and investigate national emissions scenarios using this framework.

Quantifying national contributions to global warming is valuable for two reasons. First, knowledge of the details and drivers of the warming can shed light on the best ways to curb the country's future warming impact. Second, the magnitude of this impact is important when considering issues of responsibility and climate justice.

Ireland's GHG emissions profile is distinctive, with a higher share of shorter-lived gases such as methane and nitrous oxide from agriculture than most developed nations. The prevalence of these gases introduces additional physical considerations that are less relevant in countries where emissions are predominantly driven by CO_2, as is the case for most EU Member States. However, the standard approach of comparing GHG emissions through global warming potentials fails to accurately reflect the warming dynamics of these gases, particularly in scenarios involving deep emission cuts.

To tackle this issue, the warming impact report[78] makes use of simple climate models whose outputs include the global mean surface temperature. These models reflect the latest understanding of climate parameters, processes and uncertainties, and are widely used in IPCC assessments. Here, the Finite-amplitude Impulse Response (FaIR) Simple Climate Model was used to efficiently analyse 1,196 emissions pathways for Ireland. These scenarios were developed by modelling teams from UCC, University College Galway and Teagasc, commissioned by the CBWG. They cover a wide range of feasible mitigation options for fossil fuel and industry (FFI) and AFOLU emissions.

78 Wheatley, J. (2024). Ireland's Warming Impact. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

Based on these scenarios and other data, this report finds the following:

- On a per capita basis, Ireland's historical warming impact is significant and comparable to other developed countries. About half of this warming has arisen since the year 2000 (see **Section 1**).
- Without strong agricultural mitigation, Ireland's warming impact will continue to grow through 2050, even if net zero CO_2 emissions are reached in the 2040s (scenarios on the left-hand side of **Figure 4**).
- Robust agricultural gas mitigation is very effective in limiting Ireland's future warming impact (scenarios on the right-hand side of **Figure 4**).

In the strongest agricultural mitigation scenarios (labelled d, S2_P2 and e in **Figure 4**), agricultural GHG emissions contribute little to no net additional warming, or even a slight cooling, between 2021 and 2050. This contrasts with 0.15–0.25°C of warming from FFI gases, depending on the CO_2 scenario (see **Section 2.2**). This difference is due to the shorter atmospheric lifetimes of methane and nitrous oxide compared with CO_2. Methane and nitrous oxide emissions do not need to fall to zero to induce a cooling impact. While deep reductions are necessary in the case of nitrous oxide, calculations show that this effect is relevant for Ireland.

A scenario where Ireland's warming impact is still increasing in 2050 is incompatible with the National Climate Objective. The FaIR Simple Climate Model was used to determine the probabilities of combinations of FFI and AFOLU mitigation pathways passing this neutrality test. This results are shown in the 'neutrality map' (see **Figure 5**).

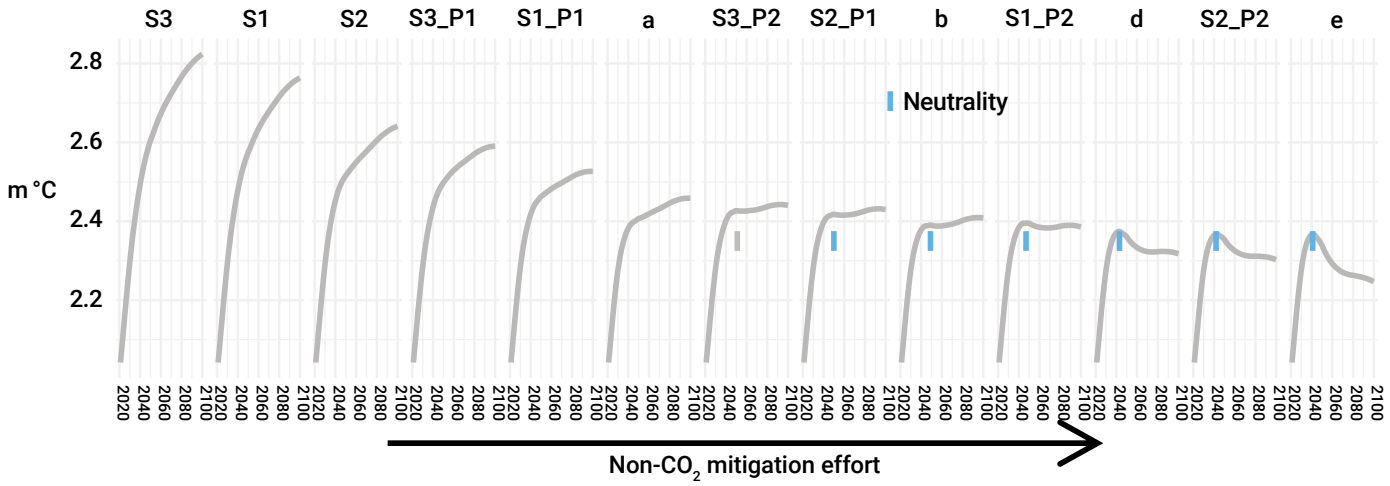

Figure 4: Median Irish warming impact in m°C for 2020–2100 for 13 agricultural gas mitigation scenarios. S1, S3 and S2 refer to FAPRI-Ireland constant, higher and lower agriculture activities, and P1 and P2 refer to the level of abatement measure adoption; a, b, d, and e refer to GOBLIN scenarios. In all cases, net zero CO_2 occurs in 2043 with 2021–2050 emissions of 440 Mt. Cases where warming peaks before 2050 are indicated by blue bars. The background global pathway is shared socioeconomic pathway SSP1-26.

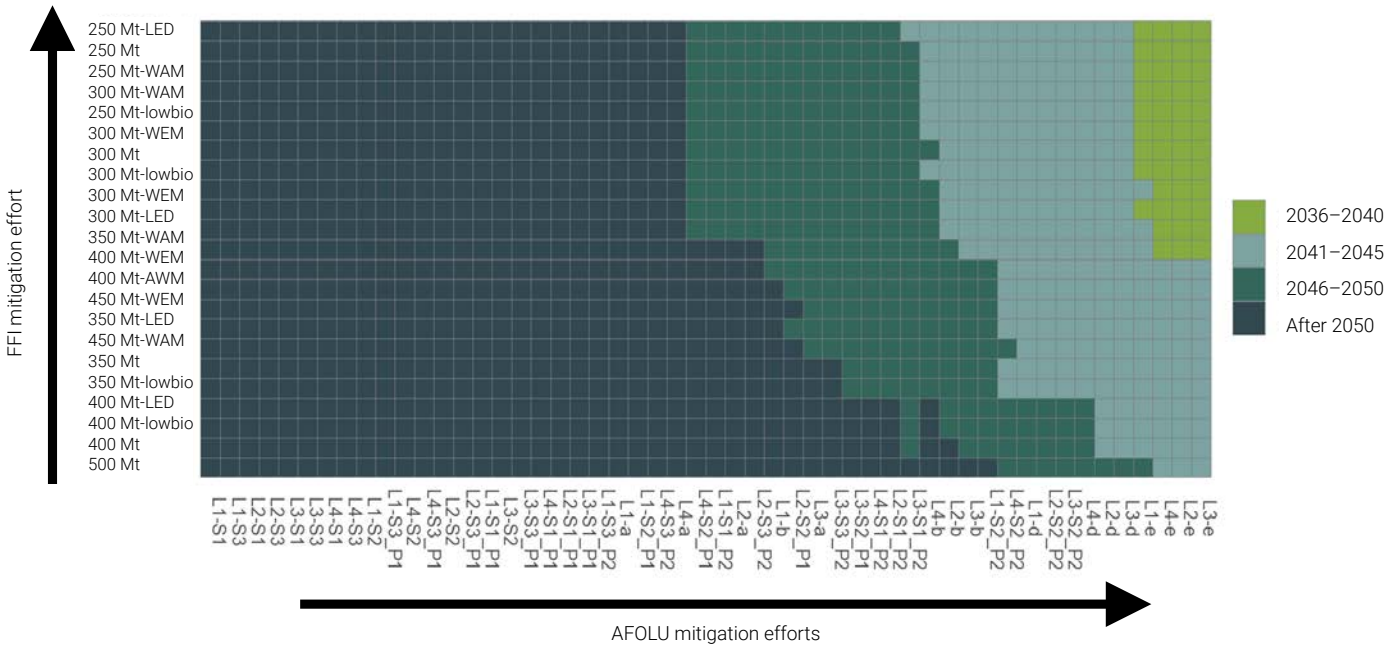

Figure 5: Neutral year ranges for all combinations of FFI and AFOLU scenarios analysed in this report. AFOLU scenarios are arranged along the x-axis in order of increasing mitigation strength. FFI scenarios are arranged in order of increasing mitigation strength along the y-axis so that the strongest mitigation scenarios occur in the top right-hand corner of the map. The probability threshold for neutrality has been set at 2/3. Dark green squares indicate the FFI/AFOLU combinations that are not temperature neutral before 2050 with a probability greater than 2/3. A legend of the scenarios run by the three core models can be found in Appendix 5.

Additional findings from **Figure 5** are as follows:

- A surprisingly wide range of FFI and AFOLU mitigation scenario combinations pass the neutrality test.
- The range of viable AFOLU options declines when 2021–2050 FFI CO_2 emissions are above 300 Mt, and, conversely, broader AFOLU options are available when FFI emissions are 300 Mt or lower.
- Strong agriculture mitigation scenarios, such as S2_P2 (2021–2050 reductions: methane −252 kt, nitrous oxide −13.4 kt) or d, are likely to be neutral by 2045 when 2021–2050 FFI CO_2 emissions are kept at 400 Mt or below.

4.4. Additional modelling and analysis of results

SEAI and NTA were requested to provide additional analysis of energy modelling outputs (see **Section 4.2.1**). These are outlined in the following sections.

4.4.1. SEAI application of the National Energy Modelling Framework

The 2021 Amendment to the Climate Action and Low Carbon Development Act established a framework for setting legally binding 5-year carbon budgets limiting total cumulative GHG emissions in Ireland. CB1 (2021–2025) and CB2 (2026–2030) have been adopted and subsequently apportioned across the GHG-emitting sectors into sectoral emissions ceilings. Although some progress has been made towards reducing emissions to comply with this first carbon budget programme, there is still significant scaling of efforts needed to reach longer-term stricter decarbonisation goals. The SEAI was engaged by the CCAC to support the development of the CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040).

SEAI's Energy Modelling Team provided views based on its own analysis, through membership of the CBWG, and performed additional testing of Energy sector carbon budget scenarios produced by UCC's EPMG. This analysis has been presented for consideration by the CCAC in the development of the CB Proposal for CB3 (2031–2035) and provisional CB4 (2036–2040).

The SEAI report[79] summarises the work completed to contribute to an evidence base for assessment of potential carbon budgets. It presents key findings from SEAI analysis of the carbon budget scenario outputs from UCC's TIM, and addresses risks and critical actions regarding the feasibility of adhering to the existing budgets and possible new budgets to 2040. The analysis consisted of a qualitative review of assumptions and outputs of the TIM scenarios, comparison with the latest SEAI National Energy Projections (NEP) WEM and WAM, risk scenarios and additional detailed testing of electricity system modelled scenarios using NEMF.

Key messages derived from this analysis are summarised below.

4.4.1.1. Required action and implications of carbon budget pathways

- The carbon budget scenarios explored for energy imply a necessary achievement of net zero in advance of 2050 to contribute to efforts to limit global warming to 1.5°C. They imply a need for deeper cuts in emissions than currently planned, beyond compliance with CB2, to aim for a near net zero energy system in the 2030s. There is no room for carbon budget overshoot and, in fact, all scenarios require the immediate implementation of higher levels of emissions reduction measures than are currently planned.
- The carbon budget pathway scenarios produced by EPMG set out necessary levels of mitigation in energy-related emissions across all sectors that exceed those currently expected to be delivered through policy targets included in planning documents such as the CAP. Although TIM modelling suggests technology deployment scale and pace and indicates where demand reduction may be needed, it is agnostic about the policies needed to achieve the emissions reductions indicated. When compared with the NEP outputs, however, the implication of these scenarios is that a significant and immediate step change in policy would be needed to make the proposed pathways achievable. Given the number of technology and policy targets already included in the CAP, increasing pre-2030 technology targets no longer seems plausible, leaving widespread reduction in energy use as the only alternative.

79 SEAI (2024). Carbon Budgets Modelling Review: 2024 Report of SEAI Analysis for Carbon Budgets Working Group. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

- Unprecedented technology change must be combined with strong policies and measures to reduce energy demand in all sectors and to disincentivise behaviours and practices that incur wasteful energy use in all parts of society. The low energy demand (LED) scenarios from EPMG are a welcome illustration of the impact that decoupling economic growth from energy demand could have on easing decarbonisation pathways and providing additional benefits to energy consumers. Currently, however, transport is the only area in energy policy with substantial direct demand reduction measures planned, and new large sources of demand, such as data centres, present a further challenge to progress. These LED scenarios are therefore unlikely to be feasible until a significant advancement of energy demand reduction policy has been implemented across all sectors.

4.4.1.2. Pace of progress to date

- To date, climate policy in the Energy sector has been focused on 2030 targets, but all scenarios examined would require both ongoing acceleration of existing policy and the addition of new policy out to 2040 and beyond to deliver the necessary level and pace of mitigation. Current policy is more technology focused than demand focused, and current policy development and implementation lead times put the achievement of a pace of action consistent with these carbon budget pathways at significant risk.
- To achieve Ireland's share of global climate goals, it is necessary to implement emissions reduction measures at an unprecedented scale and pace. The cumulative nature of the carbon budget targets necessitates an acknowledgement of where the rate of implementation has fallen behind ambition thus far, and a reflection on feasible trajectories for delivery of measures that can make up for any shortfall.
- The pace of decarbonisation in the Transport, Built Environment and Industry sectors required by the carbon budget scenarios presented is significantly beyond those in the NEP scenarios, assuming both current implemented emissions reduction measures (WEM) and the currently most ambitious set of planned policy measures (WAM). The rate of assumed uptake of renewable heating technologies, retrofit measures and electric vehicles from now to 2030 in these NEP scenarios presents a risk to compliance with the existing carbon budgets, and this risk propagates into the carbon budget scenarios explored for the energy system from 2030 to 2040.
- The energy carbon budget scenarios in which trajectories follow the WEM and WAM emissions projections to 2030 and accelerate to catch up in the period post 2030 (e.g. 350 Mt WAM) illustrate an extreme pace of implementation, pushing the limits of feasibility, particularly in the period from 2030 to 2035. However, alternative scenarios that assume greater progress than the WEM and WAM trajectories until 2030 require an immediate step change beyond the level of ambition currently included in the CAP, arguably also straining the feasibility of timely policy implementation to match. The reality is that Ireland is off track under current planned policy. If emissions cuts fall behind the core carbon budget trajectories before the end of the current decade, there is a significant risk that the post-2030 rates in the adjusted core scenarios which assume WEM or WAM to 2030 become the only carbon budget-compliant path.

4.4.1.3. Risk of further delay

- There is now a severe risk of delayed achievement of many CAP targets, including for renewable electricity, biomethane, electric vehicles, district heating, heat pumps and building energy efficiency upgrades. If even some of these risks materialise, it could result in certain target failure, higher GHG emissions, lower renewable energy share and higher energy demand.
- The risk scenarios produced by SEAI to supplement the WEM and WAM scenarios (as presented to the CBWG, publication pending) show that there are credible risks to planned CAP target achievement by 2030 across all sectors, and that these significantly impact the potential overshoot of CB1 and CB2. This should be taken into consideration when selecting CB3 and provisional CB4.
- Risk scenarios for variable electricity generation deployment were developed using a pooled forecast from surveys of a range of expert stakeholders. The scenarios represent alternative deployment rates for each variable renewable technology, as judged by a pool of expert stakeholders in Q1 2024. The provisional results of this expert elicitation were presented to the CBWG, and a report documenting the methodology and results of the surveys will be published by SEAI in late 2024.

4.4.1.4. Implication of scenario assumptions for electricity generation

- Simplified methodologies to modelling the electricity system limit the ability to capture the full picture of future emissions, as well as future investment and operational requirements and costs. In 2030 alone, SEAI's hourly resolution modelling approach[80] resulted in as much as approximately 3 Mt of additional emissions attributed to gas generation relative to the annual resolution modelling approach employed in the TIM scenarios. In the final iteration, most carbon budget scenarios show no run-hours of gas generation for the majority of CB3 (2031–2035) prior to any BECCS or hydrogen coming on stream. There are also potential additional sources of emissions that are not captured in either modelling approach, for example emissions arising from re-dispatch in the balancing market, which should be considered a possible margin around selected carbon budget trajectories.
- Immediate action on renewable electricity generation is critical to enabling electrification strategies across other sectors. This means that the risk of overestimating the date of reaching an 80% renewable share in electricity has a knock-on impact on emissions reduction achievement elsewhere. Current best estimates indicate a likely underdelivery of renewable generation in comparison with the CAP targets, particularly offshore and onshore wind.
- Lower carbon budget scenarios such as the 250 Mt scenario necessitate the acceleration of technology deployment in electricity generation by a decade before the 350 Mt scenario. The deployment of new installed capacity, increased interconnection and large-scale storage, and transmission and distribution system reinforcement all come with lead times that must be factored in and reduced, where possible, to make even the carbon budget scenarios with a more conservative level of ambition (e.g. 400 Mt) feasible to 2040. Some critical conditions

80 Hourly resolution modelling is the minimum recommended practice for modelling power systems with variable renewable energy. For more information, see https://iea-wind.org/wp-content/uploads/2021/06/RP-16-Ed-2-Wind-PV-Integration-Studies-Final.pdf or https://greeningthegrid.org/Grid-Integration-Toolkit/grid-integration-guidebook/grid-guidbook-pdf.

constraining infrastructure deployment, such as the planning system, labour market and international supply chains, could not be factored into these scenarios.

- All scenarios produced with TIM and reviewed by SEAI rely on emissions removals through CDR technologies, for which the option available in TIM is BECCS. The NEMF-modelled scenarios do not include any CDR technologies out to 2040 at present. This is due to a lack of clarity in current planned policy on the expected capacity and supports for these technologies at scale and, particularly for BECCS, the availability of a sustainable biomass supply. The results of the expert elicitation on CCS capacity demonstrate a significant level of uncertainty on the timing of the availability of this technology. The pooled best estimate from experts is that no CCS will be deployed in the Power sector before 2040, and this remains a significant risk to the feasibility of the carbon budget scenario options.

It is evident that the energy policy package currently under development, as detailed in Ireland's CAPs, is neither sufficient in scale nor delivering quickly enough to keep pace with the changes needed to meet the energy carbon budget scenarios explored by the CBWG. Without an unprecedented bolstering of existing policies and the addition of new policies and measures expanding incentives, enhancing information and applying regulation, Ireland is unlikely to reach its share of the global commitment set out in the Paris Agreement. It is critically important that every effort is made to ramp up both public and private sector capacity to deliver what has been set out in plans so far, to address underlying issues that could further slow progress and to innovate beyond current plans towards a new vision for Ireland's energy economy. Unprecedented technology change must be combined with strong policies and measures to reduce energy demand in all sectors, disincentivise behaviours and practices that incur wasteful energy use, and revolutionise Ireland's economic, market and social systems to meet the needs of people while living within planetary boundaries.

4.4.2. National Transport Authority application of the regional modelling system

4.4.2.1. Introduction and scope of work

Under the terms of the MoU between the Council and all relevant Government departments and agencies,[81] the Council requested input from the NTA to help inform the second and third iterations of modelling work undertaken as part of the second carbon budget programme. The request was for expert review and input from the NTA Transport Modelling Team between May and July 2024 to help inform the assumptions and constraints for the third and final iteration of modelling work being carried out to support the evidence base for the CB Proposal for CB3 and provisional CB4.

The request followed engagement between the NTA and the Council's CBWG that commenced in early 2023. The NTA presented to the CBWG on the Regional Modelling System and its capabilities, as well as some example outputs and use cases, particularly those that had a climate focus, such as the scenario and behaviour change policy testing undertaken as part of the preparation of the Climate Action Plan 2023 (CAP23).[82]

81 Climate Change Advisory Council (2022). Memorandum of Understanding between the Irish Climate Change Advisory Council and All Relevant Government Departments and Agencies.

82 National Transport Authority (2023). Climate Action Plan: Phase 3 Modelling Executive Summary. [online] https://www.nationaltransport.ie/wp-content/uploads/2023/01/Climate-Action-Plan-Phase-3-Modelling-Exec-Summary-v5.6.pdf

The NTA team worked with the UCC TIM Development Team to determine how best to use the NTA's expertise and tools to support the carbon budgets modelling. It was agreed to focus on a number of key transport indicators, namely person-kilometres, tonne-kilometres and vehicle fleet projections for cars, light goods vehicles (LGVs) and heavy goods vehicles (HGVs). It was agreed that the following scenarios be used for comparison, as they were most aligned with the requirements of the CBWG: the UCC reference and LED scenarios and the NTA reference case and CAP23 scenarios for the years 2028, 2030 and 2043. Additional outputs were extracted from scenarios developed using the NTA Irish Freight Model and the Department of Transport Irish Fleet Models (cars, LGVs and HGVs), which are maintained by the NTA. A report was produced to help inform the Council's proposal for carbon budgets.[83]

4.4.2.2. Comparison analysis

Passenger-kilometre comparisons

The total passenger-kilometres are quite similar in both models, with a similar growth trend in their respective base scenarios.[84] This is summarised in **Table 15**, broken down by mode of transport. The NTA CAP23 and UCC LED scenarios for 2030 reflect a necessary shift in passenger-kilometres. A notable difference between the models is the low level of active travel kilometres in all NTA scenarios compared with the UCC LED scenarios. This would suggest that UCC LED levels of active travel kilometres may be too high. An additional point to note is that the NTA reference case scenarios do not provide for the level of change in passenger-kilometres by mode that is required to meet the carbon targets. The CAPs seek to address this as they pivot from reference case scenarios.

Table 15: Percentage of passenger-kilometres travelled by main mode of transport in the NTA and UCC scenarios

	2028			2030			2043		
Mode of transport	NTA reference case	UCC reference	UCC LED	NTA CAP23	UCC reference	UCC LED	NTA reference case	UCC reference	UCC LED
Car	83%	75%	69%	71%	75%	67%	81%	75%	58%
Public transport	14%	17%	20%	25%	17%	21%	15%	17%	27%
Active	4%	8%	11%	5%	8%	12%	4%	8%	15%

83 National Transport Authority (2024). Report on Review by the NTA for the Carbon Budgets Working Group. [online] https://www.climatecouncil.ie/carbonbudgets/

84 It should be noted that an annualisation factor has been applied to the regional modelling system outputs to calculate annual billion passenger-kilometres because the regional modelling system outputs are given for an average 24-hour weekday.

Table 16 summarises the related percentages of trips in three distance ranges, namely short-, medium- and long-distance trips, for both the NTA scenarios and the UCC/TIM scenarios. The TIM assumes constant percentages in each range and scenario as we can see, while the NTA models change slightly across scenarios and are somewhat different from the TIM, especially in the short-distance trips which are also most likely to be made in the active mode of transport.

Table 16: Percentage of passenger kilometres travelled in each of three trip distance ranges

	2028			2030			2043		
Trip range	NTA reference case	UCC reference	UCC LED	NTA CAP23	UCC reference	UCC LED	NTA reference case	UCC reference	UCC LED
Short range (< 5 km)	8%	20%	22%	7%	20%	23%	8%	20%	24%
Medium range (5–30 km)	47%	43%	42%	47%	43%	41%	46%	43%	41%
Long range (> 30 km)	45%	37%	36%	46%	37%	36%	46%	37%	35%

Freight tonne-kilometre comparisons

The NTA freight tonne-kilometres presented in the report are estimates from the recently developed Irish Freight Model and demand management scenarios. These are compared with the UCC scenarios for the years 2022 and 2030. The models have different estimates for 2022, namely 18 billion tonne-km in the Irish Freight Model and 11 billion tonne-km in the TIM. The NTA scenario forecasts a slightly lower rate of growth to 2030 than the UCC scenarios. In addition, the NTA demand management work did not identify a scenario that reduced tonne-kilometres travelled in 2030.

Car stock comparisons

The 2022 car stock levels are quite similar in the two models, which makes comparisons more valid. The NTA reference case car ownership forecasts align with the UCC reference scenario with the fleet increasing by approximately 30%. The NTA CAP23 scenario aligns with the UCC median scenario. The NTA has not created a forecast with a reducing fleet size because the historical data show that car stock almost always increases. The scenario used to develop the NTA CAP23 car fleet mix projections estimates that 30% of the fleet will be battery electric vehicles (BEVs) by 2030 and 90% of the fleet will be BEVs by 2042.

Goods vehicle stock comparisons

The NTA goods fleet models were used to test four goods fleet scenarios for SEAI and EPA WEM and WAM projections work. The four scenarios were used in comparisons with the UCC scenario and are listed below:

- **SYSTRA2022:** new registrations (new and second-hand imports) fixed at 2022 levels; no change in EU mandate targets beyond 2022,
- **SYSTRABG0:** SYSTRA's 'best guess' with 0% growth; no change in EU mandate targets,
- **SYSTRABG3:** SYSTRA's 'best guess' with 3% per year growth; no change in EU mandate targets,
- **SYSTRAUP5:** SYSTRA's 'best guess' with 3% per year growth and an extra 5% added to EU mandate targets.

Note that no new internal combustion engine LGV sales are included post 2035 in all scenarios.

LGV stock comparisons

The NTA LGV definition is different from that used by UCC. The NTA LGV fleet size in 2022 is approximately 320,000, whereas the UCC fleet size is approximately 400,000. This limits our comparisons to the trends rather than absolute numbers.

The NTA 3% growth scenario for the LGV fleet aligns with the UCC reference scenario. In both scenarios the HGV fleet nearly doubles by 2050. The NTA zero growth scenario trend falls between the UCC reference and UCC LED scenarios. The NTA fixed sales scenario trend is similar to that of the UCC LED scenario. In these scenarios the LGV fleet reduces by approximately 25%. In the NTA scenarios, the LGV fleet is estimated to have between 16% and 20% BEVs by 2030 and between 89% and 92% BEVs by 2042.

HGV stock comparison

The NTA HGV definition is different from that used by UCC. The NTA HGV fleet size in 2022 is approximately 80,000, whereas the UCC fleet size is approximately 40,000. This limits our comparisons to the trends rather than absolute numbers.

The 3% growth scenario for the HGV fleet has a similar *rate* of growth to the UCC reference scenario. In both scenarios the HGV fleet nearly doubles by 2050. The NTA no growth scenario trend falls between the UCC reference and UCC LED scenarios. The NTA fixed sales scenario trend is similar to the UCC LED scenario trend. In these scenarios the HGV fleet reduces by approximately 25%. In the NTA scenarios, the HGV fleet is estimated to have between 7% and 10% zero emissions vehicles by 2030 and between 41% and 48% zero emissions vehicles by 2042.

4.4.2.3. Conclusion

In summary, there is good alignment between the data estimated by the NTA and UCC models for passenger-kilometres, tonne-kilometres and fleet. The potential differences that were identified relate to the projected increase in passenger-kilometres in active modes and the projected changes in freight tonne-kilometres, which have not been found to occur in the NTA scenarios. In addition, the NTA car stock scenario development process was not able to develop a scenario that projected a fleet decline.

4.5. Assessing the macroeconomic impact of carbon budgets

An assessment of the macroeconomic impacts of carbon budgets was conducted by Niall McInerney (Central Bank of Ireland) and John FitzGerald (Trinity College Dublin).[85] A summary of this study is provided below. Due to delays in development of the I3E model, ESRI was unable to provide modelling inputs to this report or the CBWG process.

The long-term costs of reaching the National Climate Objective in Ireland by 2050 are relatively limited, because future savings in imports of fossil fuels will largely (or possibly fully) offset the long-term costs of making the change. The biggest burden of adjustment, which will have a negative impact on living standards in Ireland will be between 2025 and 2035. However, even at its peak, the reduction in living standards, conventionally measured, will be quite manageable, probably amounting to between 0.5% and 1% of national income.

This negative impact arises from the need to redirect scarce resources to undertake the necessary climate-related investment. In a near-fully employed economy, of necessity, this will result in some reduction in investment and output in the tradable sector of the economy. However, by the 2040s, once the surge in climate-related investment is almost complete, tradable sector output will bounce back.

The way that Ireland will transition to net zero will be largely through investment in renewable electricity and related technologies. In the Household sector, much of the investment is needed to reduce energy consumption, making alternative carbon-neutral technologies possible (e.g. heat pumps using renewable electricity).

The estimated cost to Ireland of making the transition to a climate-neutral economy is significantly lower than that estimated for Ireland at the time of the first set of carbon budgets[86] because:

- Investment has already been ramped up and, crucially, fossil fuel prices are higher today than in 2021, resulting in higher savings from switching to carbon-free electricity generation.
- Using the Central Bank's macroeconomic model also means that, instead of the assumption in the 2021 study that climate-related investment would fully crowd out other productive investment, a more limited (and realistic) impact on the rest of the economy is estimated.
- The costs of transition in agriculture will probably be less than previously thought based on modelling by Teagasc.

The cost of the transition will be affected by the extent to which the rest of the world follows a similar transition path. If climate investment across the EU and the wider world needs large-scale finance, this will raise interest rates during the peak period of climate adjustment, increasing the cost of funding climate investment.

85 McInerney, N. and FitzGerald, J. (2024). Assessing the Macroeconomic Impact of Carbon Budgets. CBWG Member Report. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

86 Fitzgerald, J. (2021). The Macroeconomic Implications of Carbon Budgets for Ireland. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/documents/cbcbackgroundpapers/MacroEconomicImplications_JF_210914.pdf

While the costs of decarbonising the economy by 2050 seem limited, the major constraint now is the restrictions imposed on new climate-related investment by the regulatory system (including physical planning).

4.6. Climate justice

4.6.1. Introduction

In order to assess the CCAC's carbon budget methodology from an ethical or justice point of view, a methodology termed 'convergent evaluation' was developed.[87] The basic idea is that the role of an ethicist in a policy context is not to apply or espouse their own views but to act as a conduit for the (climate) ethics discipline.

This was done for three of the most important assumptions in the CCAC's Paris Test: (1) global climate targets, (2) carbon budget reference or baseline year and (3) equity principles.

The overall conclusion is that most of these assumptions (with the exception of the late reference year) are at least philosophically plausible (supported by some mainstream position in the literature). However, many of these are not philosophically robust, in the sense that changes in these assumptions would lead to more stringent carbon budgets. In short, from a moral point of view, carbon budgets for Ireland resulting from these Paris Test assumptions should be considered upper bounds.

4.6.2. Methodology

Convergent evaluation first involves identifying the key moral assumptions embedded in policy recommendation exercises. The context here is the Paris Test, as used by the CCAC in its first round of carbon budget planning.[88] Second, it compares various extant positions in the climate ethics literature, by taking a range of relevant and influential published philosophical theories to indicate reasonable or defensible philosophical positions. The goal is to determine how well the embedded assumptions fit the range of positions advocated in the mainstream climate ethics community.

When a moral assumption can be supported by a variety of (independent) philosophical positions, it is called in the report[89] 'philosophically plausible', with more support indicating greater 'philosophical robustness'. When it is outside these positions, it is called in the report 'philosophically objectionable'.[90]

Convergent evaluation can be supported as politically legitimate (since it produces more morally robust views), epistemologically secure (since independent justifications for a convergent view are more trustworthy than one justification) and methodologically objective (since the results are given by a community as opposed to a particular evaluator).

87 Mintz-Woo, K. (2024). Irish Carbon Budgets: Some Moral Considerations [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

88 Price, P.R. et al. (2023). Working Paper No. 19 Carbon Budgets to Inform Climate Action: A Society-wide, Integrated GHG Quota and Accounting Perspective. [online] https://www.climatecouncil.ie/councilpublications/councilworkingpaperseries/Paul%20R%20Price%20Working%20Paper%20No%2019.pdf

89 Mintz-Woo, K. (2024). Irish Carbon Budgets: Some Moral Considerations. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

90 Antecedents to convergent evaluation include Hirose, I. (2023). The Ethics of Pandemics. Abingdon: Routledge; and Rawls, J. (1971). A Theory of Justice. Cambridge: Belknap.

4.6.3. Results

The first morally important assumption of the Paris Test is Paris Agreement-aligned targets. A majority of prominent philosophers endorse the Paris Agreement targets,[91] although some suggest that those limits are insufficiently stringent, especially the philosophers who focus on the attendant likelihoods.[92] Some argue that higher limits than those in Paris Agreement targets are morally objectionable, especially given precautionary approaches.[93] Overall, the Paris-aligned targets are philosophically *robust*, since there is a strong convergence, even among different philosophical positions, on these targets.

The second morally important assumption of the Paris Test is the carbon budget reference year. Peer countries have much earlier reference years (often 1990)[94] than the 2018 and 2021 reference years that the Paris Test adopts. Some take 2015 to be the latest defensible reference year.[95] The relevant philosophical position here is that later reference years implicitly "grandfather in' earlier emissions. Summarising the philosophical literature, Schulan et al. explain that grandfathering is 'typically rejected as unjust' and that 'Generally speaking, philosophers do not defend grandfathering.'[96] Overall, later dates (after 1990) are philosophically objectionable.

The third morally important issue can be discussed in terms of 'equity principles'. In the report, this is divided into two broadly distinct conceptual camps: those focused on justice (especially distributional justice) and those focused on principles of burden sharing.[97] Generally speaking, distributional justice scholars are interested in ideal distributions at a time (hence, 'forward-looking' or abstracted from historical or causal contributions), whereas burden-sharing scholars are more often interested in who is responsible for emissions (hence, 'backward-looking' or reflecting historical emissions or benefits).

In terms of distributional justice, the Paris Test takes the 'metric' (or 'currency') of justice to be emissions and the 'pattern' (or 'shape') of justice to be egalitarian, meaning that there are implicitly

91 For instance, Caney, S. (2016) The struggle for climate justice in a non-ideal world. Midwest Studies in Philosophy 40(1), 9–26; Jamieson, D. (2014). Reason in a Dark Time. Oxford: Oxford University Press; McKinnon, C. (2012). Climate Change and Future Justice: Precaution, Compensation, and Triage. Abingdon: Routledge; and Moellendorf, D. (2014). The Moral Challenge of Dangerous Climate Change: Values, Poverty, and Policy. Cambridge: Cambridge University Press.

92 An important example is Gardiner, S.M. (2023). Climate targets and moral corruption. American Philosophical Association Blog. [online] https://blog.apaonline.org/2023/04/10/climate-targets-and-moral-corruption/

93 McKinnon, C. (2012). Climate Change and Future Justice: Precaution, Compensation, and Triage; Steel, D. et al. (2024). Collapse, social tipping dynamics, and framing climate change. *Politics, Philosophy and Economics* 23(3), 230–251.

94 O'Neill, S. (2023). Working Paper No. 25 Carbon Budgeting in Selected Countries. [online] https://www.climatecouncil.ie/councilpublications/councilworkingpaperseries/FINAL%20WP%2025%20Carbon%20Budgeting%20in%20Selected%20Countries.pdf

95 McMullin, B. et al. (2020). Assessing negative carbon dioxide emissions from the perspective of a national 'fair share' of the remaining global carbon budget. *Mitigation and Adaptation Strategies for Global Climate* 25(4), 579–602.

96 Schulan, A. et al. (2023). Distributive justice and the global emissions budget. *WIREs Climate Change* 14(5), e847.

97 Mintz-Woo, K. (2024). Irish Carbon Budgets: Some Moral Considerations. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

equal per capita emissions allowed.[98] While that is a philosophically plausible pattern, it is only one among many (utilitarian, prioritarian, sufficientarian, etc.) — and several, if not all, of these other patterns would increase the responsibility of Ireland.[99]

In terms of burden-sharing principles — polluter pays, beneficiary pays, ability to pay and polluter pays then receives — adopting any of these would almost certainly increase Ireland's responsibility and decrease its carbon budget.[100] Adopting none of them means that the carbon budgets results are philosophically non-robust. Overall, while emissions egalitarianism is philosophically plausible, it is not robust in a variety of ways.

4.6.4. Conclusion

The Paris Test adopted by the CCAC admirably wears its ethical claims on its sleeve. It still behoves us to understand how those ethical claims stand up in the philosophical discourse. (It is worth noting that the philosophical literature does not address different national (down)scaling climate contribution measures. This lacuna is worth investigated for future working groups.) The main conclusion that convergent evaluation provides is that these assumptions make the resultant carbon budgets moral upper bounds, with alternative assumptions broadly putting more stringent demands on Ireland. Of course, whether or not something is supported by philosophers should not be the end of the discussion. But this evaluation can make a helpful contribution to how Ireland is to proceed in a just and ethical way.

4.7. Socioeconomic impact of carbon budgets and Just Transition

A note on Just Transition was produced for the CBWG by the NESC Secretariat.[101]

There is both a commitment to Just Transition in Irish climate governance and some early embedding in policy but no one approach to apply it to the carbon budget process. What a Just Transition means in practice for policy and governance has been the key focus of recent NESC work to make an abstract concept more concrete. To inform the working group, two presentations and a draft note were prepared, which drew on NESC's previous work on Just Transition, most recently on agriculture and land use. Reflecting Just Transition considerations in the carbon budget narrative and as part of analysis around the potential impacts of the final carbon budget will both be important.

NESC points to some caveats in the concept and use of Just Transition but also to its potential value as part of a social and economic lens through which to consider equity and fairness in the transition

98 For an introduction to justice in climate contexts, see Zimm, C. et al. (2024). Justice considerations in climate research. *Nature Climate Change* 14(4), 22–30.

99 See Zimm et al. (2024) for more about these patterns or read the full report for an extended introduction to both distributional justice and burden-sharing principles: Mintz-Woo, K. (2024). Irish Carbon Budgets: Some Moral Considerations.

100 See the full *Irish Carbon Budgets* report for more about burden-sharing principles or consult Mintz-Woo, K. (2023). Compensation duties, in Handbook of the Philosophy of Climate Change (Pellegrino, G. and Di Paola, M., eds), 779–797.

101 Moore, J. and Garvey, N. (2004). NESC Note on Just Transition to the Carbon Budget Working Group. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

away from fossil fuels. It argues that a bespoke approach is needed for Irish climate policy, finding that no one-size-fits-all approach exists from research into international practice. EU and national policy makers are still grappling with what this broad, holistic approach to Just Transition might look like in practice. Ireland has a Just Transition framework as part of the CAP and is establishing a Just Transition Commission.[102,103] The carbon budget process and the work of the CCAC is an essential part of the climate governance system in Ireland, including how it embeds the Just Transition framework.

The note[104] observes that there is no template for applying Just Transition and no standard indicators to assess or monitor it. It outlines the potential value of principle-based considerations reflecting the four principles in the Government's Just Transition framework. Suggested areas that could be considered include how the outputs/outcomes around the carbon budget – the written reports – frame, communicate and provide context for how the budget is discussed in terms of a Just Transition. In addition, the extent to which the data and analysis that support an integrated, structured and evidence-based approach to identify and plan Ireland's response includes the kinds of evidence that support thinking around fair and equitable outcomes, and reflects on how Just Transition principles can be considered in the process of the carbon budget work – the modelling, scenario analysis and deliberations. The note concludes by identifying some questions to inform the carbon budget process and outputs.

Over time, more metrics on Just Transition may be developed that can help to further embed the concept in the carbon budget process. It is also worth reflecting on how to make room for different perspectives and views on what a Just Transition is and how it can be assessed, acknowledging that it is an emerging and contested space.

4.8. Biodiversity considerations

Biodiversity, including the diverse range of ecosystems, provides us with the range of goods and services on which we depend, including food and fibre provision, water and climate regulation. Biodiversity is in decline in Ireland and globally. The main direct drivers of this decline include land/sea use change, overexploitation, climate change, pollution and invasive non-native species. It is increasingly recognised in policy circles that biodiversity decline and climate change are interconnected challenges, and climate action and protecting biodiversity are mutually supporting goals. However, they are rarely addressed in an integrated manner in practice. There are co-benefits of biodiversity action for climate mitigation and adaptation, while a narrow focus on either climate or biodiversity action can have negative impacts. Climate mitigation and adaptation together with action to reverse biodiversity decline requires transformative societal change. The interrelatedness of biodiversity loss and climate change issues is recognised in the EU Nature Restoration Law, while Ireland's Climate Action and Low Carbon Development (Amendment) Act 2021 explicitly considers biodiversity as an integral part of the National Climate Objective. There is a clear need to ensure that

102 Government of Ireland (2024). Climate Action Plan 2024. [online] https://www.gov.ie/en/publication/79659-climate-action-plan-2024/

103 Department of the Environment, Climate Action and Communications (2024). Report of the Taskforce on Just Transition. [online] https://assets.gov.ie/292132/23f44763-b508-475b-9c25-68889e5d8ec0.pdf

104 Moore and Garvey (2004). NESC Note on Just Transition to the Carbon Budget Working Group. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

climate mitigation and adaptation plans, together with national nature restoration plans under the Nature Restoration Law, are mutually compatible.

CCAC Working Paper No. 33 (*Assessment of Biodiversity Considerations in the Carbon Budget Process*)[105] highlights that policies to address climate change and biodiversity loss are not fully aligned and that the impacts of proposed climate actions on biodiversity are not adequately assessed. There is a clear need for improved policy alignment; for land use change and systemic societal change to combat biodiversity and climate crises; for the development of a national land use strategy underpinned by updated spatial data within a spatial planning framework to manage change; for recognising key uncertainties and knowledge gaps; for increased knowledge generation and sharing; and for ensuring that Ireland does not contribute to biodiversity loss and climate change internationally by off-shoring its impacts through resource exports and imports.

The CBWG report *Biodiversity Considerations for Carbon Budgets 2031–2040*[106] attempts to assess the range of scenarios developed under core modelling work of the CBWG from a biodiversity perspective. It must be noted that these models (the FAPRI-Ireland projections, the Teagasc MACC 2023, TIM and GOBLIN) are not spatially explicit. The impact of various climate mitigation measures on biodiversity under the various scenarios is landscape context dependent, and it is only possible to flag potential impacts under the various model scenarios.

The FAPRI-Ireland projections result in three scenarios with different activity levels, ranging from continued expansion of dairy accompanied by contraction in suckler beef production (S1) to lower activity levels resulting from a larger decrease in suckler cow numbers and more modest increases in dairy cow numbers (S2). S3 is a higher activity projection with larger increases in dairy cow numbers and a modest decline in suckler cow numbers. These projections are combined with two MACC pathways, with increasing levels of ambition in efficiency measures and land diversification, including afforestation, moving from P1 to P2. The impact of the efficiency and diversification measures depends on spatial targeting of measures, together with the ongoing management practice adopted. The various scenarios imply targeted intensification of dairy production in certain areas, with conversion of land for various diversification options in other areas. Improved efficiency without spatial targeting of mitigations will do little to reduce biodiversity risks on both land and water. The scale of impact on biodiversity in some catchments will be substantial as a result of both intensification of agricultural production and land use change. There is a clear need for integrated spatial planning, recognising trade-offs at catchment scale, to realise benefits for terrestrial and aquatic biodiversity.

In the Energy sector, the move away from fossil fuels is positive for biodiversity, as fossil fuel use is associated with indirect biodiversity loss and direct habitat loss and pollution. To date, results from modelling suggest that substantial land use change will be required across forestry, agriculture and renewable energy (including bioenergy) generation. TIM, particularly under high energy demand scenarios, also requires significant CDR, which currently relies on land-based options such as afforestation, improved management of existing forest resources and peatland restoration/improved management. The impacts of various scenarios are difficult to quantify, as much is dependent on the renewable energy generation options pursued and CDR strategies adopted. The regulatory framework

105 Molloy, A. et al. (2024). Working Paper No. 33 Assessment of Biodiversity Considerations in the Carbon Budgets Process. [online] https://www.climatecouncil.ie/councilpublications/councilworkingpaperseries/WP33%20Biodiversity%20for%20web.pdf

106 Moran, J. (2024). Biodiversity Considerations for Carbon Budgets 2031–2040. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

for CDR, particularly emerging and novel CDR technologies, will need to take wider environmental considerations (including biodiversity) into account.

The GOBLIN model also identifies the need for substantial land use change in terms of afforestation (up to 25,000 ha per annum), water table management on organic soils and further intensification of agriculture to release land for other uses. Terrestrial and freshwater biodiversity impacts will depend on the spatial distribution of proposed land use change, ecosystem type/land cover type targeted and existing ecosystem condition.

In conclusion, climate action and nature restoration measures need to be implemented in a manner that maximises synergies and minimises trade-offs. Measures to achieve carbon budgets will have significant impacts on biodiversity (both positive and negative), which will vary across the country based on catchment characteristics/landscape context. Results to date from modelling suggest that substantial land use change will be required across forestry, agriculture and renewable energy generation to meet the National Climate Objective. Biodiversity needs to be explicitly considered in a more holistic integrated land use framework. This will require a national land use strategy coupled with regional/local implementation mechanisms.

4.9. Assessment of the role of negative emissions

The report on the role of negative emissions[107] focuses on the role of CDR in achieving ambitious climate targets, the incomplete representation of CDR methods in modelling frameworks, experience in other EU Member States and potential CDR-related interactions between Irish climate policy and EU climate policy.

Charting out trajectories towards net zero emissions for Ireland necessarily involves some level of CDR, to counterbalance hard-to-abate residual emissions (e.g. from aviation, agriculture or some industrial processes). However, any long-term planning is confronted with the fact that only very few CDR methods are represented in models so far, with afforestation and reforestation being the only ones deployed at a meaningful scale and many 'novel' methods currently at relatively low readiness levels.

The GOBLIN model and TIM use considerable amounts of CDR until 2050 and beyond. In GOBLIN, the combined trajectories (gross emissions and gross removals) in the LULUCF sector seem very optimistic, given the experience with declining net LULUCF sinks in other EU Member States, in the face of an already changing climate. For CDR methods beyond forestry, it may be wise to consider emerging options such as biochar and enhanced rock weathering in both future modelling efforts and policy assessment. Deployment of BECCS is shown in GOBLIN calculations but should be reported only in TIM scenarios (in the sectors with BECCS installations), in line with existing national inventory reporting.

TIM is using BECCS across all scenarios but seemingly only in the Power sector. In other Organisation for Economic Co-operation and Development countries, BECCS is also discussed and modelled in the Industry sector and in waste incineration plants, which may emerge as real-world options in Ireland as well – as will direct air CCS (already indicated in the energy modelling report[108] and modelled in

107 Geden, O. (2024). Carbon Budgets Working Group – Final Report. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

108 Daly, et al. (2024). Pathways for Ireland's Energy System to 2050: Modelling analysis to support the Climate Change Advisory Council on the second carbon budget programme. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

several countries and for the European Commission). Other novel CDR options have been tried and tested in other countries already and may emerge in modelling frameworks soon. But, given their currently very low deployment levels around the world,[109] it is at this point impossible to robustly assess what volumes of CDR could be delivered, in which countries, at what costs and with what effects and/or co-benefits.

Finally, it is foreseeable that the EU will increasingly regulate CDR, for example by integrating it into its Emissions Trading System (ETS) I. But, beyond more detailed regulation, CDR will also play a role in the 'political economy' of EU climate policy, which may lead to tensions between Irish and EU climate policy and/or to more stringent obligations for Ireland than currently expected – stemming from the (potential) use of different emission metrics in Ireland and the EU (GWP* vs GWP_{100}, which will affect the CDR volumes needed), future decisions about the basic pillars of EU climate policy (continuation of national effort sharing targets vs Agri-ETS) and EU net-negative emissions targets post 2050.

4.10. EPA report to CBWG secretariat

This report is in response to a request from the secretariat of the CCAC for short reports from each of the organisations participating in the CBWG, a working group set up by the Council to focus on the assessment of evidence for the CB Proposal for CB3 and provisional CB4 (2031–2035 and 2036–2040, respectively). Representatives of the EPA Climate Programme participated in the working group, from the first meeting in Q1 2023 until the final meeting in Q3 2024, and this report summarises some of their notes and observations together with some background information on the EPA data used by the other modelling teams on the CBWG.[110] The report serves to highlight key considerations for the setting of CB3 and provisional CB4, as emerged in the evidence presented to the CBWG over the course of its term.

4.10.1. EPA data and role

The GHG emissions inventory and projections reports produced annually by the EPA are referred to in the Climate Act 2021 as 'the Agency's reports' that the Minister is obliged to consider annually in relation to compliance with the carbon budgets. In addition to assessment of compliance with carbon budget targets, the Minister is obliged by the Act to take account of these reports in the setting and review of carbon budgets, along with consideration of consistency with EU and UN Paris Agreement obligations.

The EPA representatives on the CBWG participated fully in discussions on all topics, with their primary roles being:

- provision of data related to EPA GHG emissions inventory and projections,
- guidance on the use or interpretation of emissions data provided by the EPA,
- sharing of relevant research and insights available to the EPA,
- critique and assessment of the evidence and modelling provided to the CBWG.

109 Smith, S. et al. (2024). The State of Carbon Dioxide Removal 2024. [online] https://static1.squarespace.com/static/633458017a1ae214f3772c76/t/665ed1e2b9d34b2bf8e17c63/1717490167773/The-State-of-Carbon-Dioxide-Removal-2Edition.pdf

110 Environmental Protection Agency (2024). EPA Report to Carbon Budgets Working Group Secretariat. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

It is important that the modelling used to inform the proposal for future carbon budgets is as consistent as possible with the scope, approach and emissions factors used in the EPA inventory and projections, given their role in the setting and review of carbon budgets, as defined in the Climate Act 2021.

The EPA projections are built on the foundation of the macroeconomic and energy modelling provided by ESRI and SEAI, together with modelled scenarios from Teagasc for the Agriculture sector. There is therefore consistency of approach between the three sets of model outputs (I3E from ESRI, NEMF from SEAI, FAPRI-Ireland from Teagasc) and the two scenarios produced by the EPA. The I3E, NEMF and FAPRI-Ireland models are also used to produce additional scenarios for the purpose of the carbon budgeting work, but the approaches and emissions factors used continue to be consistent with those used for the EPA projections.

Two emissions projections scenarios are presented in the EPA GHG emissions projections, published in May 2024, which show two potential outlooks to 2050, depending on policy development and implementation. These are:

- WEM – a scenario incorporating the anticipated impact of policies and measures in place by end 2022,
- WAM – a scenario incorporating both implemented and planned measures, including the majority of those in the 2024 CAP.

In relation to the emissions and removals associated with the LULUCF sector, the EPA engaged extensively with the relevant carbon budget modelling teams to ensure the necessary understanding of the approaches used in compiling the GHG inventory and projections. Significant uncertainties remain in relation to the emissions/removals from the LULUCF sector as a result of ongoing improvements to emission factors and activity data availability; however, the modelling presented to the CBWG represents the current state of knowledge.

For two smaller source sectors (waste and fluorinated gases), the models used for investigating the temperature impact of proposed carbon budgets did not have good coverage or a strong basis for estimation. For this reason, the EPA provided the detailed sectoral data from the latest EPA projections to the carbon budget modelling teams to ensure full coverage of emissions sources for assessing budget pathways and projected temperature impact. Details of how the projections are prepared for these sectors is provided in technical reports submitted to the EU as part of the projections reporting process, and that information is summarised in this report for transparency.

4.10.2. Modelling and evidence for CB3 and provisional CB4

The modelling of possible carbon budgets for CB3 and provisional CB4, consistent with the National Climate Objective goals, was the largest block of work performed by modelling teams and presented to the CBWG. This work involved combining the emissions scenarios from several models and then assessing the temperature impact of the modelled scenarios to consider how well the resulting carbon budget pathways met the constraints of climate neutrality and other international aims/targets.

Three core models were used to produce these scenarios: TIM maintained by UCC, the FAPRI-Ireland model maintained by Teagasc and the GOBLIN model maintained by the University of Galway. Temperature impacts of modelled scenarios were then assessed by a team from UCD using simple climate models.

This process allowed the identification of those scenarios that are consistent with national objectives and the Paris Agreement goals but still left open for consideration additional criteria such as biodiversity implications, Just Transition, macroeconomic impacts and other international approaches.

A number of key points were clear to the EPA representatives from the evidence presented to the CBWG, including:

- As noted by the IPCC in its AR6, CDR is required in all global scenarios to counterbalance hard-to-abate residual emissions to achieve net zero GHG emissions and limit temperature increases. This also applies to Ireland, with a particular focus to date on traditional CDR methods such as forestry. The evidence presented to the CBWG highlighted that there is very little CDR currently from 'novel' methods such as direct air capture with carbon capture and storage, biochar and BECCS, with most still at the research and innovation stage.
- Substantial land use change will be required to facilitate changes in forestry and agriculture and to fulfil the need for renewable energy generation to achieve climate targets. Ireland's land can be used in ways that support climate action, nature restoration, protection of water quality and a sustainable economy, taking a holistic and integrated view across all the social, economic and legislative demands on the land. The national Land Use Review has a vital role to play in identifying land use opportunities and constraints, and stakeholders need to be engaged in decisions that impact them.
- At present, given the latest energy demand trajectory, there is little evidence to suggest energy demand moderation being achieved in the short term, as there is currently little (implemented or planned) policy that is likely to reduce energy demand significantly prior to 2030. The energy modelling presented to the CBWG, however, indicates that moderating final energy demand is necessary to meet most carbon budget scenarios, particularly in the case of overshoot. This will be a significant challenge to achieve in a country experiencing considerable economic and population growth and also fast-growing energy demand from large energy users such as data centres.
- The evidence from the macroeconomic analysis highlighted the challenges in delivering new infrastructure in an economy that is close to full employment. Capacity constraints in the economy and labour market are expected to add to transition costs due to inflationary pressures, particularly on wages in the Construction sector.
- There is no internationally agreed definition of what Ireland's 'fair share' of the remaining global carbon budget should be, and many 'fair share' budget proposals may not be technically feasible for Ireland. One approach to this problem, which should be assessed in more detail for Ireland's setting of carbon budgets, is that proposed by the ESABCC in relation to the EU's 2040 targets. This approach is to propose the smallest feasible budget or very close to it. This improves the fairness of the EU's contribution, and the ESABCC deemed that addressing the feasibility/fairness shortfall was important as part of the EU's commitment to the Paris Agreement temperature goal.
- The EU emissions reduction target proposed by ESABCC for the EU is an emissions reduction range of 90–95% by 2040 compared with 1990, corresponding to a GHG budget of 11-–14 Gt CO_2 e over the period 2030–2050. While this is important to consider in the context of Ireland's carbon budgets, it should be noted that it is an EU-wide target and individual country targets have not yet been agreed. The significance of the Agriculture sector in Ireland, in

particular livestock agriculture with its resulting in methane emissions, will be a consideration in determining Ireland's individual target. The filtered scenarios assessed in the ESABCC scientific advice report, on which its EU 2040 target proposal is based, generally achieve methane emissions reductions in the Agriculture sector of 15–40% between 2019 and 2040.

The question of whether short-lived climate forcers (specifically methane in Ireland's case) should be part of a net zero GHG emissions target by 2050 remains a key point to be addressed, as it has implications for the carbon budget and the amount of CDR required. While the European Climate Law targets include short-lived climate forcers in the 2050 net zero GHG emissions target, Ireland's latest long-term strategy does not. The IPCC's AR6 anticipates that deep reductions in global agricultural methane emissions will be required by 2050 in scenarios that keep warming below 1.5°C. It should be noted that the IPCC is modelling global average reductions and that the expectations for individual countries would vary for reasons including current production efficiency, ability to pay, etc.

4.11. Scenario Dialogue Tool

The Scenario Dialogue Tool (SDT) was developed by the CCAC Secretariat and introduced to the CBWG members at the April CBWG meeting (**Appendix 1, Meeting 13**). The main objective of the SDT was to provide members with a platform, in addition to their individual member report, to comment on specific emissions scenarios modelled by the CBWG core modelling teams. The tool was designed to assist the collation and presentation of the broader implications of modelled scenarios, taking into consideration inter alia criteria outlined in the Climate Action and Low Carbon Development (Amendment) Act 2021 that the CCAC should take account of when proposing carbon budgets. These criteria included impacts and opportunities, CDR, employment, investment and the economy, biodiversity, Just Transition and climate justice. The tool was complementary to the individual CBWG member reports and available to members to populate with supplementary information if they wished to do so. The SDT is published and available on the Climate Change Advisory Council website.[111]

111 Scenario Dialogue Tool (Excel spreadsheet). [online] https://www.climatecouncil.ie/aboutthecouncil/carbonbudgetsworkinggroup/

5. Summary of CBWG inputs, discussions and outputs to inform Council's considerations under the Act

Article 6A of the Act outlines the criteria that the Council shall take account of while carrying out its functions for the preparation of a CB Proposal. This includes carrying out its function in a manner that:

- 'is consistent with the ultimate objective specified in Article 2 of the United Nations Framework Convention on Climate Change done at New York on 9 May 1992', including:
  - 'any mitigation or adaptation commitments entered into by the European Union in response or otherwise in relation to that objective,
  - the steps specified in Articles 2 and 4(1) of the Agreement done at Paris on 12 December 2015 to achieve that objective',
- 'which takes account of:
  - the most recent national greenhouse gas emissions inventory and projection of future greenhouse gas emissions, prepared by the Agency,
  - relevant scientific advice, including with regard to the distinct characteristics of biogenic methane,
  - international best practice on the reporting of greenhouse gas emissions and removal,
  - in so far as practicable, the need to maximise employment, the attractiveness of the State for investment and the long-term competitiveness of the economy'.

To assist the Council in its consideration of these mandated criteria, the CBWG considered relevant inputs to assist with the completion of the relevant member reports (see **Section 4**) and scenario dialogue tool (see **Section 4.11**). The following sections outline the documents considered by the CBWG that are relevant to each of these mandated criteria.

5.1. Consistency with objective of Article 2 of the UNFCCC

To inform the Council, the CBWG considered consistency of scenarios with the ultimate objective specified in Article 2 of the UNFCCC (see **Table 17**). Temperature analysis was conducted on each of the three iterations of core scenario emissions outputs using simple climate models.

5.2. Consideration of national emissions inventory and projections

To assist the Council, the modelling of carbon budget scenarios was calibrated to and informed by data from the EPA inventory and projections. The national inventory undergoes continual updating and revisions to take account of improved scientific understanding and improved activity data. Refinements and revisions to the inventory are ongoing and reduce the uncertainty associated with the inventory. The work of the CBWG accounted for refinements and revisions to the inventory (see **Table 18**).

Table 17: Documents and discussions related to Article 2 of the UNFCCC

Document number	Document name	Category	Date
1.05	2.3 Technical report on carbon budgets 25.10.2021	Report	Mar-23
1.10	Carbon Budgeting Research Fellowship-Presentation 09.03.2023	Presentation	Mar-23
3.04	2.1 Secretariat Note on a Vision for 2050	Briefing note	May-23
3.05	2.2 Secretariat Note on Long Term Strategy For Greenhouse Gas Emissions Reductions	Briefing note	May-23
10.04	IEA A Global Pathway to Keep the 1.5 °C Goal in Reach-Presentation 18.01.2024	Presentation	Jan-24
10.05	Warming impact of national emissions pathways-Presentation 18.01.2024	Presentation	Jan-24
11.04	Victorian Emission Budgets-Presentation 29.02.2024	Presentation	Feb-24
11.06	The EU Climate target for 2040-Presentation 29.02.2024	Presentation	Feb-24
15.04	Warming impact of national emissions scenarios 2-Presentation 28.06.2024	Presentation	Jun-24
18.04	Warming impact of national emissions scenarios 3-Presentation 18.09.2024	Presentation	Sep-24

Table 18: Documents and discussions related to national emissions inventory and projections

Document number	Document name	Category	Date
3.04	2.1 Secretariat Note on a Vision for 2050	Briefing note	May-23
3.05	2.2 Secretariat Note on Long Term Strategy For Greenhouse Gas Emissions Reductions	Briefing note	May-23
7.05	EPA Projections process and modelling methods-Presentation 19.10.2023	Presentation	Oct-23
7.06	SEAI National Energy Projections Process – Input to EPA Projections-Presentation 19.10.2023	Presentation	Oct-23
7.08	Carbon budgeting under framework climate laws: analysing diversity in national practice-Presentation 19.10.2023	Presentation	Oct-23
11.03	CB WG Meeting 11-Presentation 29.02.2024	Presentation	Feb-24
16.03	CB WG Meeting 16-Presentation 25.07.2024	Presentation	Jul-24

5.3. Relevant scientific advice including biogenic methane

The appointment of the members of the CBWG was made in view of candidates' access to and experience in relation to appropriate models and expertise that would provide a sufficient evidence base for the Council to finalise its CB Proposal for CB3 (2031–2035) and a provisional CB4 (2036–2040). Members of the CBWG and external contributors were invited to present to the CBWG on relevant scientific issues, including biogenic methane (see **Table 19**).

Table 19: Documents and discussions related to relevant scientific advice including biogenic methane

Document number	Document name	Category	Date
1.05	2.3 Technical report on carbon budgets 25.10.2021	Report	Mar-23
2.06	3.1 Topics List	Draft document	Apr-23
3.06	Introduction to the TIMES-Ireland Model (TIM)-Presentation 31.05.2023	Presentation	May-23
3.07	GOBLIN: A land-balance model to identify national land sector pathways to climate neutrality-Presentation 31.05.2023	Presentation	May-23
3.08	FAPRI-Ireland Model of the Irish Agricultural Economy-Presentation 31.05.2023	Presentation	May-23
4.05	SEAI National Energy Modelling Framework Overview-Presentation 29.06.2023	Presentation	Jun-23
5.04	2.1 Secretariat Note on Methane	Briefing note	Jul-23
5.05	Irish Carbon Budgets: Methane-Presentation 27.07.2023	Presentation	Jul-23
5.06	Methane policy targets-Presentation 27.07.2023	Presentation	Jul-23
5.07	3.1 Mintz-Woo (2023) Compensation Duties	Submission	Jul-23
5.08	Regional Modelling System (RMS)-Presentation 27.07.2023	Presentation	Jul-23
5.09	Forestry models-Presentation 27.07.2023	Presentation	Jul-23
WS.03	GOBLIN Scenarios for carbon budgets towards 2050-Presentation 13.09.2023	Presentation	Sep-23
WS.04	Scenario Development for 2nd Carbon Budget Programme FAPRI-Ireland Modelling-Presentation 13.09.2023	Presentation	Sep-23
WS.05	Carbon budget scenario development with TIMES-Ireland Model-Presentation 13.09.2023	Presentation	Sep-23
7.04	4.1 Carbon Budgets Workshop Outcome Report	Report	Oct-23

Document number	Document name	Category	Date
8.04	4.1 Secretariat Note on Agriculture and Land Use	Briefing note	Nov-23
8.06	Biodiversity considerations of carbon budgets developments-Presentation 23.11.2023	Presentation	Nov-23
8.07	Carbon Budgets Working Group Agriculture and Land Use-Presentation 23.11.2023	Presentation	Nov-23
9.05	GOBLIN Scenarios for carbon budgets towards 2050-Presentation 15.12.2023	Presentation	Dec-23
9.06	Energy system pathways for carbon budgets: First iteration of TIM scenarios-Presentation 15.12.2023	Presentation	Dec-23
9.07	Teagasc FAPRI-Ireland Projections and MACC-Presentation 15.12.2023	Presentation	Dec-23
10.04	IEA A Global Pathway to Keep the 1.5 °C Goal in Reach-Presentation 18.01.2024	Presentation	Jan-24
10.06	SEAI Review of Carbon Budget Modelling 1st Iteration Outputs-Presentation 18.01.2024	Presentation	Jan-24
11.04	Victorian Emission Budgets-Presentation 29.02.2024	Presentation	Feb-24
11.05	Overview of Research on Ireland's Power Sector-Presentation 29.02.2024	Presentation	Feb-24
11.06	The EU Climate target for 2040-Presentation 29.02.2024	Presentation	Feb-24
11.07	2. Meinshausen & Nicholls 2022 GWP*	Submission	Feb-24
12.04	Non-CO2 greenhouse gas reductions implied by IPCC estimates of the remaining carbon budget-Presentation 22.03.2024	Presentation	Mar-24
12.05	2. Rogelj&Lamboll 2024, Non CO2 gases	Submission	Mar-24
13.04	Decarbonised Electricity System Study-Presentation 19.04.2024	Presentation	Apr-24
13.05	Agriculture & LULUCF Research Overview: Emissions and Mitigation-Presentation 19.04.2024	Presentation	Apr-24
14.04	GOBLIN Scenarios for carbon budgets towards 2050-Presentation 23.05.2024	Presentation	May-24
14.05	Energy system pathways for carbon budgets: Second iteration of TIM scenarios-Presentation 23.05.2024	Presentation	May-24
14.06	Agricultural Activity and Agricultural GHG projections to 2050-Presentation 23.05.2024	Presentation	May-24
15.07	Expert elicitation on plausible deployment rates of generation technologies in Ireland 2024 – 2040-Presentation 28.06.2024	Presentation	Jun-24

Document number	Document name	Category	Date
15.08	4. SEAI Note on Renewables Deployment Rates	Report	Jun-24
15.09	4. SEAI Note on Value of Expert Elicitations	Report	Jun-24
15.10	4. SEAI Note on Power Sector Technology Deployment Rates	Report	Jun-24
15.12	6.1 GOBLIN Scenario Narratives	Submission	Jun-24
15.13	6.2 TIM Scenario Narratives	Submission	Jun-24
16.04	2.1 Assessment of Biodiversity Considerations	Report	Jul-24
16.06	Modelling analysis to support the development of the second programme of Carbon Budgets-Presentation 25.07.2024	Presentation	Jul-24
16.07	Carbon Budgets Modelling Second Iteration – NEMF Additional Testing-Presentation 25.07.2024	Presentation	Jul-24

5.4. International best practice on reporting greenhouse gas emissions and removal

The Act requires the Council to take account of 'latest Inventories, Projections and Best Practice Reporting of Emissions and Removals'. Consideration of this was taken into account when preparing the thematic sessions and relevant discussions. To assist the Council, the CBWG considered these in its discussions and modelling (see **Table 20**).

5.5. Considerations on employment, investment and competitiveness of the economy

The Council must consider, in so far as is practicable, the need to maximise employment, the attractiveness of the State for investment and the long-term competitiveness of the economy. Modelling teams considered this in the range of scenarios that were produced, and members with economic and macroeconomic expertise facilitated discussions and analysis. Expert contributors were invited to present at relevant thematic sessions (see **Table 21**).

Table 20: Documents and discussions related to international best practice on reporting GHG emissions and removal

Document number	Document name	Category	Date
7.05	EPA Projections process and modelling methods-Presentation 19.10.2023	Presentation	Oct-23
7.06	SEAI National Energy Projections Process – Input to EPA Projections-Presentation 19.10.2023	Presentation	Oct-23
7.08	Carbon budgeting under framework climate laws: analysing diversity in national practice-Presentation 19.10.2023	Presentation	Oct-23
8.05	Carbon Dioxide Removal and its integration in European Union Climate Policy-Presentation 23.11.2023	Presentation	Nov-23
9.04	UNFCCC COP28 Paris Agreement GST Global Stocktake Outcomes Focus on Mitigation elements-Presentation 15.12.2023	Presentation	Dec-23
10.04	IEA A Global Pathway to Keep the 1.5 °C Goal in Reach-Presentation 18.01.2024	Presentation	Jan-24
11.04	Victorian Emission Budgets-Presentation 29.02.2024	Presentation	Feb-24
11.06	The EU Climate target for 2040-Presentation 29.02.2024	Presentation	Feb-24
15.11	5.1 Secretariat Note on Aviation and Maritime	Briefing note	Jun-24
18.10	Follow on discussion on Carbon Dioxide Removal Considerations-Presentation 18.09.2024	Presentation	Sep-24

5.6. Climate justice

The Council is to have regard to climate justice when carrying out its functions in proposing carbon budgets. Experts in climate justice were appointed to the CBWG to facilitate discussions and relevant thematic sessions were held (see **Table 22**).

Table 21: Documents and discussions related to employment, investment and competitiveness of the economy

Document number	Document name	Category	Date
2.08	Dingle Project-Presentation 20.04.2023	Presentation	Apr-23
4.06	Modelling the Macroeconomic Impact of Carbon Budgets using COSMO-Presentation 29.06.2023	Presentation	Jun-23
4.07	The Ireland Environment, Energy and Economy (I3E) Model-Presentation 29.06.2023	Presentation	Jun-23
4.08	2. ESRI I3E Note 29.06.2023	Submission	Jun-23
6.04	CSO Population Projections-Presentation 08.09.2023	Presentation	Sep-23
6.05	Demographic Projections-Presentation 08.09.2023	Presentation	Sep-23
6.06	The National Planning Framework First Revision-Presentation 08.09.2023	Presentation	Sep-23
6.07	Approaching Just Transition in Practice-Presentation 08.09.2023	Presentation	Sep-23
7.07	The Role of I3E in the NEMF-Presentation 19.10.2023	Presentation	Oct-23
10.07	Preparing for macroeconomic assessment: Data requirements-Presentation 18.01.2024	Presentation	Jan-24
11.05	Overview of Research on Ireland's Power Sector-Presentation 29.02.2024	Presentation	Feb-24
15.05	The Macroeconomic Impact of Carbon Budgets in a Semi-Structural Model of the Irish Economy-Presentation 28.06.2024	Presentation	Jun-24
16.06	Modelling analysis to support the development of the second programme of Carbon Budgets-Presentation 25.07.2024	Presentation	Jul-24
16.07	Carbon Budgets Modelling Second Iteration – NEMF Additional Testing-Presentation 25.07.2024	Presentation	Jul-24
18.05	3.1 Economic assessment of climate change impacts and adaptation options	Report	Sep-24
18.06	Using COSMO to assess Macroeconomic Impact of Carbon Budgets-Presentation 18.09.2024	Presentation	Sep-24
18.07	Climate Impacts and Adaptation in Ireland-Presentation 18.09.2024	Presentation	Sep-24
18.08	Macroeconomic implications of implementing carbon budgets-Presentation 18.09.2024	Presentation	Sep-24
18.12	De Bruin et al. (2024) Macroeconomic impacts of climate-induced damages in Ireland: A CGE analysis of secondary impacts. ESRI Working Paper No. 789 pp 23	Submission	Sep-24
18.13	De Bruin et al. (2024) Interactions between climate change mitigation, damages, and adaptation: An intertemporal Computable General Equilibrium analysis for Ireland. ESRI Working Paper No. 790 pp 23	Submission	Sep-24

Table 22: Documents and discussions related to climate justice

Document number	Document name	Category	Date
4.09	Irish Carbon Budgets: Some Moral Considerations-Presentation 29.06.2023	Presentation	Jun-23
6.07	Approaching Just Transition in Practice-Presentation 08.09.2023	Presentation	Sep-23
9.08	4.1 Mintz-Woo Note on Irish Carbon Budgets: Some Moral Considerations	Briefing note	Dec-23
13.06	4.1 NESC Note on Just Transition April 2024	Briefing note	Apr-24
13.07	Just Transition Reflections for Carbon Budget Process: A Principles-Based Approach-Presentation 19.04.2024	Presentation	Apr-24

Appendix 1: Meeting summaries

The CBWG met 19 times, including 18 scheduled monthly meetings over the course of March 2023 to September 2024 and one workshop in September 2023. The CBWG meeting agenda, minutes and all other publications are available on the CCAC website. In general, each meeting started with the approval of the minutes from the preceding meeting and a review of the action log and risk register, followed by presentations and discussions in line with the agenda. Agenda standing items included carbon budgets methodology, carbon budgets work plan and discussions on thematic topics. Thematic topics for discussion were agreed with the CBWG in advance of meetings and are summarised in **Table 23**. Each meeting ended with the agreement of actions and agenda items for the subsequent meeting and any other business. Presentation slides were circulated to members of the CBWG following each meeting. The action log from the meetings is presented in **Appendix 2** and the risk register is included in **Appendix 3**. The main agenda items and the discussions held at each meeting are summarised in the following subsections.

Table 23: Meeting summaries 2023–2024

Meeting number	Date	Thematic topics discussed
1	9 March 2023	▶ Carbon budgets methodology
2	20 April 2023	▶ Carbon budgets methodology ▶ Scoping of modelling work ▶ ESB Networks' Dingle Project
3	31 May 2023	▶ Vision for 2050 and beyond ▶ Scoping of modelling work
4	29 June 2023	▶ Scoping of modelling work ▶ Macroeconomic impacts of carbon budgets ▶ Climate justice and 'Paris Test'
5	27 July 2023	▶ Focused discussion on methane ▶ Ethics of methane emissions and climate change ▶ Scoping of modelling work
6	8 September 2023	▶ Population projections ▶ Approaching Just Transition in practice
Workshop	13 September 2023	▶ Building blocks for scenarios for CB3 and provisional CB4 ▶ Scenario development for second programme of carbon budgets ▶ Competing land use requirements ▶ Agreement of inputs, parameters and assumptions for first iteration of modelling
7	19 October 2023	▶ 2024 EPA projections process ▶ International approaches to carbon budgeting

Meeting number	Date	Thematic topics discussed
8	23 November 2023	▶ CDR and negative emissions technologies ▶ Biodiversity considerations ▶ Agriculture and land use review
9	15 December 2023	▶ COP28 – global stocktake ▶ Presentation of first iteration of core modelling results ▶ Irish carbon budgets: some moral considerations
10	18 January 2024	▶ IEA Net Zero Roadmap 2023 update ▶ Analysis of warming impact of selected core scenarios (first iteration) ▶ Additional testing of scenario results ▶ Update on economic and macroeconomic analysis
11	29 February 2024	▶ Quantitative approaches to carbon budgeting ▶ Energy and power systems modelling ▶ ESABCC scientific advice for EU-wide 2040 climate target ▶ Council feedback on first iteration of modelling
12	22 March 2024	▶ Discussion on methane and climate neutrality ▶ Discussion on potential National Transport Authority analysis for carbon budgets ▶ Agreement of inputs, parameters and assumptions for second iteration of modelling
13	19 April 2024	▶ Decarbonised Electricity System Study ▶ Research on mitigation options available to agriculture ▶ Just Transition principles and considerations in the carbon budget process
14	23 May 2024	▶ Presentation of second iteration of core modelling results
15	28 June 2024	▶ Analysis of warming impact of selected core scenarios (second iteration) ▶ Decarbonised Electricity System Study ▶ Aviation and maritime emissions
16	25 July 2024	▶ Biodiversity considerations ▶ Energy and transport additional modelling ▶ Agreement of inputs, parameters and assumptions for third iteration of modelling
17	29 August 2024	▶ Presentation of third iteration of core modelling results ▶ Biodiversity considerations
18	18 September 2024	▶ Analysis of warming impact of selected core scenarios (third iteration) ▶ Macroeconomic modelling results ▶ Additional testing of scenario results ▶ Economic assessment of climate change impacts and adaptation options ▶ Carbon dioxide removals and carbon budgets

Meeting 1 – 9 March 2023

Introduction and scene setting

The Secretariat outlined the membership and remit of the Council and provided the background to the methodology used in the first carbon budget programme. The CBWG terms of reference (ToR) and the technical report from the first programme of carbon budgets had been circulated in advance for information. The need for inputs in relation to population growth was noted, along with the requirement for climate science expertise, which could come from an international member and/or future speakers. Studies looking at mobilisation of society such as the ESB Networks' Dingle Project were also flagged as important inputs for consideration.

Carbon budgets methodology and topics for meetings

The Secretariat outlined potential pathways development and sectoral analysis under the range of carbon budgets. The working group discussed the carbon budgets methodology in detail, particularly in relation to potential gaps. Caution regarding modelling uncertainty, particularly for longer term measures in the Land Use sector, was noted. The need for due consideration of Just Transition and modelling for land use changes, the need for clarity on 2050 goals and the future need for negative emissions and carbon removal were discussed. Discussions were had on the impacts of potential adjustments to the historical inventory for the 2018 baseline and the scope to consider maritime and aviation emissions. The analysis of macroeconomic impacts of carbon budgets was expanded to also quantify the potential economic benefits and opportunities of transition pathways. There was a reframing of the socioeconomic impacts to focus on broader societal impacts and Just Transition. Finally, biodiversity considerations were expanded to also account for impacts of forestry targets on biodiversity and obligations under the Global Biodiversity Framework and the EU Nature Restoration Law.

Overview of meeting schedule and feedback

The Secretariat presented a proposed schedule and planning for CBWG meetings in 2023. It was suggested that the scope of the Vision for 2050 paper would be extended beyond 2050 and that discussions on macroeconomics and socioeconomics would be split into two distinct sessions.

Memorandum of Understanding between the CCAC and relevant Government departments and agencies

The Secretariat advised that initial requests for modelling capacity for the second CB Proposal had been sent out to appropriate departments and agencies, with more detailed follow-up requests to follow in Q2 2023.

Carbon budget research fellows

Following agenda item 6 (next steps and agenda for next meeting) presentations were made by carbon budget research fellows Paul Price from Dublin City University and Andrew Smith from UCC on research findings and outputs from their fellowships. Aideen O'Dochartaigh and Barry McMullin, supervisors of Paul Price's fellowship, also joined for this agenda item.

Meeting 2 – 20 April 2023

Carbon budget methodology

The CB Proposal 2 methodology was updated following the discussions had during meeting 1 in March and shared with the working group for review and comment. No additional comments were made on this updated document. The recent publication of the draft Stability Programme Update incorporating the Department of Finance's spring forecasts and its different migration scenarios and their implications for emissions were noted as relevant to this work.

Carbon budgets work plan and topics for meetings

An updated draft work plan and a document with proposed thematic topics had been circulated in advance of the meeting for review and comment. The Secretariat outlined the proposed work plan and schedule of topics, which had been updated further to the discussions at the first meeting of the group. Discussions were held around the proposed work plan, with a positive response to a modelling workshop in September to include representatives involved in preparing macroeconomic projections. The importance of early consideration of biodiversity constraints, macroeconomic drivers, Just Transition and land use change was noted. Potential difficulties of incorporating 2024 projection data and the National Biodiversity Action Plan in the modelling work plan were raised.

Scoping of modelling work

An overview of scenarios considered for CB1 and CB2 was presented by the Secretariat. Sequencing of models that will be used was discussed, with the three proposed iterations of the modelling noted as providing a useful basis for integrating parallel streams of modelling work. The timelines of CSO population projections were outlined and the importance of projections and implications in the Energy sector, manufacturing and housing development was discussed.

ESB Networks' Dingle Project

A presentation was made by Fergal Egan from ESB Networks on the recently completed Dingle Project that including testing of renewable technologies in people's homes. The importance of trusted sources of information, community engagement and affordability of interventions were raised.

Meeting 3 – 31 May 2023

Oliver Geden, Head of Research Cluster Climate Policy and Politics at the German Institute for International and Security Affairs, was welcomed as a new member of the CBWG, bringing expertise in international climate policy and CDR.

Vision for 2050 and beyond

The Secretariat's Vision for 2050 working paper was circulated in advance of the meeting for review and comments. Comments were received from the working group, particularly on the challenges for the specification of an end point in 2050 and the maintenance of sustainable climate neutrality following this point. The Secretariat's note on Ireland's Long-term Strategy on Greenhouse Gas Emissions Reduction was circulated for information and discussed. Challenges surrounding the specification of an emissions end point scenario in 2050 and the maintenance of sustainable climate neutrality following this point were raised.

Carbon budgets work plan

The requirement to consider Just Transition in the carbon budgets process and Ireland's Long-term Strategy, along with production and consumption-based accounting, was discussed.

Scoping of modelling work

An overview of the schedule of modelling work was provided. Modelling overview presentations were given by researchers from the core models to be used: Hannah Daly on the TIM, Kevin Hanrahan on the Teagasc FAPRI-Ireland model and David Styles on the GOBLIN model. Priority questions around start and end points of scenarios were highlighted. The ways of representing land use and biodiversity were raised, with recommendations to include in the modelling workshop discussion. Future work on climate impacts and adaptation was discussed. The importance of a future discussion on international interactions was raised.

Meeting 4 – 29 June 2023

Scoping of modelling work

Modelling overview presentations were given by CBWG members from the non-core models: Emma Lynch from the SEAI on the NEMF, Niall McInerney from the Central Bank of Ireland on its semi-structural model and Mert Yakut from ESRI on the I3E model used by ESRI, including its potential to feed into the carbon budgets process.

Macroeconomic impacts of carbon budgets

Mert Yakut from ESRI outlined the potential role for the I3E model in assisting with understanding the macroeconomic impacts of carbon budgets during his presentation to the CBWG. Modelling discussions were held around the precision and openness of models and their abilities to include consumer behaviour and global events. An updated version of the second carbon budget programme methodology was circulated in advance of the meeting that included an update following feedback from ESRI on the scope of the Department of the Taoiseach's Research and Modelling Macroeconomic Subgroup.

Climate justice and 'Paris Test'

Kian Mintz-Woo outlined some of the main, broad philosophical considerations of climate justice and the Paris Test with regard to carbon budgets. Considerations included equity principles, the reference year for calculations, the clear definition of the end point and probabilities for reaching this, the choice of metrics, the gas mixture and the responsibility of emitters. Discussions included macroeconomic considerations, the solidarity principle within decision-making and changing global carbon budgets.

Carbon budgets work plan

The Secretariat outlined the work programme for the CBWG, including future thematic topics and the schedule for modelling by the CBWG. Follow-up letters have been issued by the Secretariat to modelling teams under the terms of the MoU.

Meeting 5 – 27 July 2023

Focused discussion on methane

The Secretariat's background briefing note on methane was circulated to the CBWG in advance of the meeting for review and comment. Joseph Wheatly from the Energy Institute at UCD presented on methane policy targets in Ireland based on his physical science research using simple climate models. Key points included definitions of climate neutrality, different metrics for measuring the warming impact of methane and the implications of methane reduction for policy targets. Discussions surrounded the selection of climate targets and methane's importance in achieving these. Considerations surrounding fairness, grandfathering of emissions and implications of delayed action were raised, together with the research assumptions, methane residency duration and the influence of land use change on methane emissions. The ability of the CBWG to consider a split gas approach was discussed.

Ethics of methane emissions and climate change

Kian Mintz-Woo from the CBWG presented on the ethics of methane emissions based on research in the literature from the field of philosophy. Differences in the accounting of short- and long-lived GHGs, communication, fairness of effort and the inclusion of value judgements were raised as important considerations. Discussions included choice of metric, methodology for presenting carbon budgets, equity, uncertainty, global pledges and the development of technologies.

Scoping of modelling work

Peadar Ó Súileabháin and Karen Whitaker from the NTA gave a presentation on the regional modelling system that can inform on traffic volumes and forecast transport emissions. Discussions included emissions reductions, adherence of existing modelling results to carbon budgets and the current availability of modelling results. Kevin Black from Coillte gave an overview of forestry models, including inputs, outputs and limitations. Discussions included the availability of model results and their adherence to carbon budgets, along with sensitivities and planned model updates.

Carbon budgets work plan

The Secretariat outlined the work programme for the CBWG, including future thematic topics. The draft carbon budgets workshop agenda had been circulated for review and comment. Interviews with individual modelling teams will be held in advance of the workshop.

Meeting 6 – 8 September 2023

Population projections

External individuals delivered presentations to the CBWG on population modelling and application. Tim Linehan from the CSO presented on population projection modelling. Adele Bergin from ESRI presented on its population projection modelling. Colin Fulcher from DHLGH presented on the application of population projections to the revision of the National Planning Framework. Discussions on these population models included the methodologies, key variables (migration, fertility, mortality), assumptions, planned future changes and sensitivities of the models, along with demographic differences between Ireland and the EU, global impacts and the relative population growth of urban areas and their hinterlands.

Just Transition in agriculture

Niamh Garvey and Jeanne Moore presented on findings from the NESC report on Just Transition in the Agriculture and Land Use sector and possible implications for determining carbon budgets. Just Transition principles proposed as relevant to carbon budget process include co-ordinating action and driving ambition, enhancing socially inclusive processes, enabling people to benefit from the opportunities of transition, and sharing and mitigating the costs of transition. Discussions involved the importance of active engagement with stakeholders and a national communication campaign on opportunities and supports, along with the importance of burden sharing.

Carbon budgets work plan

The agenda for the upcoming carbon budgets workshop had been circulated for review and comment. The Secretariat outlined proposed meetings and themes for meetings in 2024, with feedback requested from members. The response from DECC supporting the previously requested modelling capacity under the MoU was noted and shared with members.

Carbon budgets modelling workshop – 13 September 2023

The September modelling workshop provided an opportunity for the members to discuss the analytical process for the second CB Proposal. The objective of the workshop was to develop a shared understanding of model inputs and expected outputs for the first iteration of modelling. A report on the outcome of the workshop[112] was produced and circulated to the Council at the CCAC meeting on 28 September and subsequently shared with the CBWG. A summary of the main outcomes of the workshop is outlined below.

2030 start points

1. **Staying within CB1 (2021–2025) and CB2 (2026–2030)**

   The achievement of the sectoral emissions ceilings was assumed to be the basis for staying within CB1 (2021–2025) and CB2 (2026–2030), with two sub-scenarios developed for the treatment of unallocated emissions savings for CB2: (a) assigned to the Energy sector and (b) assigned on a pro rata basis based on emissions.

2. **Underperformance against CB1 (2021–2025) and CB2 (2026–2030)**

   The 2023 WEM scenario was proposed as a more realistic 2030 starting point than the WAM scenario. Modelling teams were requested to use both if possible and there was an openness to using either scenario provided it was made explicit in the results.

3. **Overperformance against CB1 (2021–2025) and CB2 (2026–2030)**

   As this scenario was considered highly unlikely, it was agreed not to pursue the 5% overperformance scenario analysis at this time for the first iteration of modelling, with the potential to revisit it in subsequent modelling iterations.

112 Climate Change Advisory Council (2022). Carbon Budgets Modelling Workshop Report.

2050 targets

The primary aim of the initial modelling of first iteration was to provide a baseline for subsequent analysis and modelling iterations. The initial scenarios would be compiled and assessed against targets for specific temperature outcomes in 2050 and net zero emissions in 2050 once results were available.

Scenario development for second Carbon Budget Proposal

The points raised in discussion were to be revisited once initial results are available and used to refine parameters for subsequent modelling iterations. It was agreed that scenario results from TIM, NEMF, FAPRI-Ireland and GOBLIN would be made available for the December CBWG meeting and it was proposed that the Paris Test assessment would be conducted during December 2023 and January 2024, following receipt of the initial modelling results, and presented at the January CBWG meeting.

Competing land use requirements

The points raised in discussion were to be revisited at subsequent CBWG meetings and again once the initial modelling results were available in December.

Meeting 7 – 19 October 2023

2024 EPA projections process

Presentations were given by CBWG members from ESRI, SEAI and EPA related to the GHG emissions projections process due for completion and publication in 2024: Mert Yakut on ESRI's inputs to the EPA projections from the I3E model and Emma Lynch on SEAI inputs to the projections using the NEMF model. Discussions were held around the models' abilities to capture historical policy changes and assumptions for new technologies, along with possibilities for feedback processes between models and sensitivities to future energy demand composition. EU regulatory requirements and comparisons with EPA emission projection scenarios were raised and also the level of incorporation of external model outputs and consumer behaviour change. The inclusion of international aviation and maritime emissions in projection modelling and the national co-ordination of Irish modelling teams were discussed. Stephen Tracey presented an overview of the EPA 2024 projections process including timeline, planned future activity and key outputs. Discussions that followed included the utility of input models to Government departments, the modelling and projection of international aviation and maritime emissions, and the national co-ordination of modelling teams.

International approaches to carbon budgets

Sadhbh O'Neil presented on her study to the Council on international approaches to carbon budgeting, conducted by her as an independent researcher. This included approaches to setting targets and trajectories from selected jurisdictions where relevant, with potential lessons for an Irish context. The role of carbon budgets as one part of a comprehensive policy package to reduce emissions was highlighted. Discussions included the relevant bodies responsible for carbon budgets in other jurisdictions, separate methane targets, alignment of national and global carbon budgets, and credibility around the non-achievement of budgets, along with production versus consumption emissions and the role public participation could have in setting carbon budgets.

Carbon budgets work plan

The CBWG workshop outcome report had been shared with members for information. The Secretariat outlined the work programme for the CBWG including future thematic topics, with the December meeting including discussions of the first iteration of core modelling results. Feedback from members was requested on proposed thematic topics and their timings.

The proposal to use simple climate models looking at temperature stabilisation for the carbon budgets temperature Paris Test was outlined. The potential for an international review for this process was raised. A note outlining the data requirements for an analysis of the impact of mitigation actions on employment and the wider economy will be circulated for review and feedback from members.

Meeting 8 – 23 November 2023

Carbon dioxide removal and negative emissions technologies

Oliver Geden, a member of the CBWG, presented on CDR and its integration in EU climate policy. A range of CDR methodologies was included, with their requirements under different future scenario pathways. Potential future policy directions were outlined, with implications for EU mitigation trajectories and requirements for CDR to achieve net zero emissions. Discussions included applications and impacts both in Ireland and internationally.

Biodiversity considerations

Yvonne Buckley, a member of the CBWG, presented on biodiversity considerations for carbon budgets. The presentation included the need for increased work to protect biodiversity. The complexity of biodiversity assessments in carbon budgets was outlined along with acute limitations in Ireland regarding existing research capacity and understanding of the impacts of biodiversity considerations and mitigation options for carbon budget scenarios. Discussions included the ability for models to include biodiversity variables for both carbon budgets and land use, and the time constraints of the current CB Proposal. The importance of early identification and outline of synergies and conflicts of biodiversity consideration options for this and future CB Proposals was raised.

Agriculture and Land Use Review

Phillip O'Brien from the Secretariat presented on a paper on the Agriculture and Land Use sector in Ireland. The presentation included the value of the sector to Ireland, measures of its sustainability, demographics of farming in Ireland and mitigation options. Potential impacts of policy measures were outlined. Within the discussion that followed, historical context, land use dynamics, recent structural changes and the need for a diverse evidence base were noted.

Carbon budgets work plan

The remaining thematic topics and timelines were outlined. Following a request from the Council, presentations from the modelling groups on the results from the first iteration of modelling due in December will be shared with the Council.

Meeting 9 – 15 December 2023

COP28 – global stocktake

Frank McGovern from the EPA gave a presentation on the outcome of the UNFCCC global stocktake at COP28. It was noted that, while progress has been made, and the 1.5°C target remains, Parties are not on track to achieve the purpose of the Paris Agreement. Discussions included definitions of the agreement, Just Transition, negative emissions technologies, nationally determined contributions and the challenge for Ireland to transition from fossil fuel energy.

Presentation of the first iteration of core modelling results

Presentations were made from the three institutions that conducted the first iteration of modelling for the CB Proposal using the three core models. Kevin Hanrahan from Teagasc presented on results from the FAPRI-Ireland model and MACC analysis. Impacts on existing carbon budgets were noted along with model uncertainties. David Styles from the University of Galway presented on results of the GOBLIN model with scenarios modelled towards 2050. Over 25 scenarios were run, with differences including changes in animal numbers and forestry area. Initial results included the importance of afforestation for balancing GHG emissions, and difficulty in achieving net zero AFOLU GHG emissions by 2050. Hannah Daly and Vahid Aryanpur from UCC presented on results from TIM focusing on energy systems. Two IPCC Working Group III global carbon budgets were downscaled to Ireland, with four primary scenarios modelled. Model scenarios required different levels of investment and timing of monetary and non-monetary benefits of energy transition. The significant gap between current policies and what is required to remain within either the 300 Mt CO_2 eq or 400 Mt CO_2 eq budget was outlined.

Following presentations, discussions were had on all three model results, including assumptions and outputs. The importance of outlining the costs of mitigation measures (capital and ongoing), quantifying the impact of Government policy controls, and the impact of stranded assets was discussed. The possibility for the Council to provide guidelines on carbon budget constraints and objectives was raised.

Irish carbon budgets: some moral considerations

Kian Mintz-Woo from UCC presented on moral considerations of Irish carbon budgets for discussion within the CBWG. This included the importance of moral evaluation, assumptions of the Paris Agreement, carbon budget reference year and equity principles. Discussions included the obligations of nation states, grandfathering and public perceptions.

Agenda item 5: carbon budgets work plan

The remaining timelines of the carbon budgets work plan were outlined, along with the upcoming analysis of the warming impact of core model scenarios.

Meeting 10 – 18 January 2024

International Energy Agency Net Zero Roadmap 2023 update

Cristophe McGlade, Head of Energy Supply at the International Energy Agency, gave an update on its Net Zero Roadmap. The continued need to increase the pace of change to achieve net zero by 2050 was outlined. During the discussion, the importance of grid connections, financing mechanisms and cost of capital in facilitating renewables was raised.

Analysis of warming impact of selected core scenarios (first iteration)

Joe Wheatly from UCD presented on an analysis of the warming impact of selected scenarios from TIM and GOBLIN outputs from the first iteration of carbon budget modelling. The use of simple climate models was outlined with Ireland's marginal warming contribution presented. Discussions included warming implications

Additional testing of scenario results

Emma Lynch from SEAI presented on additional testing of TIM energy system outputs from the first iteration of the modelling results using the NEMF. Observations and recommendations relevant to the Electricity, Residential, Transport and other energy sectors were made. In the following discussion, the importance of model refinements was stated. Relevant assumptions and outputs that will be required for the Energy and Agriculture sectors were outlined.

Update on economic and macroeconomic analysis

John Fitzgerald presented on requirements for consideration in the upcoming economic and macroeconomic analysis of the modelling for this CB Proposal. Discussions included availability of data, updates to economic models and costs of mitigation actions.

Carbon budgets work plan

Upcoming thematic topics were discussed. The timeline for the second iteration of modelling was outlined, with expected upcoming guidance from Council.

Meeting 11 – 29 February 2024

Quantitative approaches to carbon budgeting for Parties to the Paris Agreement

Malte Meinshausen presented on quantitative approaches to carbon budgeting for Parties to the Paris Agreement, including establishment of the Victorian carbon budgets. A process for translating budgets into milestone targets was presented, along with the characteristics of Victoria's emissions. The application of the simple climate model MAGICC (Model for the Assessment of Greenhouse Gas Induced Climate Change) was highlighted. Discussions included land sinks, global carbon budget parameters, sociopolitical issues, economics and the Just Transition of decarbonising the Electricity sector.

Energy and power systems modelling

Paul Deane from UCC presented an overview of research on Ireland's Power sector. The importance of emissions reductions, energy demand reduction and emissions removals was stated, together with the need for policy-consistent scenarios. Discussions included interconnectors, renewable energy deployment, carbon price and timelines to net zero.

ESABCC scientific advice for the determination of an EU-wide 2040 climate target and greenhouse gas budget for 2030–2050

Miles Perry from the Secretariat of the ESABCC presented on the advice provided on the EU climate target for 2040, including the 2030 policy framework and EU climate objectives. Discussions included emissions reductions, scenario formation, equity and feasibility.

Council feedback on the first iteration of modelling

Guidance points from the Council to the core modelling groups were conveyed to the CBWG. These included the need to widen the scope of modelling for the second iteration of modelling, consideration of the European Commission's 2040 proposal for emission reductions and the options to address the emissions gap for waste and fluorinated gases. Specific modelling requests were provided to individual modelling teams. Discussions were had on the energy systems, negative emissions, deployment rates and feasibility. The limitations of the models and projections were noted, along with the importance of expert judgement.

Carbon budgets work plan

The work plan was shared with the working group with a focus on timelines for the second iteration of modelling.

Meeting 12 – 22 March 2024

The Secretariat noted that, due to her appointment to the CCAC, Yvonne Buckley has resigned her position on the CBWG. James Moran from Atlantic Technological University will be appointed to take her place with Eamon Haughey as an alternative for when James is unavailable to attend.

Follow-on discussion on methane and climate neutrality

Joeri Rogelj from Imperial College London presented on the non-CO_2 reductions implied by IPCC estimates of the remaining carbon budget. The assumed relationship between warming and non-CO_2 contributions implies that substantial reductions in non-CO_2 emissions are made in the future. Discussions included the allocation of different gases in carbon budgets, costs, equity and national targets.

Discussion of potential NTA analysis for carbon budgets

An overview of the timeline of the CB Proposal was briefly outlined by the Secretariat to observers from the NTA. Peadar O'Sullivan gave an overview on the work of the modelling work by the NTA. Discussions involved the inputs to and assumptions of the existing NTA model, including sectoral emissions ceilings and fleet modelling. A further meeting between the NTA and relevant modelling teams was outlined.

Agree inputs, parameters and assumptions for second iteration of modelling

The Secretariat outlined the Council's general guidance points that were previously presented to the modelling teams. Short descriptive narratives were requested from the modelling teams to accompany scenarios. A proposal to develop a tool to compile feedback on individual scenarios, or a group of scenarios, from members of the working group was made. Discussions included abatement costs, modelling time frame, scenario feasibility and limitations of model forecasts.

Carbon budgets work plan

The work plan was shared with the working group focusing on the second iteration of modelling with results due in May. The need for co-ordination between FAPRI-Ireland and GOBLIN teams prior to models being finalised for the second iteration was highlighted.

Meeting 13 – 19 April 2024

Decarbonised Electricity System Study

Kerrie Sheehan, John McCann and Jean-Pierre Roux from SEAI and Sarah Kelly of Byrne Ó Cléirigh presented on insights from their Decarbonised Electricity System Study. Preliminary results from the expert elicitation on plausible deployment rates of variable renewables in Ireland were presented. Discussions included study methodology, scenario modelling and renewable deployment rates.

Research on mitigation options available to agriculture

Karl Richards, Gary Lanigan and Laurence Shalloo of Teagasc presented their ongoing research at the Teagasc Climate Centre and emissions inventory research. Ongoing research for modelling pathways to net zero was outlined and the work of the National Agricultural Soil Carbon Observatory highlighted. Reductions in the emissions inventory for LULUCF for 2024 were outlined together with the impacts of mitigation options for LULUCF and AFOLU. Discussions included carbon fixation, emissions inventory, MACC mitigation measures and knowledge transfer.

Just Transition principles and considerations in the carbon budget process

Jeanne Moore and Niamh Garvey opened the discussion on Just Transition and implications for carbon budgets. The four principles introduced for discussion included social dialogue, integrated evidence-based approaches, equipping of people with the right skills, and cost-sharing. Discussion included the importance of a Just Transition, accessibility, climate justice and the challenges fairness posed for the setting of the carbon budgets.

Carbon budgets work plan

The scenario dialogue tool was presented to the CBWG, including requirements for consideration under the Act. The ability to comment on aspects of the scenarios from all CBWG members was outlined. The work plan and meeting schedule were presented with the short number of remaining meetings highlighted. The Secretariat presented next steps for the Scenario Dialogue Tool to the group.

Meeting 14 – 23 May 2024

Presentation of the second iteration of core modelling results

Presentations were made from the three institutions that conducted the second iteration of modelling for the CB Proposal using the three core models. Kevin Hanrahan presented on FAPRI -Ireland modelled results out to a 2050 horizon. The modelling team acknowledged the request from the CCAC to incorporate a range of MACC measure uptake rates. However, progress on this range of mitigation measure uptake rates has not been possible due to unforeseen resource limitations. During the presentation, the modelling assumptions, inputs and outputs were outlined, including the limitations of extending modelling to 2050. Following the presentation discussions included model assumptions, technical measures, sectoral emissions ceilings and carbon costs.

Hannah Daly presented on TIM modelled results. The team noted engagement with external groups to refine model assumptions and inputs. Additional model scenarios to 2050 were run for the second iteration. A preliminary comparison of modelled results with indicative 2040 EU-proposed targets was made. Following the presentations, discussions included model assumptions, carbon costs, mitigation measures, land requirements for energy production and timelines for a transition to a net zero power system.

David Styles presented on GOBLIN modelled results, including modelling approach, assumptions and inputs. Scenarios for varying agricultural emissions reductions were modelled, along with varying activity levels for agricultural practices, CDR and CCS. The importance of long-term policy thinking in the Agriculture sector was highlighted with the difficulty for AFOLU of reaching net zero stressed. Following the presentations, discussions included inputs and assumptions, mitigation measures and impacts to biodiversity.

Carbon budgets work plan

The work plan was shared with the working group, focusing on the upcoming temperature analysis and additional testing of scenario results. Prioritisation of in-person attendance at the July and August meetings was proposed.

Meeting 15 – 28 June 2024

Analysis of warming impact of selected core scenarios (second iteration)

Joe Wheatley from UCD presented on the warming impact of selected core scenarios from the second iteration of TIM and GOBLIN scenarios. An overview of the simple climate model MAGICC7 and its use was provided. Ireland's marginal warming contribution was presented, with variability due to variations in climate sensitivity and the probability of temperature neutrality across different years and modelled scenarios. Discussions that followed included the importance of revised emission factors, methane, historical emissions and grandfathering of emissions.

Presentation of the macroeconomic impacts of modelling scenarios

Niall McInerney presented on the macroeconomic impacts up to 2050 of core modelled scenarios using the Central Bank's semi-structural model. The model considered the level of investment required to meet decarbonisation targets as provided by the TIM across energy sectors. Discussion

following the presentation included the required investment, impact on GDP, and the future labour requirements for development of infrastructure to 2050. Impacts to other sectors of the economy, along with the phasing out of fossil fuels, were also discussed.

Decarbonised Electricity System Study

Jean-Pierre Roux, accompanied by Kerrie Sheehan and John McCann of SEAI, with Jeremiah Higgins from DECC and Sarah Kelly from Byrne Ó Cléirigh, presented on the SEAI report *Expert Elicitation on Plausible Deployment Rates of Generation Technologies in Ireland 2024–2040*. The objectives, methodology, results and key findings were presented, with a focus on rate of renewables roll-out and technology adoption in the Power sector. The discussion included the deployment of and barriers to infrastructure development, national planning and CCS.

Aviation and maritime emissions

The Secretariat introduced the paper on aviation and maritime emissions for discussion that had been previously circulated to the CBWG members. The presentation illustrated the emission trends for aviation and maritime activities. Discussion following the presentation included relevance to the Paris Agreement, production of synthetic fuels, carbon capture and barriers to action.

Carbon budgets work plan

The final three remaining meetings were outlined to the group, focusing on the additional testing of scenario results, the third iteration of modelling and remaining thematic topics.

Meeting 16 – 25 July 2024

Biodiversity report

Aoife Molloy, Caren Jarmain and Yvonne Buckley presented initial findings of a research report commissioned by the CCAC on an assessment of the biodiversity considerations in the carbon budgets process. The study sought to assess the alignment of existing national climate and biodiversity policy targets and to assess impacts of climate mitigation measures on biodiversity. In the discussion that followed the presentation, a number of specific potential conflicts between climate mitigation and protecting biodiversity were explored. It was noted by the report authors that, due to the spatially and temporally dependant nature of biodiversity impacts, the lack of high-resolution spatial land use and land use change data is a barrier to fully assessing trade-offs and synergies.

Energy and transport additional modelling

Barry Colleary from the NTA and Emma Lynch from SEAI presented on additional analysis of the first and second iteration core modelling results. The presentation provided results across different scenarios including passenger-kilometre comparisons, freight tonne-kilometre comparisons, car/LGV/HGV stock comparisons and fleet mix comparisons. A discussion followed the presentation regarding the main differences between the CBWG model and the NTA model assumptions. It was noted that the interaction with the NTA was extremely useful for developing and assessing aspects of the TIM modelling.

Emma Lynch presented modelling results from the SEAI analysis of the second iteration TIM core modelling using the NEMF model. The impact of emissions to 2030 was outlined along with additional

risk analysis across WEM and WAM assumptions. In the following discussion, model assumptions and impact of mitigation actions were outlined along with further planned work.

Agree inputs, parameters and assumptions for third iteration of modelling

The Secretariat presented the Council guidance with regard to the inputs, parameters and assumptions for the third and final iteration of CBWG modelling. The modelling teams were requested to incorporate recent inventory refinements and assume compliance with CB1 and CB2. The three core modelling teams were requested to carry out a sensitivity analysis accounting for carbon budget exceedance, with additional specific requests for individual teams.

Carbon budgets work plan

The meeting schedule was presented with only two remaining meetings highlighted, with thematic topics including biodiversity considerations. The agenda items for the final meeting were outlined. The work plan was shared with the working group focusing on the final key deliverables, including the CBWG outputs report that will be presented to Council for its consideration when proposing the next carbon budgets.

Meeting 17 – 29 August 2024

Biodiversity report – impacts to carbon budgets

James Moran gave a presentation on the biodiversity considerations for carbon budgets in the context of the core modelling results to date. The interrelated issues between biodiversity and climate change were presented, including drivers of biodiversity loss, highlighting the importance of considering biodiversity alongside climate change. In the discussion that followed, the importance of guidance on and community buy-in for biodiversity protection was raised, along with challenges to developing effective biodiversity policy.

Presentation of the third Iteration of core modelling results

Presentations were made of the third iteration of core modelling results by Teagasc (FAPRI), University of Galway (GOBLIN) and UCC (TIM).

Gary Lanigan and Kevin Hanrahan presented results from the FAPRI-Ireland model. The presentation provided an overview consisting of nine scenarios projected to 2050. Uncertainties in projecting the model out to this time horizon were noted. The main results were outlined, which included the reductions in GHG emissions for different modelled scenarios and challenges for the sector. The following discussion included agricultural activity levels, mitigation measures, impacts of nitrogen derogation and comparison with other models.

David Styles presented the results from the GOBLIN model. Thirteen scenarios were modelled to 2100, with inputs and outputs outlined. The results indicated the difficulty in attaining net zero GWP_{100} by 2050, with achievement possible by 2100 dependent on measures implemented. In the discussion, afforestation and biodiversity implications were raised and the importance of coherent policy noted. Historical land use and sectoral allocation of carbon savings were also discussed.

Hannah Daly presented the results from TIM. An overview of the changes to the third iteration from previous iterations of modelling and analysis was given. The model assumptions and mitigation

pathways to 2050 were presented, with cumulative emissions and marginal abatement costs of the core scenarios, including considerations of WEM and WAM scenarios. Relationships of the scenarios to proposed European reduction targets were highlighted, with the implications of failing to meet the existing carbon budget. The discussion included drivers of energy demand reductions, maintaining capacity and operation of the Power sector, and assumptions of the scenarios.

Carbon budgets work plan

The topics for the final meeting were presented to the group with remaining timelines of the work plan. Timelines for the provision of final repots by CBWG members were outlined, including provision of executive summaries. The Secretariat presented updates regarding the scenario dialogue tool to the group.

Meeting 18 – 18 September 2024

Analysis of warming impact of selected core scenarios (third iteration)

Joe Wheatley presented on the warming impact of the third iteration of modelling of national emissions. The FaIR model was employed to model the warming impact of 1,196 scenarios. The warming impact assessment highlighted that less than 20% of scenarios modelled would reach temperature neutrality by 2050 if the global scenario shared socioeconomic pathway SSP1-26 was followed.

Following the presentation, the discussion included carbon capture, alignment with EU policy, fairness, historical emissions, temperature objectives and emissions projections.

Economic and macroeconomic impacts of core modelling results (third iteration)

The Secretariat presented an update on the actions to facilitate the macroeconomic impacts analysis. Kelly de Bruin (KDB) provided an update on the application of the I3E model to the carbon budget process, although development delays restricted the model's application to this Carbon Budget Proposal. KDB also presented on recent research by ESRI on climate impacts and adaptation in Ireland. In the following discussion, the importance of costs and limitations of the model were noted.

Niall McInerney presented on the modelling of the macroeconomic impacts of the third iteration of the core modelling scenarios using the Central Bank model, including the investment levels required to meet decarbonisation targets provided by TIM. Discussion included transitions in the Transport sector, the model's ability to include price volatility and wider costs and the incorporation of equity considerations.

John Fitzgerald presented on the macroeconomic impacts of the core modelling scenarios, including a methodology for quantifying the macroeconomic implications of the carbon budgets for national and international considerations. Additional data requirements for completing the assessment were noted. Discussions included future costs, a transitioning Transport sector, model assumptions and constraints, and the ability to incorporate ecosystem services. Council guidance on prioritising core model scenarios for analysis was requested.

Energy additional modelling

Emma Lynch presented on the additional analysis of the third iteration modelling results by the NEMF. The presentation included the approaches to additional testing of TIM outputs and updates between the model iterations. The presentation highlighted the risk of delay in the implementation of measures critical for the achievement of the carbon budgets. In the discussion that followed, it was noted that there is a substantial gap between the CAP delivery and what is needed to reach climate neutrality and that this could lead to failure to achieve emission reduction targets.

Follow-on discussion on carbon dioxide removal and carbon budgets

Oliver Geden presented on CDR considerations for carbon budgets. The presentation outlined the main characteristics and methods of CDR. CDR policy and modelling issues related to GOBLIN and TIM scenarios were presented, including the sectoral allocation of CDR. The discussion included the incorporation of CDR into national inventories and international reporting.

Next steps

The Secretariat presented the final steps in the work plan, along with upcoming deadlines for submission of inputs by CBWG members. The potential further involvement of CBWG members in the Carbon Budget Proposal process was outlined. The members of the CBWG were thanked for their contributions and the time they had given to the CBWG meetings.[113]

113 Approval of the minutes of the final meeting on the authority of the Chair.

Appendix 2: Action log

Action number	Date raised	Description	Owner	Due	Status
1	09/03/2023	Secretariat to invite a speaker to provide an update on demographics and inform the group about the process for outputs from the 2022 Census	CCAC Secretariat	Q2 2023	Closed: Update provided at CBWG meeting 2 on 20/04/2023 and CSO presentation scheduled for meeting 6 on 08/09/2023
2	09/03/2023	Working group members to provide written comment on the draft methodology and list of topics for consideration by 20/03/2023	CBWG members	Mar-23	Closed: Comments received by 20/03/2023 and feedback discussed at CBWG meeting 2
3	20/04/2023	Expand discussion of macroeconomic inputs/drivers	CCAC Secretariat and relevant CBWG members	Q3 2023	Closed: Update provided at CBWG meetings 4 and 6 Bilateral discussions held with economists in August and October Further update for the CBWG scheduled for January 2024
4	20/04/2023	Provide update on timelines for the Land Use Review	CCAC Secretariat	May-23	Closed: Update provided at CBWG meeting 3
5	20/04/2023	Further develop the approach and preparation for topical discussions	CCAC Secretariat	Q3 2023	Closed: Secretariat provided an update on the approach and preparation for upcoming topical discussions at each meeting in advance of meeting 6
6	27/07/2023	CBWG members to provide comment on the draft agenda for the September workshop by 04/08/2023	CBWG members	Aug-23	Closed: Feedback provided by meeting 6
7	27/07/2023	CCAC Secretariat to schedule individual meetings with modellers prior to finalising the September workshop agenda	CCAC Secretariat	Sep-23	Closed: Pre-workshop meetings held with CBWG members from UCC, University of Galway, SEAI and Teagasc in advance of meeting 6
8	08/09/2023	CBWG members to provide feedback on the proposed meeting schedule for 2024	CCAC Secretariat	Sep-23	Closed: Feedback provided in advance of meeting 7
9	19/10/2023	CBWG members to provide feedback and/or suggestions on the proposed topics for consideration in 2024 as outlined in the meeting 7 presentation	CBWG members	Nov-23	Closed: CBWG members still welcome to provide suggestions for additional thematic topics on an ad hoc basis

Action number	Date raised	Description	Owner	Due	Status
10	19/10/2023	Secretariat to share a note on the inputs required for macroeconomic analysis and a template regarding the temperature impact analysis with the core modelling teams for review and feedback	CCAC Secretariat/ CBWG Members	Nov-23	Closed: Feedback on the inputs required for macroeconomic analysis was discussed in meeting 10
11	15/12/2023	Modelling groups to provide projected GHG emission data for temperature analysis	CBWG core modelling groups	Dec-23	Closed: Modelling groups provided data by 18/12/2023 and shared with Joe Wheatly for temperature impact analysis
12	18/01/2024	Secretariat to follow up on planetary boundaries as thematic topic	CCAC Secretariat	Mar-24	Closed: Doughnut economics horizon scanning event scheduled for 10/04/2024 10:00–11:30 with invitation extended to the members of the CBWG
13	18/01/2024	Secretariat to provide guidance from the Council with regard to the second iteration of modelling and analysis following the February CCAC meeting	CCAC Secretariat	Feb-24	Closed: Council feedback provided to CBWG in February meeting
14	29/02/2024	Secretariat to schedule bilaterals with each of the core modelling group to discuss Council feedback in more detail	CCAC Secretariat	Mar-24	Closed: Bilaterals with each of the three core modelling teams held on 07/03/2024
15	29/02/2024	Request for clarification on the role of the CBWG in terms of presenting a range of scenarios for Council consideration as opposed to proposing a particular feasible pathway	CCAC Secretariat	Apr-24	Closed: Role of CBWG outlined in the ToR reiterated for clarity at the Council meeting on 25/04/2024
16	29/02/2024	Request for a more detailed discussion within the CBWG on the feasibility of various scenarios	CBWG members	May-24	Closed: (1) Accompanying descriptive narrative for each of the modelled scenarios requested from core modelling teams (2) Scenario dialogue tool developed to facilitate a collective narrative on impacts of various scenarios based on feedback from all CBWG members

Action number	Date raised	Description	Owner	Due	Status
17	29/02/2024	Core and additional modelling teams to confirm delivery timelines for the second iteration of modelling and analysis in line with the carbon budgets work plan	CBWG members	Mar-24	Closed: (1) Core modelling teams confirmed delivery of second iteration results on 23/05/2024 (UCC, Teagasc and University of Galway) (2) Additional modelling teams confirmed delivery of results on 28/06/2024 (Central Bank) and 25/07/2024 (SEAI) (3) The Secretariat and CBWG economists (JF, ESRI, Central Bank) met on 14/05/2024 to discuss macroeconomic analysis
18	29/02/2024	Chair to consider the participation of an additional member from the FAPRI modelling team within the CBWG	CCAC Secretariat	Mar-24	Closed: Response provided. Participation welcomed at future meetings where the team is presenting results of its analysis. Not inclined to appoint additional members at this late stage
19	22/03/2024	Secretariat to schedule trilateral discussion with NTA, TIM and SEAI CBWG members	CCAC Secretariat	May-24	Closed: Trilateral discussion with NTA, UCC and SEAI CBWG members on 27/05/2024 Follow-up discussion with NTA and UCC on 22/07/2024
20	22/03/2024	Secretariat to share template of feedback document to the CBWG at the April meeting	CCAC Secretariat	Apr-24	Closed: Template of scenario dialogue tool was shared with CBWG in meeting 13
21	22/03/2024	Secretariat to issue a poll to hold an in-person meeting in an alternative location	CCAC Secretariat	May-24	Closed: Poll in relation to July and August meetings issued on 23/04/2024
22	28/06/2024	DS to provide guidance to Joe Wheatley for the third iteration of analysis and ST to facilitate a bilateral call with the EPA inventories team regarding the revised soil emissions factor	CBWG Members	Aug-24	Closed: ST facilitated a discussion on the latest update to the inventory with DS, CD, the Secretariat, and the EPA inventories and projections teams DS provided guidance to JW regarding the incorporation of the latest inventory refinement to the third iteration of the GOBLIN analysis
23	28/06/2024	Secretariat to follow up with potential sources on assumptions regarding the required grid investment for NMcI to consider as part of the next iteration of COSMO analysis	CCAC Secretariat	Jul-24	Closed: Secretariat followed up to flag EU reference scenarios information on likely scale of investments in power grids required at EU level along with relevant EirGrid publications on grid investment projects

Action number	Date raised	Description	Owner	Due	Status
24	28/06/2024	JF to follow up with NMcI regarding comments on the macro analysis	CBWG members	Jul-24	Closed: JF followed up to provide a note outlining his comments on the macroeconomic analysis
25	28/06/2024	Secretariat to circulate the supplementary brief on the factors influencing power generation technology deployment in Ireland that was prepared by SEAI	CCAC Secretariat	Jul-24	Closed: Supplementary brief provided to Secretariat and circulated to CBWG members via SharePoint
26	28/06/2024	Each member was asked to fill at least one scenario in the dialogue tool before the 25/07/2024 meeting. The Secretariat will set up a call with each member to walk through the tool in more detail and address any questions the members might have	CBWG members and CCAC Secretariat	Jul-24	Closed: Secretariat had calls with individual CBWG members to discuss the approach to the scenario dialogue tool. The CBWG members were asked to fill one scenario and to report any user issues with the tool by meeting 16
27	28/06/2024	Secretariat will schedule a call with KH and TD to discuss FAPRI-Ireland scenario results the week of 08/07/2024	CCAC Secretariat	Jul-24	Closed: Secretariat had a call with KH and TD to discuss the next steps for the FAPRI-Ireland analysis on 11/07/2024
28	29/08/24	The Secretariat to follow up with Teagasc to provide direction as to how to present emissions reductions, i.e. changes from business as usual vs changes from 2018 levels	CCAC Secretariat	Sep-24	Closed: Secretariat requested emissions reductions to be presented in the context of changes from a 2018 baseline in final reporting
29	29/08/24	Hold discussion between Secretariat, GOBLIN and FAPRI on the appropriate combination of FAPRI and GOBLIN agriculture and land use scenarios	CCAC Secretariat and CBWG members	Sep-24	Closed: Discussion held on 23/09/2024
30	29/08/24	Secretariat to follow up with the TIM and GOBLIN teams to discuss the allocation of emissions savings from BECCS between the AFOLU and Energy sectors	CCAC Secretariat and CBWG members	Sep-24	Closed: Discussion held during meeting 18 developed a shared understanding of the allocation of emissions savings from BECCS, with savings to be allocated to the Energy sector. Further bilateral discussions on core modelling results are scheduled for late September and the Secretariat requests that the relevant teams provide specific detail on the allocation of emissions savings from BECCS in their final reporting

Action number	Date raised	Description	Owner	Due	Status
31	29/08/24	Secretariat will liaise with each CBWG member individually on the submission their final output reports by 30/09/2024	CCAC Secretariat and CBWG members	Sep-24	Closed: Secretariat has been in contact with each CBWG member regarding the submission their final outputs reports by 30/09/2024. Secretariat request that CBWG members reach out if any further guidance on reporting is required or if they foresee any difficulty with submission by the requested deadline
32	18/09/24	Secretariat to relay Council guidance on selected scenarios for economic analysis to relevant teams and to schedule bilateral meetings with CBWG economists and core modelling teams to address queries as required	Secretariat and CBWG economists	Sep-24	Closed: Secretariat met with CBWG economists on 30/09/2024 to relay Council guidance on selected scenarios for economic analysis. Additional bilateral meetings were scheduled as required in early October with bilateral meetings with CBWG economists and core modelling teams to address any follow-up queries

Appendix 3: Risk register

Risk description	Likelihood of risk occurring	Impact if risk occurs	Severity	Mitigating action	Progress on action	Status
Revision of carbon budgets, as provided for under Section 6D of the Act	**Medium**	**Medium**	**Medium**	The Minister, at any stage, can request a revision of carbon budgets as provided for under Section 6D of the Act. The potential for the Minister to request a revision of carbon budgets has been reflected in both the carbon budgets' methodology and the terms of reference for the CBWG. The role of the CBWG in responding to any request from the Minister to the Council for a review will be determined by Council if it arises	Ongoing monitoring	Closed
Insufficient time to incorporate a potential step change in 2023 emissions from the Q2 2024 provisional emissions inventory publication	**Medium**	**Low**	**Low**	It is proposed that the 2030 start points for scenario modelling will account for both overperformance and underperformance of CB2 An activity-related step change in the 2023 provisional inventory in the Q2 2024 provisional emissions inventory publication is deemed a manageable risk mitigated by quarterly inventory reporting available from late 2023 and ongoing engagement with relevant CBWG members No updates to the methodology are expected in the Q2 2024 provisional inventory publication. However, if there are major methodological changes of relevance there is the potential for the Minister to request a review under Section 6D of the Act – see risk 1 above	Ongoing monitoring	Closed

Appendix 4: Directory of CBWG documents

Associated meeting	Document number	Document name	Category
CBWG01	1.01	Carbon Budgets Working Group agenda 09.03.2023	Agenda
CBWG01	1.02	Carbon Budget Working Group minutes 09.03.2023	Minutes
CBWG01	1.03	CBWG meeting 1-presentation 09.03.2023	Presentation
CBWG01	1.04	2.2 Carbon Budgets Working Group Terms of Reference	Guidance
CBWG01	1.05	2.3 Technical report on carbon budgets 25.10.2021	Report
CBWG01	1.06	2.4 Climate Action and Low Carbon Development (Amendment) Act 2021	Submission
CBWG01	1.07	3.1 Council carbon budget programme 2 draft methodology v1.1	Draft document
CBWG01	1.08	3.2 Topics list for Carbon Budgets Working Group discussions	Draft document
CBWG01	1.09	4.1 Draft schedule of meetings 2023	Draft document
CBWG01	1.10	carbon budgeting research fellowship-presentation 09.03.2023	Presentation
CBWG02	2.01	Carbon Budgets Working Group agenda 20.04.2023	Agenda
CBWG02	2.02	Carbon Budget Working Group minutes 20.04.2023	Minutes
CBWG02	2.03	CBWG meeting 2-presentation 20.04.2023	Presentation
CBWG02	2.04	1.2 Carbon Budgets Working Group Terms of Reference	Submission
CBWG02	2.05	2.1 Council carbon budget programme 2 methodology V1.2	Draft document
CBWG02	2.06	3.1 Topics list	Draft document
CBWG02	2.07	3.2 Carbon budgets draft workplan	Draft document
CBWG02	2.08	Dingle Project-presentation 20.04.2023	Presentation
CBWG02	2.09	2. Draft methodology comments & responses	Draft document
CBWG02	2.10	3. Topics list comments & responses	Draft document
CBWG03	3.01	Carbon Budgets Working Group agenda 31.05.2023	Agenda
CBWG03	3.02	Carbon Budget Working Group minutes 31.05.2023	Minutes
CBWG03	3.03	CBWG meeting 3-presentation 31.05.2023	Presentation

Associated meeting	Document number	Document name	Category
CBWG03	3.04	2.1 Secretariat note on a Vision for 2050	Guidance
CBWG03	3.05	2.2 Secretariat Note on Long Term Strategy For Greenhouse Gas Emissions Reductions	Briefing note
CBWG03	3.06	Introduction to the TIMES-Ireland Model (TIM)-presentation 31.05.2023	Presentation
CBWG03	3.07	GOBLIN: A land-balance model to identify national land sector pathways to climate neutrality-Presentation 31.05.2023	Presentation
CBWG03	3.08	FAPRI-Ireland model of the Irish agricultural economy-presentation 31.05.2023	Presentation
CBWG03	3.09	3. Carbon budgets workplan	Draft document
CBWG04	4.01	Carbon Budgets Working Group agenda 29.06.2023	Agenda
CBWG04	4.02	Carbon Budget Working Group minutes 29.06.2023	Minutes
CBWG04	4.03	CBWG meeting 4-presentation 29.06.2023	Presentation
CBWG04	4.04	3.1 Council carbon budget programme 2 methodology V1.3	Guidance
CBWG04	4.05	SEAI National Energy Modelling Framework overview-presentation 29.06.2023	Presentation
CBWG04	4.06	Modelling the macroeconomic impact of carbon budgets using COSMO-presentation 29.06.2023	Presentation
CBWG04	4.07	The Ireland Environment, Energy and Economy (I3E) model-presentation 29.06.2023	Presentation
CBWG04	4.08	2. ESRI I3E Note 29.06.2023	Submission
CBWG04	4.09	Irish carbon budgets: some moral considerations-presentation 29.06.2023	Presentation
CBWG05	5.01	Carbon Budgets Working Group agenda 27.07.2023	Agenda
CBWG05	5.02	Carbon Budget Working Group minutes 27.07.2023	Minutes
CBWG05	5.03	CBWG meeting 5-presentation 27.07.2023	Presentation
CBWG05	5.04	2.1 Secretariat note on methane	Briefing note
CBWG05	5.05	Irish carbon budgets: methane-presentation 27.07.2023	Presentation
CBWG05	5.06	Methane policy targets-presentation 27.07.2023	Presentation
CBWG05	5.07	3.1 Mintz-Woo (2023) Compensation duties	Submission
CBWG05	5.08	Regional modelling system (RMS)-presentation 27.07.2023	Presentation

Associated meeting	Document number	Document name	Category
CBWG05	5.09	Forestry models-presentation 27.07.2023	Presentation
CBWG05	5.10	5.1 DRAFT agenda Carbon Budgets Working Group Workshop September 2023	Draft document
CBWG06	6.01	Carbon Budgets Working Group agenda 08.09.2023	Agenda
CBWG06	6.02	Carbon Budget Working Group minutes 08.09.2023	Minutes
CBWG06	6.03	CBWG meeting 6-presentation 08.09.2023	Presentation
CBWG06	6.04	CSO population projections-presentation 08.09.2023	Presentation
CBWG06	6.05	Demographic projections-presentation 08.09.2023	Presentation
CBWG06	6.06	The National Planning Framework first revision-presentation 08.09.2023	Presentation
CBWG06	6.07	Approaching Just Transition in practice-presentation 08.09.2023	Presentation
CBWG06	6.08	5.1 DRAFT agenda Carbon Budgets Working Group workshop September 2023	Draft document
CBWGWS	WS.01	Carbon Budgets Working Group agenda 13.09.2023	Agenda
CBWGWS	WS.02	CBWG workshop-presentation 13.09.2023	Presentation
CBWGWS	WS.03	GOBLIN scenarios for carbon budgets towards 2050-presentation 13.09.2023	Presentation
CBWGWS	WS.04	Scenario development for 2nd carbon budget programme FAPRI-Ireland modelling-presentation 13.09.2023	Presentation
CBWGWS	WS.05	Carbon budget scenario development with TIMES-Ireland Model (TIM)-presentation 13.09.2023	Presentation
CBWGWS	WS.06	SEAI NEMF Carbon budgets modelling input-presentation 13.09.2023	Presentation
CBWGWS	WS.07	2. Styles GOBLIN runs	Submission
CBWG07	7.01	Carbon Budgets Working Group agenda 19.10.2023	Agenda
CBWG07	7.02	Carbon Budget Working Group minutes 19.10.2023	Minutes
CBWG07	7.03	Climate Change Advisory Council Secretariat CBWG meeting 7-presentation 19.10.2023	Presentation
CBWG07	7.04	4.1 Carbon budgets workshop outcome report	Report
CBWG07	7.05	EPA projections process and modelling methods-presentation 19.10.2023	Presentation

Associated meeting	Document number	Document name	Category
CBWG07	7.06	SEAI national energy projections process – input to EPA projections-presentation 19.10.2023	Presentation
CBWG07	7.07	The role of I3E in the NEMF-presentation 19.10.2023	Presentation
CBWG07	7.08	Carbon budgeting under framework climate laws: analysing diversity in national practice-Presentation 19.10.2023	Presentation
CBWG07	7.09	O'Neil, S. (2023) Carbon Budgeting in Selected Countries. Working Paper No. 25	Report
CBWG08	8.01	Carbon Budgets Working Group agenda 23.11.2023	Agenda
CBWG08	8.02	Carbon Budget Working Group minutes 23.11.2023	Minutes
CBWG08	8.03	CBWG meeting 8-presentation 23.11.2023	Presentation
CBWG08	8.04	4.1 Secretariat note on agriculture and land use	Briefing note
CBWG08	8.05	Carbon dioxide removal and its integration in European Union climate policy-presentation 23.11.2023	Presentation
CBWG08	8.06	Biodiversity considerations of carbon budgets – developments-presentation 23.11.2023	Presentation
CBWG08	8.07	Carbon Budgets Working Group agriculture and land use-presentation 23.11.2023	Presentation
CBWG09	9.01	Carbon Budgets Working Group agenda 15.12.2023	Agenda
CBWG09	9.02	Carbon Budget Working Group minutes 15.12.2023	Minutes
CBWG09	9.03	CBWG meeting 9-presentation 15.12.2023	Presentation
CBWG09	9.04	UNFCCC COP28 Paris Agreement GST global stocktake outcomes focus on mitigation elements -presentation 15.12.2023	Presentation
CBWG09	9.05	GOBLIN scenarios for carbon budgets towards 2050-presentation 15.12.2023	Presentation
CBWG09	9.06	Energy system pathways for carbon budgets: First iteration of TIM scenarios-presentation 15.12.2023	Presentation
CBWG09	9.07	Teagasc FAPRI-Ireland projections and MACC-presentation 15.12.2023	Presentation
CBWG09	9.08	4.1 Mintz-Woo note on Irish carbon budgets: some moral considerations	Briefing note
CBWG10	10.01	Carbon Budgets Working Group agenda 18.01.2024	Agenda
CBWG10	10.02	Carbon Budget Working Group minutes 18.01.2024	Minutes
CBWG10	10.03	CBWG meeting 10-presentation 18.01.2024	Presentation

Associated meeting	Document number	Document name	Category
CBWG10	10.04	IEA A global pathway to keep the 1.5 °C goal in reach-presentation 18.01.2024	Presentation
CBWG10	10.05	Warming impact of national emissions pathways-presentation 18.01.2024	Presentation
CBWG10	10.06	SEAI review of carbon budget modelling 1st iteration outputs-presentation 18.01.2024	Presentation
CBWG10	10.07	Preparing for macroeconomic assessment: data requirements-presentation 18.01.2024	Presentation
CBWG10	10.08	Barret, A., Curtis, J. (2024) The National Development Plan in 2023: Priorities and Capacity. *ESRI Survey and Statistical Report Series Number 12*: 130pp	Submission
CBWG10	10.09	Pisani-Ferry, J., Mahfouz, S. (2023) The economic implications of climate action: a report to the French Prime-Minister. *République Français Report*: 160pp	Submission
CBWG10	10.10	Guillemette, Y., Chateau, J. (2023) Long Term Scenarios: Incorporating the Energy Transition. *OECD Economic Policy Paper* No 33: 62pp	Submission
CBWG11	11.01	Carbon Budgets Working Group agenda 29.02.2024	Agenda
CBWG11	11.02	Carbon Budget Working Group minutes 29.02.2024	Minutes
CBWG11	11.03	CBWG meeting 11-presentation 29.02.2024	Presentation
CBWG11	11.04	Victorian emission budgets-presentation 29.02.2024	Presentation
CBWG11	11.05	Overview of research on Ireland's power sector-presentation 29.02.2024	Presentation
CBWG11	11.06	The EU climate target for 2040-presentation 29.02.2024	Presentation
CBWG11	11.07	Meinshausen & Nicholls (2022) 'GWP* is a model, not a metric'. *Environmental Research Letters* 17, 041002	Submission
CBWG12	12.01	Carbon Budgets Working Group agenda 22.03.2024	Agenda
CBWG12	12.02	Carbon Budget Working Group minutes 22.03.2024	Minutes
CBWG12	12.03	CBWG meeting 12-presentation 22.03.2024	Presentation
CBWG12	12.04	Non-CO2 greenhouse gas reductions implied by IPCC estimates of the remaining carbon budget-presentation 22.03.2024	Presentation
CBWG12	12.05	2. Rogelj & Lamboll, 2024, Non CO2 gases	Submission
CBWG12	12.06	Rogelj, J., Lamboll, R.D., (2024) 'Substantial reductions in non-CO2 greenhouse gas emissions reductions implied by IPCC estimates of the remaining carbon budget' *Communications Earth & Environment* 5, 35	Submission

Associated meeting	Document number	Document name	Category
CBWG13	13.01	Carbon Budgets Working Group agenda 19.04.2024	Agenda
CBWG13	13.02	Carbon Budget Working Group minutes 19.04.2024	Minutes
CBWG13	13.03	CBWG meeting 13-presentation 19.04.2024	Presentation
CBWG13	13.04	Decarbonised electricity system study-presentation 19.04.2024	Presentation
CBWG13	13.05	Agriculture & LULUCF research overview: emissions and mitigation-presentation 19.04.2024	Presentation
CBWG13	13.06	4.1 NESC note on Just Transition April 2024[114]	Briefing note
CBWG13	13.07	Just Transition reflections for carbon budget process: a principles-based approach-presentation 19.04.2024	Presentation
CBWG13	13.08	Scenario dialogue tool	Draft document
CBWG14	14.01	Carbon Budgets Working Group agenda 23.05.2024	Agenda
CBWG14	14.02	Carbon Budget Working Group minutes 23.05.2024	Minutes
CBWG14	14.03	CBWG meeting 14-presentation 23.05.2024	Presentation
CBWG14	14.04	GOBLIN scenarios for carbon budgets towards 2050-presentation 23.05.2024	Presentation
CBWG14	14.05	Energy system pathways for carbon budgets: Second iteration of TIM scenarios-presentation 23.05.2024	Presentation
CBWG14	14.06	Agricultural activity and agricultural GHG projections to 2050-presentation 23.05.2024	Presentation
CBWG14	14.07	4.1 Scenario dialogue tool	Draft document
CBWG15	15.01	Carbon Budgets Working Group agenda 28.06.2024	Agenda
CBWG15	15.02	Carbon Budget Working Group minutes 28.06.2024	Minutes
CBWG15	15.03	CBWG meeting 15-presentation 28.06.2024	Presentation
CBWG15	15.04	Warming impact of national emissions scenarios 2-presentation 28.06.2024	Presentation
CBWG15	15.05	The macroeconomic impact of carbon budgets in a semi-structural model of the Irish economy-presentation 28.06.2024	Presentation

114 NESC presented on Just Transition principles to inform a follow-on discussion on its consideration as part of the carbon budgets process. A draft note on Just Transition was presented by NESC to the CBWG at Meeting 13, and a final version of the note is published on the CCAC website with the CBWG reports: Moore, J. and Garvey, N. (2004). NESC Note on Just Transition to the Carbon Budget Working Group. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

Associated meeting	Document number	Document name	Category
CBWG15	15.06	4.1 Draft SEAI DESS report[115]	Draft report
CBWG15	15.07	Expert elicitation on plausible deployment rates of generation technologies in Ireland 2024 – 2040-Presentation 28.06.2024	Presentation
CBWG15	15.08	4. SEAI note on renewables deployment rates	Report
CBWG15	15.09	4. SEAI note on value of expert elicitations	Report
CBWG15	15.10	4. SEAI note on power sector technology deployment rates	Report
CBWG15	15.11	5.1 Secretariat note on aviation and maritime	Briefing note
CBWG15	15.12	6.1 Styles GOBLIN scenario narratives	Submission
CBWG15	15.13	6.2 Daly TIM scenario narratives	Submission
CBWG15	15.14	6.3 Scenario dialogue tool	Draft document
CBWG15	15.15	Jackson and Kelleher (2023) Ireland's Second-Generation Climate Act: Still Playing the Laggard During the Climate Crisis? *Irish Jurist* 283, 283–321	Submission
CBWG16	16.01	Carbon Budgets Working Group agenda 25.07.2024	Agenda
CBWG16	16.02	Carbon Budget Working Group minutes 25.07.2024	Minutes
CBWG16	16.03	CBWG meeting 16-presentation 25.07.2024	Presentation
CBWG16	16.04	2.1 Assessment of biodiversity considerations	Report
CBWG16	16.05	Assessment of biodiversity considerations in the carbon budgets process-presentation 25.07.2024	Presentation
CBWG16	16.06	Modelling analysis to support the development of the second programme of carbon budgets-presentation 25.07.2024	Presentation
CBWG16	16.07	Carbon budgets modelling second iteration – NEMF Additional testing-presentation 25.07.2024	Presentation
CBWG 17	17.01	Carbon Budgets Working Group agenda 29.08.2024	Agenda
CBWG 17	17.02	Carbon Budget Working Group minutes 29.08.2024	Minutes
CBWG 17	17.03	CBWG meeting 17-presentation 29.08.2024	Presentation
CBWG 17	17.04	Biodiversity considerations for carbon budgets- current state of play!-presentation 29.08.2024	Presentation

115 SEAI presented provisional results of this expert elicitation to the CBWG in April and June 2024. A final Decarbonised Electricity System Study report documenting the methodology and results of the surveys will be published by SEAI in late 2024.

Associated meeting	Document number	Document name	Category
CBWG 17	17.05	FORESIGHT scenarios for carbon budgets towards 2050-presentation 29.08.2024	Presentation
CBWG 17	17.06	Energy system pathways for carbon budgets: third iteration of TIM scenarios-presentation 29.08.2024	Presentation
CBWG 17	17.07	MACC 2050-presentation 29.08.2024	Presentation
CBWG17	17.08	Food, farming & countryside commission high-level round table: land use decision making in UK and Ireland	Submission
CBWG 18	18.01	Carbon Budgets Working Group agenda 18.09.2024	Agenda
CBWG 18	18.02	Carbon Budget Working Group minutes 18.09.2024	Minutes
CBWG 18	18.03	CBWG meeting 18-presentation 18.09.2024	Presentation
CBWG 18	18.04	Warming impact of national emissions scenarios 3-presentation 18.09.2024	Presentation
CBWG 18	18.05	3.1 Economic assessment of climate change impacts and adaptation options	Report
CBWG 18	18.06	Macroeconomic implications of implementing carbon budgets-presentation 18.09.2024	Presentation
CBWG 18	18.07	Climate impacts and adaptation in Ireland-presentation 18.09.2024	Presentation
CBWG 18	18.08	Macroeconomic implications of implementing carbon budgets-presentation 18.09.2024	Presentation
CBWG 18	18.09	Carbon budgets modelling third iteration NEMF additional testing-presentation 18.09.2024	Presentation
CBWG 18	18.10	Follow on discussion on carbon dioxide removal considerations-presentation 18.09.2024	Presentation
CBWG 18	18.11	Scenario dialogue tool	Draft document
CBWG 18	18.12	De Bruin et al. (2024) Macroeconomic impacts of climate-induced damages in Ireland: A CGE analysis of secondary impacts. ESRI Working Paper No. 789 pp 23	Submission
CBWG 18	18.13	De Bruin et al. (2024) Interactions between climate change mitigation, damages, and adaptation: An intertemporal Computable General Equilibrium analysis for Ireland. ESRI Working Paper No. 790 pp 23	Submission

Appendix 5: Core scenarios legend

FAPRI-Ireland scenarios		
Agricultural activity	**S1** (base case)	In the base case agricultural activity scenario (S1), by 2050 dairy cow numbers rise by 14%, increasing total milk production by 38% relative to 2022 due to higher milk yields. Total cattle inventories decrease by 7%, while beef production declines by 11%. Fertiliser use is projected to rise by 10%, and cropland area shrinks by 16% as grassland farming, especially dairying, becomes more profitable. Sheep numbers drop by 25%, while pig and poultry production grows by 25% and 30%, respectively.
	S2 (lower agricultural activity)	In the lower agricultural activity scenario (S2), with reduced economic incentives for dairy and beef in this scenario, by 2050 total cattle inventories drop by 22% relative to 2022, driven by an 84% decline in beef cow numbers. Dairy cow numbers still rise by 7% and, with higher milk yields, milk production increases by 28%, but beef production falls by 26% by 2050. Fertiliser use decreases by 12%, cropland contracts by 14%, and sheep numbers drop by 25%. Pig and poultry production grows by 25% and 35%, respectively.
	S3 (higher agricultural activity)	Higher milk prices and support for beef farmers lead to a 22% increase in dairy cow numbers by 2050 and a slower decline in beef cow numbers than in the other two scenarios. Total cattle inventories grow by 1%, milk production rises by 47% and beef production drops by less than 5%, a smaller decrease than S1 and S2. Fertiliser use rises by 22%, cropland area contracts by 24%, and sheep numbers decline by 25%. Pig and poultry production grow by 24% and 34%, respectively.
MACC adoption rate	**BAU** (no mitigation)	No mitigation (business as usual): The projected emissions in 2050 for S1, S2 and S3 without any emissions mitigation in 2050 are 23,171, 20,227 and 25,118 kt CO_2 e, respectively. Emissions without any mitigation are projected to decrease by 0.7% under S1 and by 4.2% under S2. Emissions from agriculture without any mitigation are projected to decrease by 3.0% under scenario S3.
	P1 (ambitious adoption rates)	Pathway 1 (P1) assumes an ambitious adoption rate following the 2023 Teagasc MACC.
	P2 (very ambitious adoption rates)	Pathway 2 (P2) assumes very ambitious adoption rates, with many measures extended close to the maximum potential rate to 2050. Achieving substantial reductions in agricultural GHG emissions by 2050 necessitates very ambitious adoption of mitigation measures (P2). High levels of uptake would allow the Agriculture sector to contribute significantly to Ireland's national climate goals, including the 25% reduction target for agriculture by 2030 and further reductions by 2050, with potential reductions in agricultural emissions of between 38% and 48% by 2050 relative to 2018.

GOBLIN scenarios		
Forestry	**Sc-1 (L1)**	Forest management: More sustainable management (longer rotations, more continuous cover forestry). Afforestation: BAU mix (50:50 conifer:broadleaf), 15% on organo-mineral soils: 8 kha per year 2030–2080.
	Sc-2 (L2)	Forest management: More sustainable management (longer rotations, more continuous cover forestry). Afforestation: BAU mix (50:50 conifer:broadleaf), 15% on organo-mineral soils: 25 kha per year 2030–2080.
	Sc-3 (L3)	Forest management: More sustainable management (longer rotations, more continuous cover forestry). Afforestation: 70:30 conifer:broadleaf mix, 100% on mineral soils: 25 kha per year 2030–2080.
	Sc-4 (L4)	Forest management: More sustainable management (longer rotations, more continuous cover forestry). Afforestation: 70:30 conifer:broadleaf mix, 100% on mineral soils: 17.5 kha per year 2030–2080.
Agriculture	**Sc-a (A)**	Current herd structure: Current cattle herd and sheep flock structure is maintained. Constant level of bovine protein production in Ireland is maintained to minimise the risk of carbon leakage. MACC+: High rates of deployment of efficient management practices and abatement technologies, proxying maximum deployment of existing proven practices and technologies by 2050. Agriculture sector emissions reductions of 34% vs 2020 by 2050.
	Sc-b (B)	Intermediate herd structure: Assumes a shift out of suckler beef and towards milk plus more dairy beef. Average dairy and beef cow productivity scales up from current performance (Sc-a) to intermediate performance. MACC+: High rates of deployment of efficient management practices and abatement technologies, proxying maximum deployment of existing proven practices and technologies by 2050. Agriculture sector emissions reductions of 40% vs 2020 by 2050.
	Sc-c (C)	Agriculture sector emissions reductions of 45% vs 2020 by 2050.
	Sc-d (D)	Dairy specialisation, high yield: Reduces dairy cow numbers needed to maintain bovine protein output owing to an average increase in milk productivity. Average dairy and beef cow productivity scales up from current performance (Sc-a) through intermediate performance (Sc-b) to higher levels of performance. MACC+: High rates of deployment of efficient management practices and abatement technologies, proxying maximum deployment of existing proven practices and technologies by 2050. Agriculture sector emissions reductions of 52% vs 2020 by 2050.
	Sc-e (E)	Scales down animal numbers and production from Sc-d to achieve Agriculture sector emissions reductions of 60%. Average dairy and beef cow productivity scales up from current performance (Sc-a) through intermediate performance (Sc-b) to higher levels of performance. MACC+: High rates of deployment of efficient management practices and abatement technologies, proxying maximum deployment of existing proven practices and technologies by 2050. Agriculture sector emissions reductions of 60% vs 2020 by 2050.

Forestry scenarios (Sc-1 to Sc-4) are labelled to equate to the warming impact analysis (L1–L4) scenario labels.

Agriculture scenarios (SC-a to SC-e) are labelled to equate to the warming impact analysis (A–E) scenario labels.

Wheatley, J. (2024). Ireland's Warming Impact. [online] https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

TIM scenarios		
250 Mt		A carbon budget of 250 Mt CO_2 eq is imposed as a constraint on total GHG emissions from the sectors covered in TIM fossil fuel combustion across Ireland's energy system (covering power, buildings, transport) plus industrial process emissions and excluding international aviation and shipping. A BAU energy demand is projected.
300 Mt		A carbon budget of 300 Mt CO_2 eq is imposed as a constraint on total GHG emissions from the sectors covered in TIM fossil fuel combustion across Ireland's energy system (covering power, buildings, transport) plus industrial process emissions and excluding international aviation and shipping. A BAU energy demand is projected.
350 Mt		A carbon budget of 350 Mt CO_2 eq is imposed as a constraint on total GHG emissions from the sectors covered in TIM fossil fuel combustion across Ireland's energy system (covering power, buildings, transport) plus industrial process emissions and excluding international aviation and shipping. A BAU energy demand is projected.
400 Mt		A carbon budget of 400 Mt CO_2 eq is imposed as a constraint on total GHG emissions from the sectors covered in TIM fossil fuel combustion across Ireland's energy system (covering power, buildings, transport) plus industrial process emissions and excluding international aviation and shipping.A BAU energy demand is projected.
450 Mt		A carbon budget of 450 Mt CO_2 eq is imposed as a constraint on total GHG emissions from the sectors covered in TIM fossil fuel combustion across Ireland's energy system (covering power, buildings, transport) plus industrial process emissions and excluding international aviation and shipping. A BAU energy demand is projected.
Energy scenario sensitivity cases	**WEM**	An additional scenario run for a sensitivity analysis which does not impose carbon budgets and instead aligns each sector's GHG emissions with the EPA WEM scenario for 2024–2050.
	WAM	An additional scenario run for a sensitivity analysis which does not impose carbon budgets and instead aligns each sector's GHG emissions with the EPA WAM scenario for 2024–2050.
	No mitigation	No carbon budget or GHG target is imposed in this scenario.
	LED	The low energy demand case increases the feasibility of faster emissions reductions, particularly in the first and second carbon budget periods (2021–2030), and allows more ambitious carbon budgets to be met and mitigation to be achieved with less rapid deployment of mitigation measures and with lower reliance on more speculative measures or those that have higher risks of negative trade-offs, such as BECCS and hydrogen.
	Low Bio	A sensitivity case, Low Bio, is also included where there is no increase in bioenergy demand relative to 2020 in order to explore the implications across the energy system of limiting bioenergy imports.
	High Solar PV	A sensitivity case, High Solar PV, is also included, which enables greater solar PV capacity than is assumed in core scenarios.

LED, low energy demand; Low Bio, low bioenergy; PV, photovoltaic; WAM, with additional measures; WEM, with existing measures.