



Title of paper:	Second Programme of Carbon Budgets Draft Methodology
Purpose:	<p>The aim of this paper is to present an outline of work to be carried out by the CCAC and Secretariat, supported by a Carbon Budgets Working Group, to propose the second programme of carbon budgets by the end of 2024.</p> <p>The review of the methodology and process for first programme of carbon budgets carried out with CCAC and Carbon Budget Committee Members during 2022 and the carbon budgets modelling workshop held on the 18<sup>th</sup> of October 2022 were key inputs to this draft methodology.</p> <p>This document will be discussed and developed further as part of the initial meetings of the Carbon Budgets Working Group in 2023.</p>
Length:	26 pages

## Document Revision Summary

Version Number	Revision Date	Description
1.0	8/12/22	Initial draft circulated for consideration ahead of the CCAC meeting on the 15 <sup>th</sup> of December 2022
1.1	01/03/23	Updated draft incorporating feedback from the CCAC meeting on the 15 <sup>th</sup> of December 2022 and circulated for consideration ahead of the 1 <sup>st</sup> Carbon Budgets Working Group meeting on the 9 <sup>th</sup> of March 2023.
1.2	13/04/23	Updated draft incorporating feedback following the 1 <sup>st</sup> Carbon Budgets Working Group meeting on the 9 <sup>th</sup> of March 2023.
<u>1.3</u>	<u>29/06/23</u>	<u>Update to Section 3.3 following feedback from ESRI on D/Taoiseach's Research &amp; Modelling Macroeconomic Subgroup.</u>

## Table of Contents

<a href="#">1. Introduction</a>	4
<a href="#">2. Research, Inputs and Parameters</a>	6
<a href="#">2.1 Baseline Year and Emissions Target</a>	6
<a href="#">2.2 National Climate Objective</a>	7
<a href="#">2.3 Ongoing monitoring of progress for CB1 and CB2</a>	7
<a href="#">2.4 Monitoring of changes to Inventories and Projections</a>	8
<a href="#">2.5 Consistency with Regulations Assessment</a>	9
<a href="#">2.6 Obligations under EU Legislation Assessment</a>	9
<a href="#">2.7 Assessment of Treatment of Methane</a>	10
<a href="#">2.8 Assessment of Treatment of LULUCF</a>	11
<a href="#">2.9 Assessment of Treatment of Maritime and Aviation emissions</a>	12
<a href="#">2.10 Review of International Approaches to Carbon Budgets</a>	12
<a href="#">2.11 Review of Global Carbon Budget</a>	13
<a href="#">3. Pathways development and sectoral analysis under range of carbon budgets</a>	14
<a href="#">3.1 Pathways development and Modelling</a>	14
<a href="#">3.2 Paris Test of pathways – Objectives of the UNFCCC and Paris Agreement and Climate Justice</a>	18
<a href="#">3.3 Analysis of Macroeconomic Impact of Carbon Budgets</a>	19
<a href="#">3.4 Analysis of Socioeconomic Impact of Carbon Budgets and Just Transition</a>	20
<a href="#">3.5 Biodiversity Considerations</a>	21
<a href="#">3.5 Assessment of Overshoot Scenarios and role of negative emissions</a>	22
<a href="#">3.6 Sectoral Engagement for carbon budgets</a>	22
<a href="#">4. Carbon Budgets Working Group</a>	23
<a href="#">4.1. Key Outputs for the Carbon Budgets Working Group</a>	23
<a href="#">5. Development of Technical Report</a>	23
<a href="#">6. High-Level Project Plan</a>	24
<a href="#">Appendix 1: Inputs to Methodology</a>	25
<a href="#">Appendix 2: Research Inputs</a>	26

# 1. Introduction

Under the Climate Action and Low Carbon Development (Amendment) Act 2021, the Council was initially mandated to propose the first programme of carbon budgets to the Minister of Environment, Climate and Communications as soon as may be after the coming into effect of the Act. Under the 2021 Act, subsequent carbon budget proposals will need to be made at least one year before the end of each of the current carbon budgets and each proposal will always be made up of a programme of three carbon budgets for the State.

As part of the second programme of carbon budgets, the Council is required to submit to the Minister (1) proposed amendments to the provisional carbon budget (CB3 from 2031-2035) and (2) a provisional carbon budget (CB4 from 2036-2040), not less than 12 months before the expiry of CB1, being the budget for the period 2021-2025. On the expiry of CB1, the Second Carbon Budget Programme will comprise CB2 from 2025-2030, CB3 from 2031-2035 and provisional CB4 from 2036-2040 (as these will be the three carbon budgets in effect).

In short, proposals for CB3 (2031-2035) and CB4 (2036-2040) will be required by the end of 2024<sup>1</sup>. The aim of this draft methodology is to outline the process for development of the CCAC proposals for the second programme of carbon budgets, building on the process for CB1 and CB2 and accounting for inputs including;

1. Feedback received from CCAC members and members of the Carbon Budgets Committee through a review process carried out in 2022.
2. Feedback from the carbon budgets workshop held on the 18<sup>th</sup> of October 2022.
3. The updated Terms of Reference for the Carbon Budgets Working Group.

Version 1.0 of this methodology was prepared by the Secretariat for consideration at the CCAC meeting on the 15<sup>th</sup> of December 2022 in order to outline the inputs needed for the second programme of carbon budgets. An updated document (Version 1.1) was subsequently prepared based on Council feedback and circulated for consideration ahead of the 1<sup>st</sup> Carbon Budgets Working Group meeting on the 9<sup>th</sup> of March 2023. Following discussion at the 1<sup>st</sup> Carbon Budgets Working Group meeting on the 9<sup>th</sup> of March 2023 and receipt of written comments after the meeting, Version 1.2 of this document was prepared incorporating feedback from working group members and circulated ahead of the 2<sup>nd</sup> Carbon Budgets Working Group meeting on the 20<sup>th</sup> of April 2023.

An initial task of the Carbon Budgets Working Group will be to consider this methodology and propose any additions or revisions, particularly in relation to Section 3 below regarding pathways development, with a revised version to be prepared based on feedback from the Working Group. This will feed into the workplan and topics to be considered by the Working Group in 2023 and 2024, to be discussed at the second meeting of the group.

This document is divided into three main sections. **Section 2** covers the research, inputs and parameters to be developed in the first instance based on the requirements under the Act, updates to inputs from the first programme of carbon budgets, and updates to scientific

---

<sup>1</sup> Section 6.A (6) of the Act as amended states that 'Not less than 12 months prior to the expiry of the first carbon budget in a carbon budget programme, the Advisory 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, and proposed amendments, if any, to the provisional carbon budget'.

knowledge and to relevant EU policies and legislation. **Section 3** covers the sequencing and development of sectoral pathways and scenarios for the second programme of carbon budgets, to be input to macroeconomic, socioeconomic and climate justice-based assessments and wider considerations, including biodiversity and environmental sustainability. **Section 4** covers the process to consolidate these elements into a technical report to be submitted by the Secretariat to the CCAC in order to inform its final deliberations on carbon budget proposals.

## 2. Inputs and Parameters for Carbon Budget Proposals

Many of the inputs and parameters for development of carbon budgets are determined through the Climate Action and Low Carbon Development (Amendment) Act 2021 and Regulation (S.I. No. 531/2021) and are summarised in the subsections below. A number of these inputs will also be informed by the latest scientific developments and EU policies and legislation.

### 2.1 Baseline Year and Emissions Target

The base year of emissions to be considered under the Act is the *'total amount of annual greenhouse gas emissions reported for the year ending on 31 December 2018.'*

Adjustments to the historical inventory may impact the first programme of carbon budgets. Specifically, a downwards or upwards revision of the EPA emissions inventory for 2018 may prompt the Minister to carry out a revision of carbon budgets, as provided for under Section 6D of the Act<sup>2</sup> and outlined under Section 2.3 below. However, this revision would be a purely mathematical adjustment to the first carbon budget (2021-2025) and/or second carbon budget (2026-2030) accounting for the adjustment to the greenhouse gas emissions reported for the 2018 baseline year.

#### **Inputs for Second Programme of Carbon Budgets:**

- The Act notes that the Government may make regulations to specify the base year in relation to the reduction of greenhouse gas emissions for budget periods after 31 December 2030. This will need to be monitored and accounted for if there are any changes.
- In April 2024, the EPA will publish the national emissions inventory for the years 1990- 2022. Under the Act, the CCAC must use the estimated 2018 emissions from this inventory as the baseline for the second programme of carbon budgets.
- The baseline for emissions for each prospective carbon budget, or any revisions to the carbon budgets, will need to take account of the latest GWP<sub>100</sub> values<sup>3</sup> as

<sup>2</sup> Section 6.D of the Act as amended states; '(1) The Minister may revise a carbon budget in the circumstances set out in subsection (2), (4) or (5).

(2) The Minister may revise a carbon budget where –

(a) new obligations are imposed on the State under the law of the European Union or any international agreement referred to in section 2, or

(b) there are significant developments in scientific knowledge in relation to climate change.

(4) Where the total greenhouse gas emissions for a preceding budget period are less than the carbon budget for that period, the Minister may carry forward the surplus from the preceding budget period to the current budget period and the current carbon budget shall be increased by the surplus carried forward.

(5) Where the total greenhouse gas emissions for a preceding budget period exceed the carbon budget for that period, the Minister shall carry forward the excess greenhouse gas emissions from the preceding budget period to the current budget period and the current carbon budget shall be decreased by the amount of greenhouse gas emissions that are carried forward.

(6) The Minister shall consult with and consider the advice of the Advisory Council prior to requesting the approval of the Government in relation to a revision of a carbon budget under this section'.

<sup>3</sup> S.I. No. 531 of 2021 states; *'The manner of calculating and accounting for the emissions (including any reductions) referred to in Regulation 3 is specified –*

*(a) in the UN reporting guidelines,*

specified by the most up to date regulation and any changes reported by the EPA in the emissions inventory for the relevant baseline year (due to any changes to the methodology being used to estimate emissions for example).

## 2.2 National Climate Objective

*‘A carbon budget, consistent with furthering the achievement of the national climate objective, shall be proposed by the Advisory Council...’*

The national climate objective as defined in the Act is a *‘climate resilient, biodiversity rich, environmentally sustainable and climate neutral economy’*.

The second programme of carbon budgets will need to account for a trajectory towards a climate neutral economy by 2050.

### **Inputs for Second Programme of Carbon budgets:**

- Developing policy and research on the long-term climate objective and the definition of a climate neutral economy.
- An input to this will be the Secretariat’s paper on a vision for 2050 which will be discussed with the CCAC and CB WG. This includes a discussion of the long-term climate objective under the Act and what climate neutrality means for Ireland in the context of national, EU and International targets. A thematic discussion on this topic is being held with the CCAC in April 2023 the outcomes of which could inform the first CB WG discussion in May 2023.
- Ireland’s Long Term Climate Strategy, which is due to be submitted to the European Commission and published in 2023.
- Analysis to confirm proposed budgets between 2031 and 2040 are consistent with the long-term climate objective under the Act.

## 2.3 Ongoing monitoring of progress for CB1 and CB2

Ongoing monitoring of compliance with the first carbon budget and sectoral emissions will be an important consideration in developing CB3, in particular as this will be relevant to how any under or over performance is accounted for in subsequent budgets. The latest available projections<sup>4</sup> for CB1 (2021-2025) compliance, for the final year of CB1 in 2025, will be a key input to this monitoring.

The Council has also previously recommended to Government that a review of budgetary compliance should be carried out on an annual basis and in its press release on carbon budgets stated *‘Every year, the Climate Change Advisory Council will undertake a review of progress made against these carbon budgets. The review will assess reductions achieved in GHG emissions, compliance with the carbon budget, and every sectoral emissions ceiling for that period’*.

---

(b) with regard to the global warming potential, in the Annex to Commission Delegated Regulation (EU) 2020/1044, and

(c) with regard to the sources and sink categories, in the part of the CRF titled ‘Total CO2 equivalent emissions with land use, land use change and forestry’.

<sup>4</sup> The EPA publish Ireland’s Greenhouse Gas Emissions Projections on an annual basis, c.a. June of each year.

In relation to banking of excess savings in Ireland, Section 6D(4) of the amended Act states *'Where the total greenhouse gas emissions for a preceding budget period are less than the carbon budget for that period, the Minister may carry forward the surplus from the preceding budget period to the current budget period and the current carbon budget shall be increased by the surplus carried forward.'*

The Act also states *'Where the total greenhouse gas emissions for a preceding budget period exceed the carbon budget for that period, the Minister shall carry forward the excess greenhouse gas emissions from the preceding budget period to the current budget period and the current carbon budget shall be decreased by the amount of greenhouse gas emissions that are carried forward.'*

The Second Programme of Carbon Budgets may also include scope for further consideration of Carbon Budget 2 from 2026-30 in the context of any revision of carbon budgets, as provided for under Section 6D of the Act. Section 6D of the Act as amended states that the Minister may revise a carbon budget *'where new obligations are imposed on the State under the law of the European Union or any international agreement referred to in section 2, or there are significant developments in scientific knowledge in relation to climate change'*.

The Act also states that *'The Minister shall consult with and consider the advice of the Advisory Council prior to requesting the approval of the Government in relation to a revision of a carbon budget'*.

#### **Inputs for Second Programme of Carbon Budgets:**

- Establish tracking of annual emissions against carbon budgets and annual average percentage change in emissions against sectoral emissions ceilings using indicators and inventories for 2021-2023<sup>5</sup>.
- Consider projections for 2024 to inform compliance with CB1 (as provisional inventories up to 2023 will be available).
- Consider projections for 2026-2030 to inform compliance with CB2.
- Consider any request for consultation in relation to carbon budgets, if requested by the Council.

## **2.4 Monitoring of changes to Inventories and Projections**

The modelling of carbon budget scenarios was calibrated to and informed by data from the EPA inventory and projections and the Act requires the use of *'latest Inventories, Projections and Best Practice Reporting of Emissions and Removals'*.

Changes are made to the EPA inventory each year to update and improve underlying data and methods to estimate emissions.

It was noted during the carbon budgets modelling workshop that progress on draft emissions inventories and earlier publication of projections is very useful to the carbon budget process,

---

<sup>5</sup> Performance against each 5-year budget will be reviewed once final inventories for the budget period are known.



particularly for CB3 (2031 – 2035) when projections of progress against CB1 and CB2 and the pathway to 2050 become more important.

**Inputs for Second Programme of Carbon Budgets:**

- Latest emissions inventories and projections published in 2023 and 2024 as inputs to iterations of modelled scenarios across different sectors.
- Compilation of close to real time indicators using for example SEAI and EPA developments.

## 2.5 Consistency with Regulations Assessment

*‘The Government shall make regulations for determining the greenhouse gas emissions to be taken into account, and the manner of calculating and accounting for such emissions (including any reductions), for the purpose of—*

*(i) the first 2 carbon budgets referred to in subsection (5), and*

*(ii) every carbon budget thereafter.’*

S.I. No. 531 of 2021, ‘Climate Action and Low Carbon Development Act 2015 (Greenhouse Gas Emissions) Regulations 2021’ was adopted on 12/10/2021. This requires emissions from the greenhouse gases specified in the Common Reporting Format (CRF) Tables to be taken into account in the carbon budgets, on the basis of Global Warming Potential values evaluated over 100 years, GWP<sub>100</sub>, published in the IPCC Fifth assessment report (AR5). The Regulation also requires the gross-net accounting approach to be applied in relation to LULUCF emissions.

**Inputs for Second Programme of Carbon Budgets:**

- Tracking of new regulations under Section 6.A (11) of the Act, such as regulations for determining the greenhouse gas emissions to be taken into account, regulations to specify the base year in relation to the reduction of greenhouse gas emissions for budget periods after 2030, and regulations for the purpose of determining how the removal of greenhouse gas emissions may be taken into account.
- Tracking of regulations in relation to the approach for LULUCF emissions.

## 2.6 Obligations under EU Legislation Assessment

Developing EU legislation and Ireland’s compliance with new targets will need to be monitored as part of the enduring carbon budgets process.

Under the EU Fit for 55 package, there is a target for a reduction in EU ETS emissions by 61% (relative to 2005) by 2030 and a reduction in emissions covered by the Effort Sharing Regulation of 40% relative to 2005 by 2030.

The EU’s 2050 long-term strategy is “*to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions*”. Analysis underpinning this long-term goal uses global carbon budgets (from AR5) that are consistent with global temperature targets of “well below

2°C or 1.5°C”; however, the long-term target is still framed in terms of a single year (i.e. 2050) rather than a cumulative amount of emissions (i.e. a carbon budget).

The European Climate Law sets out a binding objective of climate neutrality in the European Union 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 a European Scientific Advisory Board on Climate Change which will provide independent scientific advice and produce reports on EU measures, climate targets and indicative greenhouse gas budgets and their coherence with the European Climate Law.

This is an area that will require certainty as early as possible around new National and EU targets, which will inform modelling required under Section 3.

#### **Inputs for Second Programme of Carbon Budgets:**

- Ongoing monitoring of developments in EU legislation and Ireland’s compliance in this area, along with assessment of impacts or constraints for CB3 and CB4.
- Assessment of how particular emissions reduction constraints for particular sectors under EU targets may need to be reflected in scenarios developed.
- A key output from the work of the ESAB that will be relevant to the carbon budgets is its input to the definition of a science-based EU greenhouse gas target for 2040 that is aligned with the EU’s 2050 climate neutrality objective.

### **2.7 Assessment of Treatment of Methane**

The Act requires the Council to take account of “*relevant scientific advice, including with regard to the distinct characteristics of biogenic methane*”.

The IPCC AR6 updated our understanding of the global carbon budget and the need for net zero emissions of long-lived gases (e.g. CO<sub>2</sub> and N<sub>2</sub>O) and for a strong, rapid and sustained reduction in methane (CH<sub>4</sub>) emissions.

The approach specified in the Act and Regulation does not require separate budgets for methane and other greenhouse gases. This is an area that could be considered as part of the preparation of CB3 and CB4 before final combined budgets are submitted. New Zealand has notably taken a split-gas approach, with a 2050 net-zero policy for long-lived gasses and a separate target for biogenic methane i.e., a reduction of 10% by 2030 and 24-47% by 2050 compared to 2017<sup>6</sup>.

The Council’s 2019 Carbon Budgets background paper recommended that; ‘*Carbon budgets should include all gases from all sectors, cognisant of any different net reduction targets applying to GHGs. There should be provision for review and revision of carbon budgets in the case of changes in the science of measurement and reporting etc. These can be routinely adopted. Substantive revision to carbon budgets should be limited to only happen ex ante and in the case of significant change in understanding or circumstances.*’

---

<sup>6</sup> <https://environment.govt.nz/acts-and-regulations/acts/climate-change-response-amendment-act-2019/>

The 2019 Council paper also suggested that it would be appropriate to take a different approach to biogenic methane, recognising the consensus of the IPCC that the required pathway for biogenic methane to 2050 is different to that for the fossil fuel and industrial long-lived greenhouse gases. It noted that further work would be required to determine an appropriate target for biogenic methane in an Irish context. Notably, the ‘Paris Test’ carried out as part of the first programme of carbon Budgets did explicitly consider different pathways for methane emissions with the analysis showing that the temperature impact of the carbon budgets depends on the assumed mix of gases.

#### **Inputs for Second Programme of Carbon Budgets:**

- Review of approach and latest scientific advice in relation to the role of biogenic methane and appropriate pathway to 2050.

## **2.8 Assessment of Treatment of LULUCF**

The National Inventory undergoes continual update and revisions to take account of improved scientific understanding and improved activity data. If updates in the inventory lead to significant changes in reported emissions, revision of carbon budgets may be necessary under the provisions in the Amended Act (2021)<sup>7</sup>.

There has been a significant revision to the methodology and country-specific emission factors applied to soil carbon emissions and removals on afforested lands, based on improved understanding of the underlying processes and advanced observations of carbon fluxes from these soils. This reduces uncertainty in the inventory. However, given the complex, biological nature of the processes involved, uncertainty remains high. This has led to the estimate of carbon removals associated with forest land being revised downwards through the entire time series. Further refinements and revisions to the inventory for the LULUCF sector are expected over the coming years.

As a result of developments in the scientific knowledge of the metrics for monitoring and reporting of LULUCF emissions, the 2021 EPA With Existing Measures (WEM) projections for LULUCF for 2030 of 7 MtCO<sub>2</sub>eq net emissions, were updated to 11 MtCO<sub>2</sub>eq. The first phase of the Land-use Review (the gathering of evidence and data) will report in Q3 2023. Its findings will inform the second phase of the Land-use Review (policies and measures) which will be used to develop a sectoral emissions ceiling in this area and may have implications for carbon budgets.

EU legislation also addresses LULUCF emissions with a number of key policy changes due to come into effect in the short term. The current system for LULUCF accounting for EU reporting purposes, the net-net accounting system, expresses emissions and removals

---

<sup>7</sup> Section 6D of the Act outlines the provisions for revisions of carbon budgets. *‘(2) The Minister may revise a carbon budget where—*

*(a) new obligations are imposed on the State under the law of the European Union or any international agreement referred to in section 2, or*

*(b) there are significant developments in scientific knowledge in relation to climate change.’* Under the Act, the Minister is required to consult with and consider the advice of the Advisory Council prior to requesting the approval of the Government in relation to a revision of a carbon budget.

relative to a baseline or reference period. The EU has proposed that the LULUCF sector transition to a gross-net system from 2026 and that from 2031 onwards LULUCF and Agriculture will be combined into a specific Agriculture Forestry and Other Land Uses (AFOLU) sector.

**Inputs for Second Programme of Carbon Budgets:**

- Assessment of scientific updates to the national inventory in the area of LULUCF emissions.
- Review of EU and national targets in relation to emissions reductions in the LULUCF sector.

## 2.9 Assessment of Treatment of Maritime and Aviation emissions

Emissions from international aviation and maritime navigation are reported as “memo items” in the national emission inventory. This means they are not counted as part of Ireland’s national total emissions but are reported by Ireland to the UNFCCC and EU for information purposes.

While the Regulation excludes International Aviation and Maritime from the 51% target and thus the carbon budget calculations for CB1 and CB2, notable EU policy developments include proposals for the inclusion of international shipping in the EU ETS and the ReFuelEU proposal which will involve all aviation emissions. Despite the Regulation excluding International Aviation and Maritime emissions from legislated carbon budgets, there is scope for the Carbon Budgets Working Group to carry out an assessment of these emissions for their impact on carbon budgets and compliance with the Paris Agreement and report to the CCAC on their additional impact for consideration.

The UK’s sixth carbon budget, running from 2033 to 2037, for the first time includes aviation and maritime emissions, while the French Climate Council has recommended the inclusion of international aviation and maritime emissions in French national targets.

**Inputs for Second Programme of Carbon Budgets:**

- Assessment of any updates to EU legislation or National Policy in this area.

## 2.10 Review of International Approaches to Carbon Budgets

A number of countries have set carbon budgets related to the cumulative amount of emissions from specified greenhouse gases which can be permitted over a certain period of time to keep within a certain temperature range. These include the UK, France and New Zealand and previous work of the CCAC has reviewed the different approaches to carbon budgets and governance in each jurisdiction.

There is further work to be carried out to understand the modelling approaches in each case used to propose carbon budgets.

**Inputs for Second Programme of Carbon Budgets:**

- Small Scale Study review of international approaches to carbon budgets. This work will consider approaches in the UK, New Zealand, the Netherlands, France, Finland and Denmark in particular and also the EU approach to setting targets and trajectories where relevant.
- Bilateral meetings and workshop with international climate councils and engagement with the European Scientific Advisory Board on Climate Change.

## 2.11 Review of Global Carbon Budget

In order to limit global warming to a given temperature level, the total amount of greenhouse gases which 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 broad assessment of consistency with the Paris Agreement (the 'Paris Test' in the first programme of carbon budgets) which is also considered in this methodology.

As the science progresses, and global GHG cumulative emissions continue to grow, it is highly likely that global budgets will continue to be revised. The IPCC's AR6 WG1 report updates the remaining global carbon budget estimates from AR5 noting that several factors such as estimates of historical warming, future emissions from thawing permafrost, variations in projected non-CO<sub>2</sub> warming and the global surface temperature change after cessation of CO<sub>2</sub> emissions affect the exact value of carbon budgets.

A number of studies have attempted to quantify the remaining carbon budget<sup>8</sup> for different probabilities of different global temperature increases. Efforts have also been made to downscale the global carbon budgets to a national level<sup>9</sup>.

### Inputs for Second Programme of Carbon Budgets:

- An updated literature review addressing the latest science in relation to the remaining carbon budget and the role of different greenhouse gases.
- A second expert meeting on the science of carbon budgets, building on the discussion from the first carbon budgets programme through the invitation of experts to a meeting of the Carbon Budgets Working Group.

---

<sup>8</sup> Matthews, Damon, H. et al. (2021). An integrated approach to quantifying uncertainties in the remaining carbon budget. *Communications Earth & Environment*, 2(1), 1–11. <https://doi.org/10.1038/s43247-020-00064-9>

<sup>9</sup> Glynn, J., Gargiulo, M., Chiodi, A., Deane, P., Rogan F., Ó Gallachóir, B., 2019. Zero carbon energy system pathways for Ireland consistent with the Paris Agreement. *Climate Policy* 19:1, 30-42. Available at: <https://www.tandfonline.com/doi/pdf/10.1080/14693062.2018.1464893> and <https://calculator.climateequityreference.org>

## 3. Pathways development and sectoral analysis under range of carbon budgets

### 3.1 Pathways development and Modelling

#### CB1 and CB2

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

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

There is no single model in Ireland that captures in sufficient detail the technical information on mitigation options across all sectors.

Modelling of carbon budget scenarios was carried out by three groups; University College Cork (UCC) TIMES Ireland Model (TIM) focusing on the energy system, Teagasc Food and Agriculture Policy Research Institute (FAPRI) Ireland model focusing on agriculture and University of Limerick (UL) Goblin model focusing on land use was carried out for CB1 (2021-2025), CB2 (2026-2030) and provisional CB3 (2031-2035).

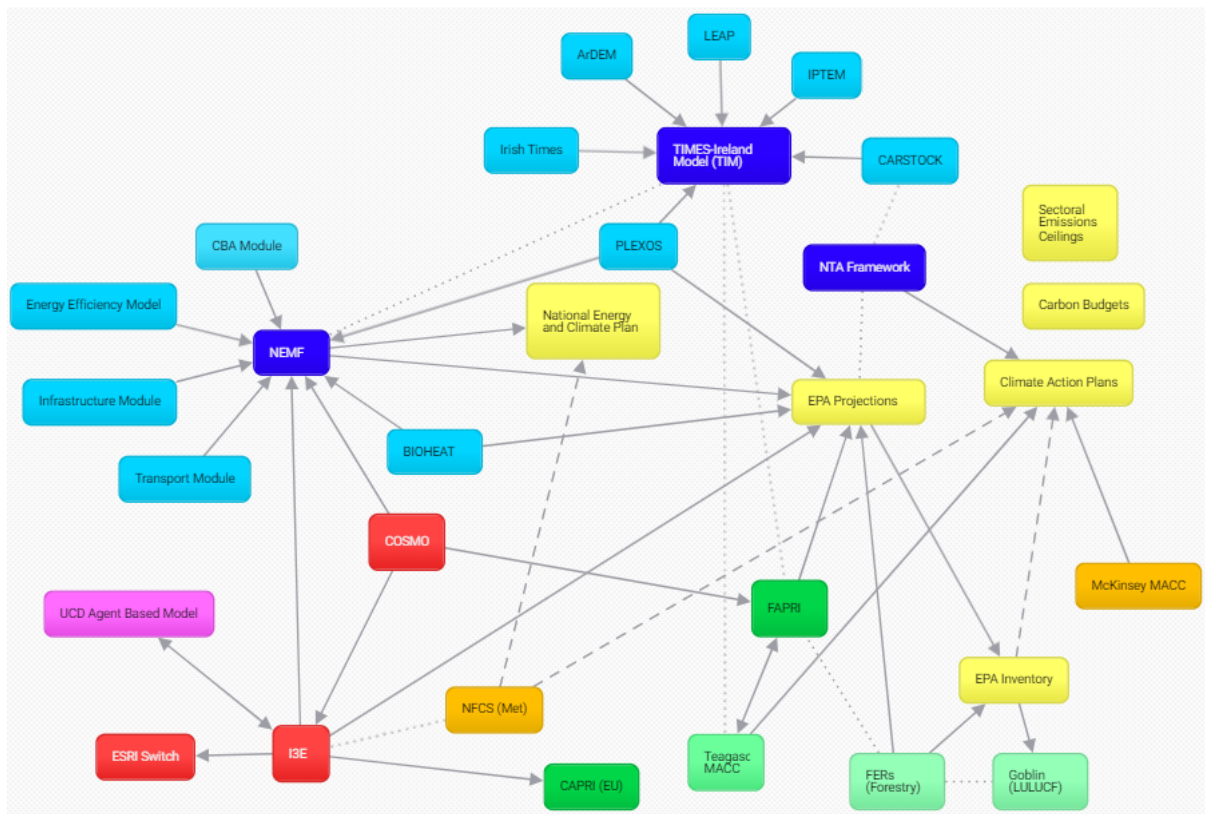
#### CB3 and CB4

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

1. The pathway from a number of baseline scenarios in 2030 to 2040, which align with climate neutrality in 2050, accounting for the role of negative emissions (discussed further in Section 3.5 below) i.e., initial ranges for carbon budgets.
2. The relative level of mitigation feasible and potential range across different sectors based on different carbon budgets.

Outputs for carbon budgets (i.e., proposed budgets and technical report) require multiple model inputs, a process mirrored across a number of national outputs e.g., Climate Action Plans, Sectoral Emissions Ceilings, Emissions Inventories and Projections. This is shown in Figure 1 below based on the work of the Department of Taoiseach's Research and Modelling Group.





**Figure 1: National Climate Modelling Assets and Interactions (Research and Modelling Group Schematic)**

**Figure 1 Legend:**

- Red = Economic
- Blue = Energy / Transport
- Green = Agriculture / Land Use
- Yellow = End Uses
- Orange = Orange = Combined Modelling Services
- Purple = Social / Behavioural
- Arrows = Direction of connection
- Dashed Line = Possible connection
- Dotted Line = Potential future connection

Based on feedback from the review of carbon budgets and modelling workshop, the three sectoral models used for CB1 & CB2 will be important inputs to this analysis, with additional testing or comparison and discussion of results for example from TIM within SEAI’s National Energy Modelling Framework (NEMF) and GOBLIN modified to incorporate key parameters for Ireland’s forestry matrix used by FERs Ltd for the NIR. Additional analysis focusing on the transport sector could also be carried out utilising the NTA’s framework. The utilisation of I3E and Cosmo is discussed further in Section 3.3.

These models are not integrated and are limited in their time horizon, so proposed research to develop an integrated assessment model for Ireland, mapping integrated pathways for rapidly and deeply decarbonising the energy, land and food systems out to 2100 will be

beneficial to future programmes of carbon budgets but will not form a timely input for the second programme.

Capacity for modelling support for this analysis will be sought under the Memorandum of Understanding (MoU) between the Irish Climate Change Advisory Council and all relevant Government departments and Agencies<sup>10</sup>. Draft letters to relevant organisations requesting this analysis support were submitted to the CCAC for review at the 15<sup>th</sup> of December 2022 meeting. Letters were issued under the MoU on 3<sup>rd</sup> of March and the CB WG project plan currently includes a placeholder for discussion of resource requirements for more detailed requests under the MoU in Q2 2023.

A related issue which was raised at the carbon budgets workshop on the 18<sup>th</sup> of October 2022 concerns ensuring that there is enough capacity to carry out and develop modelling in the longer term.

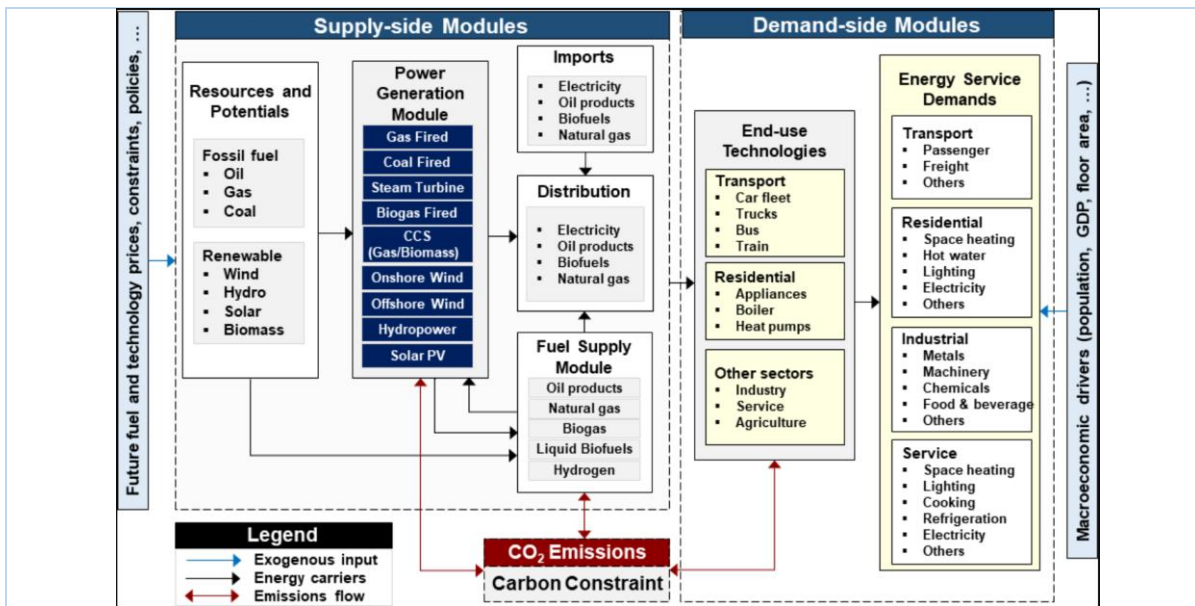
The Secretariat also intends to commission a separate research/consultancy piece of work to consider the pathways within each sector to 2050 and develop carbon budget estimates based on these pathways, which will be used for benchmarking the outputs of the Carbon Budgets Working Group (See Appendix 2 for more detail). In 2024, further work will be carried out to assess the impacts of reductions in emissions on air and water quality and broader environmental sustainability.

#### Summary of sectoral models for initial pathways development across sectors

##### UCC MAREI TIMES Ireland Model

- **The TIMES-Ireland Model (TIM) produces energy system pathways for energy supply and demand in Ireland consistent with either a carbon budget or a decarbonisation target. It calculates the lowest-cost pathway for new investment in energy system technologies and operation and fuel consumption**
- **Levels of mitigation effort in electricity, transport, heat and industry.**
- **Optimisation model, rational central planner, respecting emission reduction targets.**
- **"Balyk, O., et al. (2021). Carbon budget scenarios for Ireland's energy system, 2021-50 (v1.0). Data set. Zenodo. Available online: <https://doi.org/10.5281/zenodo.5517363> Energy Policy & Modelling Group (2021).**
- **Model documentation: <https://doi.org/10.5194/gmd-15-4991-2022>**
- **Carbon budget scenarios for Ireland. Available online: <https://tim-carbon-budgets-2021.netlify.app/results>" Energy systems optimisation modelling (ESOM)**





#### Teagasc FAPRI Ireland Model

- The Teagasc FAPRI-Ireland model is a dynamic partial equilibrium model of Irish agricultural commodity markets and the Irish agricultural economy. Using the model, Teagasc generates projections of agricultural activity levels, agricultural commodity supply and use tables, agricultural input and output prices and the full economic accounts for agriculture to a medium term (10 year) horizon.
- BAU includes implementation of CAP 2019 measures, alternative scenarios reduce emissions relative to 2018 base.

#### UL GOBLIN - Land use

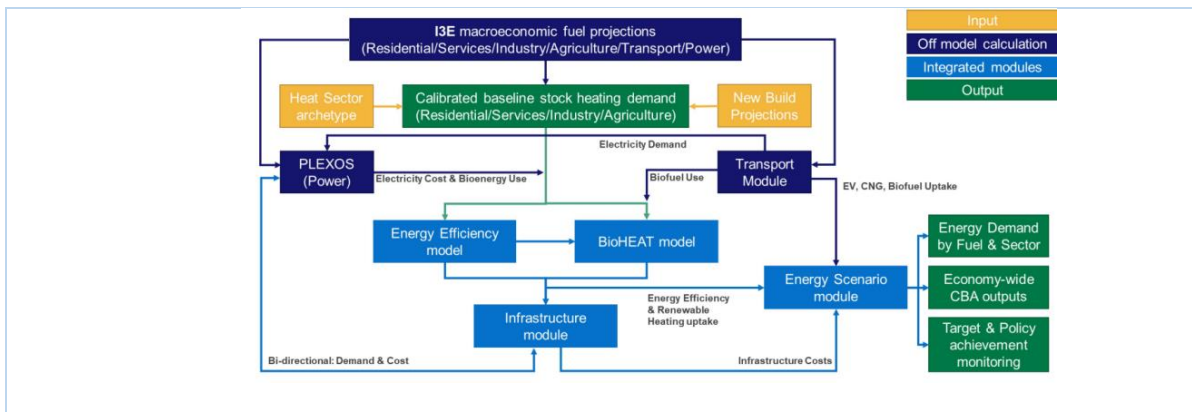
- GOBLIN (General Overview for a Back-casting approach of Livestock Intensification) is designed to run randomised scenarios of agricultural activities and land use combinations for Ireland in 2050 within biophysical constraints (e.g. available land area, livestock productivities, fertiliser-driven grass yields and forest growth rates).
- Based on AFOLU emission factors used for national GHG inventory reporting, GOBLIN then calculates annual GHG emissions out to 2100 for each scenario

#### FERs CBM model and other products

- This is used as an input to the EPA emissions projections in the forest sector and in other areas, and could be used in combination with GOBLIN. The global CBM model is currently being built into GOBLIN, and will be parameterised using Ireland-specific input from FERS to fully align GOBLIN with forestry accounting in the national GHG inventory.

#### SEAI NEMF

- National energy-economy model that assesses the impacts of energy policies and measures on energy supply and demand,
- Combines several sectoral SEAI models with the ESRI's I3E macroeconomic model.



### NTA Framework – Regional Modelling System

- Transport modelling was carried out by the NTA to support/inform the deliberations in the development of the Climate Action Plan 2023.
- This was used to identify a pathway to deliver 50% carbon emissions reduction in the transport sector by 2030 based on packages of measures applied to forecasts for traffic growth.
- The RMS has a hierarchical structure with three main components. These are the National Demand Forecasting Model (NDFM), the five Regional Multi-modal Models (RMMS) and the Appraisal Modules.
- <https://www.nationaltransport.ie/wp-content/uploads/2023/01/Climate-Action-Plan-Phase-3-Modelling-Exec-Summary-v5.6.pdf>

### Potential scenarios and pathways

- Total emissions from each sector aggregated to give economy total for each scenario.
- Total emissions from each scenario averaged to give final carbon budget amounts.
- After 2030, model constrained to achieve net zero emissions.
- Early action, late action, core & linear/non-linear pathways.
- Additional scenarios to be discussed with CB WG

## 3.2 Paris Test of pathways – Objectives of the UNFCCC and Paris Agreement and Climate Justice

### CB1 and CB2

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)’

The long-term goals and objectives of the Paris Agreement, with reference to mitigation (the temperature goals and peaking of emissions as soon as possible with rapid reductions thereafter), adaptation and climate finance are considered to represent a climate-just approach on the international stage.

Given the bottom-up nature of Nationally Determined Contributions (NDCs) as defined in the Paris Agreement, there is no top-down allocation of mitigation effort – instead each country has to determine what they consider their fair share of domestic action and international action to be.

The consistency of the carbon budgets with the Paris Agreement was assessed in order to propose national budgets which were in line with a climate just approach.

#### CB3 and CB4

During the carbon budgets workshop, the timing of an assessment of the alignment of the carbon budget proposals with the Paris Agreement was discussed. Ideally this should be conducted using the first iteration of model results from Section 3.1 along with the macroeconomic and socioeconomic assessments to be carried out under Sections 3.2 and 3.3, potentially leading to a refinement of carbon budget proposals.

Paul Price, DCU & CCAC Carbon Budgeting Fellow, has carried out a significant package of work with recommendations for refining the Paris test for Ireland's second Carbon Budgeting programme. This involves introducing greater clarity on explicit choices being made under the test and potential refinements to Paris Test quantification with regards to the GWP\* GHG metric, alignment with national GHG scenarios using CO<sub>2</sub>+N<sub>2</sub>O+CH<sub>4</sub> and International Aviation and Shipping. This detailed analysis and recommendations will be considered in developing a test to apply to a range of carbon budgets as an output through Section 3.1.

The Secretariat also intends to commission a Small-Scale Study to assess the temperature impact of different pathways developed by the Carbon Budgets Working Group and the outputs of the pathways development and modelling analysis detailed in Section 3.1.

A member of the Carbon Budgets Working Group with a Climate Justice focus has been appointed in order to include climate justice considerations in these discussions.

### **3.3 Analysis of Macroeconomic Impact of Carbon Budgets**

The Climate Action and Low Carbon Development Act mandates both the Council in terms of their responsibilities in respect of the proposal of Carbon Budget programmes and the Government in terms of plan-making and considering actions for inclusion in Climate Action Plans to take account of '*the need to maximise employment, the attractiveness of the State for investment and the long-term competitiveness of the economy*'. The scale of investment required to achieve the carbon budgets will be very significant. Increasing investment on such a scale will have knock-on implications due to the diversion of investment from other areas, with implications for consumption, taxation policy, interest rates, competitiveness and output over the longer term.

#### CB1 & CB2

The macro-economic implications of the Carbon Budgets were explored in a paper by Professor John Fitzgerald (which built on a paper by Pisani-Ferri 2021<sup>11</sup>), but there is a need to build greater capacity in this area for the second programme of carbon budgets.

#### CB3 & CB4

There is a need for a coordinated body of work to be conducted on the most relevant economic models within Ireland in order to ensure that the macro-economic implications of deep decarbonisation pathways can be explored and explained in greater detail.

The value of testing scenario modelling using macroeconomic analysis in relation to jobs, impacts on the economy, impacts on sectors and distributional effects was affirmed throughout the climate modelling information sessions and carbon budgets workshop. This was deemed important to measure the feasibility of proposed climate actions, assess their cumulative impact and determine necessary investment costs. The Dept. of Taoiseach's macroeconomic modelling subgroup is encouraging efforts to link models across Ireland, specifically the link between the and ESRI's Ireland Environment, Energy and Economy Model (I3E) model and the UCC TIM model and a recalibration of the link between I3E and the NEMF (these are already linked) group efforts to try and link up NEMF and TIM models to look at National Climate Action Plan measures, along with The Central Bank's COre Structural MOdel of the Irish economy (COSMO) and ESRI's Ireland Environment, Energy and Economy Model (I3E) were was also noted as having potential to feed into the carbon budgeting process.

This will involve engagement with the Department of Finance, Central Bank and ESRI in relation to the process for macroeconomic assessment of the impacts of the transition and CCAC support and funding for this work to be carried out. In relation to carbon budgets, this will specifically involve testing of the results of the scenario modelling carried out under Section 3.1 in relation to jobs, impacts on the economy, impacts on sectors and distributional effects in addition to the potential economic benefits and opportunities of transition pathways.

A provision for funding for a project of this nature has been included in the 2023 CCAC work programme and the Secretariat is sitting on the Research and Modelling Group Macroeconomic Sub-group which is also considering this area.

### **3.4 Analysis of Societal Impacts of Carbon Budgets and Just Transition**

#### CB3 & CB4

There are many societal impacts associated with selecting different Carbon Budgets. Most notable amongst these are the significant changes required across all sectors of society and the associated challenges and benefits that arise. Mobilising society to deliver on carbon budgets is essential and complex, acknowledging the varying capacities and infrastructures available to different groups and regions within Irish society.

---

<sup>11</sup> Pisani-Ferry, J. (2021) Climate policy is macroeconomic policy, and the implications will be significant. No. PB21-20. [online] <https://www.piiie.com/publications/policy-briefs/climate-policy-macroeconomic-policy-and-implications-will-be-significant>

A report published by the Joint Committee on Environment and Climate Action on the Carbon Budgets recommended that further work on equity, climate justice and fair share should be undertaken for the 2030-2035 budget and any future review of the 2025-2030 budget.

‘Just transition’ and ‘climate justice’ are both cited in the Climate Action and Low Carbon Development (Amendment) Act 2021. Just Transition is noted in the Paris Agreement and can also be related to the overall agenda of the UN SDGs. Section 7 of the Act as amended<sup>12</sup> states that ‘*The Minister and the Government shall have regard for the requirement for a just transition to a climate neutral economy which endeavours, in so far as is practicable, to maximise employment opportunities, and support persons and communities that may be negatively affected by the transition*’. The 2021 Climate Action Plan committed to delivering a just transition, setting out Just Transition Principles and recognising that the economic and behavioural burden of achieving the transition to a climate neutral economy must be as fairly distributed as possible. The 2023 Climate Action Plan further strengthened this commitment to progressively embed just transition principles into the delivery of climate action through each annual Climate Action Plan.

A member of the Carbon Budgets Working Group with a just transition focus has been appointed in order to include just transition considerations in these discussions. Consideration of just transition as part of the pathways development and modelling outlined under Section 3.1 will be informed by a Carbon Budgets Working Group discussion of how just transition aligned to climate justice and ethics, can be reflected in the carbon budget process.

### **3.5 Biodiversity Considerations**

#### **CB1 & CB2**

A study of the Impacts of Climate Change Mitigation Measures on Biodiversity was commissioned by the CCAC as an input to the carbon budgets process. The CCAC noted in the technical report; ‘The Council’s review of the analysis suggests that it is possible to implement carbon budgets while protecting and enhancing biodiversity. However, it is critical that further pressure on biodiversity from all aspects of climate mitigation measures is avoided, in particular from poor siting of renewable energy infrastructure and inappropriate land-use change such as over reliance on, or poor siting of, mono-species afforestation. Care must be taken to identify and implement measures which deliver ‘synergistic gains’ for climate mitigation, biodiversity protection and restoration and catchment resilience.’

#### **CB3 & CB4**

It is intended that further small-scale studies will be carried out in 2023 to build on earlier work on biodiversity, with a particular focus on impacts of offshore wind generation on marine biodiversity and the effects of new forestry targets on biodiversity. Outputs of these small-scale studies will be incorporated into the consideration of proposals as part of the second programme of carbon budgets.

In addition, post-hoc analysis of proposed carbon budgets for potential impacts on biodiversity accounting for obligations under the Global Biodiversity Framework<sup>13</sup> and the EU Nature

---

<sup>12</sup> <https://revisedacts.lawreform.ie/eli/2015/act/46/revised/en/pdf?annotations=false>

<sup>13</sup> <https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf>

Restoration Law<sup>14</sup> will also be undertaken, as it is not necessarily feasible to directly build in biodiversity constraints to the modelling outlined under Section 3.1.

A member of the Carbon Budgets Working Group with a biodiversity focus has been appointed in order to include biodiversity considerations in these discussions.

### **3.5 Assessment of Overshoot Scenarios and role of negative emissions**

#### **CB1 & CB2**

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

A literature review on the potential for negative emissions was prepared by Research Fellow Paul Price (Dublin City University) and the physical potential of LULUCF was discussed at a meeting of LULUCF experts convened by the Secretariat.

#### **CB3 & CB4**

An updated literature review on the latest science in relation to negative emissions will be carried out by the Secretariat.

### **3.6 Sectoral Engagement for carbon budgets**

The Secretariat intends to include a discussion on carbon budgets within each Sectoral Engagement scheduled for Q1 and Q2 of 2023. In 2024, more detailed discussions will be held with each sector based on the outputs detailed throughout Section 3.

---

<sup>14</sup> <https://environment.ec.europa.eu/system/files/2022-06/Proposal%20for%20a%20Regulation%20on%20nature%20restoration.pdf>



## 4. Carbon Budgets Working Group

The Carbon Budgets Working Group will be tasked with assisting and advising the Council in development of a methodology and evidence base for carbon budget proposals, in particular to provide modelling and analytical support for the development of carbon budgets.

As set out in the draft Terms of Reference for the Carbon Budgets Working Group, the existence of the Carbon Budgets Working Group does not in any way diminish the overall responsibility of the Council with regards to taking the final decision on the carbon budget proposals to submit to Government.

The Secretariat will Chair the Carbon Budgets Working Group and will also have responsibility for support running of meetings as well as acting as a liaison between the Working Group and the Council. The Secretariat will present the findings of the Carbon Budgets Working Group to the Council following each Working Group meeting.

### 4.1. Key Outputs for the Carbon Budgets Working Group

The key outputs of the Carbon Budgets Working Group are set out below, however, the Council may give direction as to other key areas of work that it considers important which can be incorporated on an ad hoc basis for the term of the Working Group;

1. Review the assumptions for each model and improvements to the development of effort sharing scenarios using sectoral models.
2. Agree required outputs in terms of scenarios and pathways.
3. Document strengths and limitations of each model for this use case.
4. Use complementary models (outlined in Section 3.2) to compare modelling results on a system-wide basis and align assumptions with 2030 and 2050 emissions reduction targets.
5. Assess the outputs in terms of scenarios and different carbon budget pathways against the requirements in Sections 3.2-3.5 above.
6. Incorporate changes based on this assessment into these scenarios.

## 5. Development of Technical Report

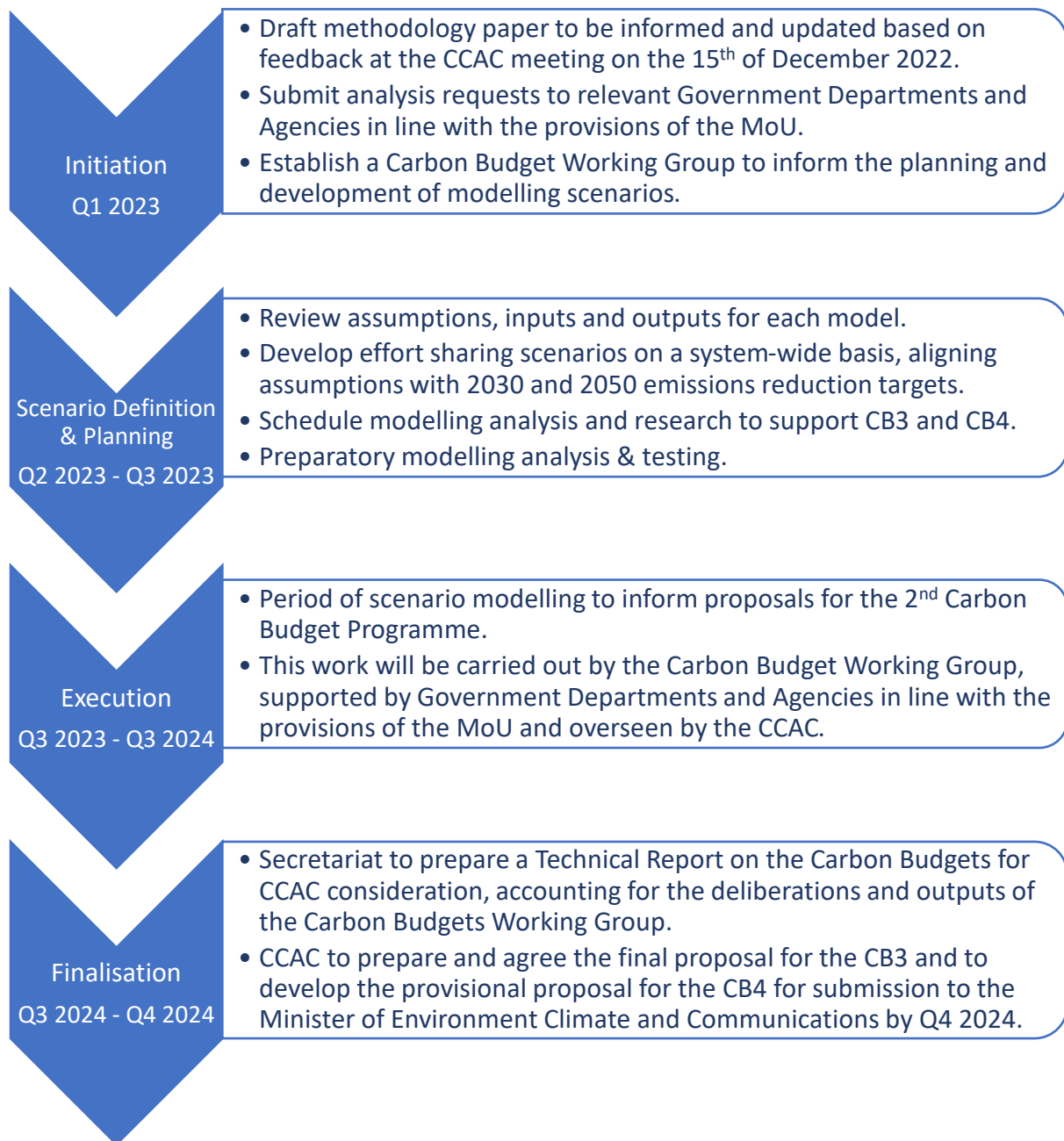
As set out in the draft Carbon Budgets Working Group Terms of Reference, the Secretariat will be responsible for managing the outputs of the Carbon Budgets Working Group for Council consideration in the context of its role in submitting carbon budget proposals to Government.

The outputs of the Carbon Budgets Working Group will be fed back to the Council for consideration on an ongoing basis by the Secretariat for the term of the working group i.e., from its establishment until the end of Q3 2024. There will be no requirement for formal decision making through the Carbon Budgets Working Group, however, the Council may endorse or adopt the recommendations from the Carbon Budgets Working Group where required for the development of the final Carbon Budgets proposals.

Following the conclusion of the work of the Carbon Budgets Working Group in Q3 2024, the Secretariat will have responsibility for preparing a Technical Report on the Carbon Budgets to submit to the Council for consideration in Q4 2024, accounting for the deliberations and outputs of the Working Group. The Council will have responsibility for approval of the Carbon Budgets Technical Report in addition to proposed Carbon Budgets.

## 6. High-Level Project Plan

A high-level project plan is outlined below. This plan will be revised and further developed based on input from the Council and as the programme of work progresses.





## Appendix 1: Inputs to Methodology

<a href="#">Memorandum of Understanding between Departments and the Climate Change Advisory Council.</a>
<a href="#">Carbon Budgets Technical Report</a> and background research.
<a href="#">Carbon Budgets Modelling Workshop Report.</a>
Carbon Budgets Working Group Terms of Reference.

## Appendix 2: Research Inputs

The table below outlines expected commissioned research, in addition to the outputs of the Carbon Budget Research Fellows, internal Secretariat research and analysis and the outputs of the Carbon Budgets Working Group.

Additional projects may be identified during the course of discussions with the Climate Change Advisory Council and Carbon Budgets Working Group in 2023.

Description	Timeline
Modelling the Macroeconomic Impacts of the Transition: The scale of investment required to achieve the carbon budgets will be very significant, with impacts on consumption, taxation policy, interest rates, competitiveness and output over the longer term. There is a need to build greater capacity in this area for the second programme of carbon budgets.	12-18 months, to be completed by Q3 2024
Review of International Approaches to Carbon Budgets SSS: The aim of this small-scale study would be to review approaches to carbon budgeting in other jurisdictions (in the UK, New Zealand, the Netherlands, France, Finland and Denmark in particular and also the EU approach to setting targets and trajectories where relevant)	2 months, to be completed by Q1 2023
Pathways to 2050: This study would consider emissions reduction pathways within each sector from 2030 to 2040 on a trajectory to climate neutrality in 2050 under different 2030 scenarios, sharing assumptions and spreadsheet analysis of pathways modelled. Using these as a basis for initial carbon budget reference points and overall work as a benchmark to outputs of TIM, FAPRI and Goblin models.	3 months, to be completed by Q4 2023
Climate impact of pathways: Assess the temperature impact of different pathways developed by the Carbon Budgets Working Group and the outputs of commissioned research.	2 months, to be completed by Q1 2024
Biodiversity Small Scale Studies: To be scoped further but could for example look at marine biodiversity impacts of offshore wind, effects of new forestry targets on biodiversity and effects of Global Biodiversity Framework and EU restoration law on land/sea area available for climate action.	TBC
Just Transition Small Scale Study: Exploration of how Just Transition considerations are incorporated as part of other countries carbon budget process.	TBC
Impact of carbon budgets from sustainable development perspective	TBC, 2024

**Table 1: List of Commodities**

C_AGR	Agriculture	C_HTP	High-tech products
C_PEA	Peat	C_TRE	Transportation equipment
C_COA	Coal	C_ELC	Electricity
C_CRO*	Crude oil	C_NGS	Natural gas
C_OMN*	Other mining	C_WAT	Water and sewerage
C_FBT	Food, beverage, and tobacco	C_CON	Construction
C_TEX	Textile	C_TRD	Trade
C_WWP	Wood and wood products	C_LTS	Land transportation
C_OIN	Other industrial products	C_WTS	Water transportation
C_GAL	Gasoline	C_ATS	Air transportation
C_KRS	Kerosene	C_OTR	Other transportation
C_FUO*	Fuel-oil	C_ACC	Accom. and hotel serv.
C_LPG	Liquid petroleum gas	C_TEL	Telecommunication services
C_DIE	Diesel	C_FSR	Financial services
C_OPP	Other petroleum products	C_RES	Real estate services
C_OTM	Other manufacturing	C_PSE	Professional services
C_CHE	Chemical products	C_ADS	Admin and support services
C_BPP	Basic pharmaceuticals	C_PUB	Publis services
C_RUP	Rubber and plastic	C_EDU	Education
C_ONM	Other non-metallic minerals	C_HHS	Health
C_BFM	Basic fabricated metals	C_OSE	Other services

\*: Not subject to private consumption.

**Table 2: List of Composite Commodities**

<b>Household-related</b>		<b>Firm-related</b>	
CC	Total Consumption	QX	Output
TRP	Transportation	VA	Value-added
LND	Land Transportation	K	Capital
PRV	Private Transportation	CLD	Composite Labour
REN	Residential Energy	LSL	Low-skilled Labour
RHC	Residential Heating	MSL	Medium-skilled Labour
SLD	Solid Fuels	HSL	High-skilled Labour
LQD	Liquid Fuels	BEN	Business Energy
NTR	Nourishment	OTE	Other (Auxiliary) Energy
SER	Services	OTI	Other Inputs
OTC	Other		

The parameter  $\sigma$  in the nested structures of consumption and production represents the elasticity of substitution (ES). It measures the ease with which one can switch across the elements composing the composite commodity. A positive value of it indicates a certain degree of substitutability. There are two extreme cases; the elements are perfect substitutes (as the value of ES approaches positive infinity), and the elements are perfect complements (the value of ES is zero).