EPA report to Carbon Budget Working Group secretariat

October 2024

Contents

Executive Summary

This report is in response to a request from the secretariat of the Climate Change Advisory Council for short reports from each of the organisations participating in the Carbon Budget Working Group (CBWG), a working group set up by the CCAC to focus on the assessment of evidence for the proposal of Carbon Budgets 3 and 4 (CB3 and CB4, from 2031-2035 and 2036-2040 respectively). Representatives of the EPA Climate Programme participated in the Carbon Budget Working Group, from the first meeting in Q1 2023 until the final meeting in Q3 2024 and this note presents some of their notes and observations together with some background information on the EPA data used by the other modelling teams on the CBWG. The report serves to highlight key considerations for the setting of Carbon Budgets 3 and 4 as emerged in the evidence presented to the CBWG over the course of its term.

EPA data and role

The greenhouse gas Inventory and Projections reports produced annually by the EPA are referred to in the Climate Act 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 greenhouse gas emission Inventories and Projections
- Guidance in 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

It is important that the modelling used to inform the proposal of 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.

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

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

• With Existing Measures (WEM) – a scenario incorporating the anticipated impact of policies and measures in place by end 2022

• With Additional Measures (WAM) – a scenario incorporating both implemented and planned measures, including the majority of those in the 2024 Climate Action Plan

In relation to the emissions and removals associated with Land Use, Land Use Change and Forestry (LULUCF), the EPA engaged extensively with the relevant Carbon Budget modelling teams to ensure the necessary understanding of the approaches used in compilation of 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 F-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.

Modelling and evidence for the third and fourth Carbon Budgets

The modelling of possible carbon budgets for the third and fourth carbon budget periods, 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; the TIM maintained by University College Cork, 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 University College Dublin using Simple Climate Models.

This process allowed the identification of those scenarios that were 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 the consideration of 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 sixth assessment report (AR6), Carbon Dioxide Removals are required in all global scenarios to counterbalance hard to abate residual emissions to achieve net zero GHG emissions and limit temperature increases. This applies also 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 (DACCS), biochar, Bioenergy with Carbon Capture and Storage (BECCS) etc. with most still at the research and innovation stage.

- Substantial land use change will be required to facilitate changes to forestry, agriculture and the need for renewable energy generation to achieve climate targets. We can use our land 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 we have for Ireland's 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 CBWG however indicates that moderating final energy demand is necessary to meet most carbon budget scenarios, particularly in the case of overshoot. This will present a significant challenge to achieve in a country experiencing significant economic and population growth as well as fast growing energy demand from large energy users such as data centres.
- The evidence from the macroeconomic analysis highlighted the challenge 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, that should be assessed in more detail for Ireland's setting of carbon budgets, is that proposed by the European Scientific Advisory Board (ESAB) 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 ESAB 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 ESAB for the EU is a 2040 emission reduction range of 90–95% compared to 1990, corresponding to a greenhouse gas budget of 11-14 Gt CO2e over the period 2030-2050. Whilst 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 the process of agreeing individual country targets has not yet happened. The significance of the Agriculture sector in Ireland, in particular livestock agriculture resulting in methane emissions, will be a consideration in determining Ireland's individual target. The filtered scenarios assessed in the ESAB scientific advice report, on which its EU 2040 target proposal is based, generally achieve agriculture sector methane emissions reductions of 15-40% between 2019 and 2040.
- The question of whether short-lived climate forcers (SLCFs - specifically methane in Ireland's case) should be part of a net-zero GHG by 2050 target remains a key point to be addressed as it has implications for the Carbon Budget and amount of carbon dioxide removals that would be required. While the European Climate Law targets include SLCFs in the 2050 net-zero GHG target, Ireland's latest long-term strategy does not. The IPCC's AR6 anticipates that deep reductions to global agricultural methane emissions will be required by 2050 in scenarios that keep warming below 1.5 degrees. It should be noted that the IPCC is modelling global average reductions and the expectations for individual countries would vary for reasons including current production efficiency, ability to pay etc.

Introduction and context

The Climate Change Advisory Council (CCAC) agreed at its meeting on 15 September 2022 to establish a Carbon Budgets Working Group (CBWG) to support the second programme of Carbon Budgets. This includes the finalisation of Carbon Budget 3 from 2031-35 (currently provisional) and presenting a proposal for Carbon Budget 4 from 2036-40 by the end of 2024. The CCAC approved Terms of Reference for CBWG at its meeting on 15 December 2022.

The Terms of Reference state that the CBWG is 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. The working group provides the Council with key findings, recommendations and outputs for consideration but the existence of the CBWG 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.

Along with providing the CCAC with key findings, recommendations and outputs for consideration in the context of the Council's role is proposing Carbon Budgets 3 and 4, the scope of the working group may also include 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 Climate Act[1] that deals with how Carbon budgets can be revised.

Ahead of the first meeting of the CBWG, the Council specified the key outputs for the term of the Working Group and also gave direction as to other key areas of work that it considered important on an ad hoc basis. A draft methodology for the second Programme of Carbon Budgets was prepared by the CCAC secretariat incorporating input from the Council to guide the work of CBWG. Key topics considered by the CBWG as relevant input included:

- The vision for 2050 – an examination of Ireland's long-term climate objective under the Climate Act and what climate neutrality means for Ireland in the context of national, EU and International targets.
- Pathways development and modelling – modelling multiple pathways and effort sharing across sectors for CB3 and CB4 from a start point in 2030 that are on a pathway to climate neutrality in 2050 (including accounting for the role of negative emissions and feasible levels of mitigation across different sectors).
- Climate Justice and 'Paris test' – an examination of how Ireland's carbon budgets approach complies with the Paris Agreement and has regard to climate justice as required by the Climate Act.
- Focussed discussion on LULUCF emissions – Given the level of uncertainty associated emissions/removals from the Land Use, Land Use Change and Forestry (LULUCF) sector in the National Inventory and significant ongoing research, a discussion with relevant experts on this sector specifically was required to examine the role that greenhouse gas removals from LULUCF may potentially play.
- Focussed discussion on International Carbon Budget approaches – To learn from carbon budget best practice and approaches elsewhere and to ensure that obligations under EU legislation are considered as required b the Climate Act.
- Focussed discussion on methane – the Climate Act requires the CCAC to take account of the distinct characteristics of biogenic methane. This discussion considered the IPCC AR6 update to our understanding of the global carbon budget and the need to achieve net zero

[1] Climate Act 2015 as amended

emissions of long-lived gases as well as a strong, rapid and sustained reduction in methane emissions.
- Macroeconomic and socioeconomic impacts of carbon budgets – an examination of the likely impacts on society and the economy of carbon budgets in consideration of the Climate Act requirement for the CCAC to take account of *'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'*.
- Biodiversity considerations – an examination (including small scale research studies) into the biodiversity impacts that might arise due to actions associated with complying with carbon budgets (eg. siting of renewable energy infrastructure).
- Role of negative emissions – examination within the CBWG centred on the role of LULUCF with literature review by the CCAC Secretariat of international developments.

EPA Role on Carbon Budget working group

The Director General of the EPA is an ex-officio member of the Climate Council, reflecting the importance of the work of the EPA in assessing trends and projections of Ireland's greenhouse gas emissions, including compliance with Carbon Budgets and international emissions targets. The role of EPA members of the Carbon Budget Working Group (CBWG) includes:

- Provision of data related to EPA greenhouse gas emission Inventories and Projections to assist the modelling teams with their efforts.
- Guidance in the use or interpretation of emissions data provided by the EPA and in relation to the scope and methodology of Inventory data production.
- Sharing of relevant research and insights available to the EPA, including the results of EPA-funded research
- Critique and assessment of the evidence and modelling provided to the CBWG, in common with all other CBWG members.

Description of data inputs from the EPA

The greenhouse gas Inventory and Projections reports produced annually by the EPA are referred to in the Climate Act 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.

It is important therefore that the modelling used to inform the proposal of future Carbon Budgets is as consistent as possible with the scope, approach and emissions factors used in the EPA Inventory and Projections.

While the modelling framework used for the production of the EPA Projections does not easily lend itself to multiple scenario analyses as required to assess many possible carbon emission pathways, the Projections nonetheless provide an important base point of comparison with current and planned policies and measures when considering different possible ways that carbon budgets could be achieved.

The EPA Projections are fully consistent with the National greenhouse gas emissions Inventory also produced by the EPA (including the same emission factors), with the starting point for the Projections being the latest published Inventory year. As the EPA Projections are built on the macroeconomic and energy modelling provided by the ESRI and SEAI, there is also consistency of approach between the three sets of model outputs for the two scenarios produced by the EPA.

For several emissions sources where the various models provided by the modelling teams of other CBWG members don't have sufficient coverage, EPA Projections data can be used to ensure full coverage of projected emission pathways. These sources primarily relate to emissions from the Waste sector and from fluorinated gases (F-gases) that typically have high emission factors. A brief summary of some of the EPA Projections approach follows, highlighting key assumptions and the estimation approach for Waste and F-gas emissions.

EPA Projections Scenarios and Assumptions

Two emissions projections scenarios are presented in the EPA greenhouse gas emissions projections which show two potential outlooks to 2050 depending on policy development and implementation. These are called:

- With Existing Measures
- With Additional Measures

The With Existing Measures (WEM) scenario is based primarily on SEAI's Baseline energy projection which incorporates the anticipated impact of policies and measures that were in place (and legislatively provided for) by the end of the most recent Inventory year (2022 in the case of EPA Projections published in May 2024).

The With Additional Measures (WAM) scenario is based primarily on SEAI's energy projection that accounts for implementation of the With Existing Measures scenario as well as planned policies and measures. Energy demand projections underpinning the latest emissions projections were prepared by the SEAI using their National Energy Modelling Framework (NEMF), building on demand projections provided by the ESRI. The ESRI produce energy demand projections using the I3E model[2] (Ireland Environment, Energy and Economy model). Future international fossil fuel prices are given as input to the I3E model. In the case of the energy related projections described in this document the fuel price assumptions use European Commission recommended harmonised trajectories. A varying carbon tax that increases by €7.50 per annum and reaches €100 per tonne by 2030 and is constant thereafter is used in both scenarios.

The recommended EU-ETS carbon prices are based on the EU Reference Scenario. Energy Projections for WEM transport activity are based on projections of private car and goods vehicle activity from the National Transport Authority's (NTA) Reference Case scenario for 2030. Fuel price assumptions are implicit in the NTA Reference Case scenario modelling. For the WAM scenario these projections align with the NTA CAP23 scenario and do not assume any reduction in transport activity due to fuel price changes. To produce the finalised WEM energy projections, SEAI amends the output of the energy demand produced by ESRI to take account of the expected impact of energy efficiency measures put in place before the end of 2022 but which are considered too recent to be detectable in any time-series analysis.

2 https://www.esri.ie/current-research/the-i3e-model

The WAM energy projections builds on the WEM projections with adjustments made to account for implementation of additional policies and measures outlined in the Climate Action Plan 2024. The EPA published a detailed Input Assumptions document alongside the Projections report on the EPA website[3] that outlines the key sectoral policy and modelling assumptions inherent in the Projections.

Table 1 Key macroeconomic assumptions underlying the projections out to 2050

	2023	2025	2030	2035	2040	2045	2050
	Average Annual % Growth Rate						
GNI*	-4.4	3.1	3.0	3.2	3.2	3.2	3.3
	2022	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Housing Stock ('000)	1,944	1,995	2,165	2,308	2,450	2,590	2,728
Population ('000)	4,962	5,043	5,250	5,466	5,690	5,924	6,166
EUETS: Carbon €/tCO_2	82	82	82	84	87	133	164
Carbon tax €/tCO_2 (WEM Scenario)	48.5	63.5	100	100	100	100	100
Coal €/toe	146	128	130	131	139	146	153
Oil €/toe	442	643	643	643	680	738	824
Gas €/toe	389	554	473	473	473	473	494
Peat €/MWh	25	25	25	25	25	25	25

* Modified GNI

Key parameters underlying the economic outlook and therefore the With Existing Measures and With Additional Measures emission projections scenarios are shown above in Table 1. These parameters are agreed between the EPA, SEAI and ESRI at the start of the modelling process (in August/September 2023 in the case of Projections published in May 2024) as they are used in the ESRI's I3E modelling, the foundation on which the rest of the modelling is built. Parameters core to the I3E model, such as population projections, are updated by the ESRI less frequently and in line with broader updates/revisions to the model itself.

Waste sector emissions (IPCC sector 5)

There is only one scenario (*With Existing Measures*) for greenhouse gas emissions projections from the Waste sector. Emission projections for the waste sector are developed for CO_2, CH_4 and N_2O. Solid waste disposal to landfill (IPCC sector 5.A) is currently the main source of emissions from the waste sector. Methane emissions arise from (i) solid waste disposal in landfill sites and (ii) wastewater and sludge treatment (IPCC sector 5.D), whilst N_2O emissions also arise from the production of human sewage. In addition, CO_2, CH_4 and N_2O emissions arising from the incineration of hazardous wastes (solvents) in the pharmaceutical industry (IPCC sector 5.C) and the mechanical and biological treatment of waste (IPCC sector 5.B) are also estimated. The emissions associated with the incineration of municipal solid waste for electricity generation (WtE) are included in emissions estimates for electricity generation (IPCC sector 1.A.1.a).

Methane (CH_4) is the important emission from solid waste disposal to landfill, emitted through the anaerobic decomposition of biodegradable municipal waste (BMW) which is disposed in solid waste disposal sites. The CH_4 production potential of biodegradable solid wastes is determined by the amount of degradable organic carbon (DOC) in the wastes, which in turn depends on the amount and composition of the waste material. The projected composition of BMW going to landfill in the

[3] https://www.epa.ie/publications/monitoring--assessment/climate-change/air-emissions/Input-Assumptions-for-Irelands-Greenhouse-Gas-Emissions-2023-2050.pdf

future takes into account the status of remaining operating landfills and national waste treatment capacity. The approach to determine CH_4 emissions from decomposing BMW is the 2006 IPCC Guidelines model and is the same as that used in compiling the annual greenhouse gas emission inventory.

The one scenario is created using activity data related to the total municipal solid waste that has historically been landfilled in addition to the total amount that is projected to be landfilled in remaining operating landfills out to 2040. It is assumed that the use of unmanaged sites for the receipt of waste stopped with the advent of waste licences for landfills circa 1998 and that all waste sent to landfill after this time and thus also for projected years is to managed sites. Emissions of CH_4 from landfill are minimised through landfill gas flaring and utilisation for energy production. It is estimated that in 2019 there was 59 per cent methane recovery from solid waste disposal. It is assumed that the amount of landfill gas flared and utilised for energy production reduces from 59% in 2019 to 39 per cent by 2035, and remaining at 39 per cent to 2040, in line with recovery trends in the latest inventory.

Fluorinated-gas emissions (IPCC sector 2.E, 2.F, 2.G) and N_2O from Product Uses

Industrial Processes and Product Use (IPCC sector 2) is the only sector for which emissions of Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6) and Nitrogen trifluoride (NF_3), collectively known as fluorinated gases, are reported in air emission inventories. There is no production of fluorinated gases in Ireland, but these substances are used in activities such as Ireland's electronics industry and for refrigeration, air conditioning and heatpumps.

The EPA's emissions projections use the latest available inventory as the starting point for projecting fluorinated-gases (F-Gas) emissions. Fluorinated gases accounted for 1.4 per cent of Ireland's total national greenhouse gas emissions in 2020. The key sources of fluorinated gas emissions in Ireland are production, use and disposal of equipment containing these fluids (e.g. refrigerators, mobile air conditioning systems, metered dose inhalers and electrical switch-gear).

Projections were developed for four fluorinated gases/gas types: HFCs, PFCs, SF_6 and NF_3. In 2020, HFCs accounted for approximately 89 per cent of total fluorinated gas emissions. Perfluorinated compounds, used in semi-conductor manufacturing, accounted for 9 per cent of total fluorinated gas emissions in 2020 while SF6 accounted for 2.47 per cent and NF3 accounted for 0.2 per cent.

Projections were developed for all four fluorinated gases and for all the sources reported in the national greenhouse gas inventory. Table 1 below summarises the key assumptions for developing projections for F-gases.

Only one scenario was developed for F-Gas Projections (excluding heat-pumps). The impact of Directive 2006/40/EC relating to emissions from air-conditioning systems in motor vehicles is included as a result of SI No. 127 of 2009. HFCs are projected to reduce by 10.6 per cent between 2020 and 2035 in this scenario, with the phasing out of HFC-134a use in mobile air conditioning being the primary driver of the projected reduction.

In relation to heat pumps, an update to the latest inventory numbers of new heat pumps installed from 2011 to 2018 has resulted in an increase in the projected disposal emissions compared to previous submissions, as the bank of F-gases (HFC-125, HFC-134a and HFC 32) has increased with the latest data. Updates to the number of heat pumps in the projections for two scenarios (WEM and

WAM) are made based on projected uptake numbers from the SEAI that are agreed with the relevant Departments as part of the Projections Assumptions process.

R-32 (GWP 677) is anticipated to account for 50% of HFC emissions by 2050, nearly all from heat pumps. The other 50% is from expected to come air conditioners (mostly HFC-125). In 2030, heat pumps are expected to account for 10-15% of HFC emissions as there would be little end-of-life emissions anticipated by then. R-32 is the only HFC in the modelling for Heat Pumps from 2022 with R-410a having been phased out.

Table 1. Key assumptions underlying the F-gas projections in the EPA Projections

Sector	F-gases	Basis for projection
Refrigeration and air conditioning	HFC	Table 34, page 126 Emission Projections Guidelines
Mobile Air Conditioning (MAC)	HFC	Projected new car registrations and introduction of low (< 150) GWP fluids
Fire-extinguishers	HFC	Current disposal factor maintained with no net growth in the number of units installed as older units are replaced
Aerosols	HFC	Pro-rata basis using UK emission projections and UK and Irish population projections
Metered dose inhalers	HFC	Population projections and prevalence of asthma in the Irish population
Semi-conductor manufacture	HFC, PFC, SF_6 and NF_3	Economic growth indicator
Electrical equipment	SF_6	Projected use and stock of SF_6 used in switchgear in the electricity transmission network provided by electricity distribution operator
Window sound-proofing	SF_6	Projections are based on the known current stock of SF_6 in installed windows, annual leakage and disposal factors
Medical Applications	SF_6	The use of SF_6 in Irish hospitals is assumed to remain constant at 2018 levels

EPA notes and observations on the topics considered by the CBWG

This section details some of the key points discussed and observations from the EPA attendees on the CBWG with reference to the topics covered by the group and described in the introduction.

Vision for 2050

Discussion on the vision for 2050 centred around the Vision for 2050 working paper originally presented to the CCAC and then subsequently presented to the CBWG. This identified the proposed building blocks for the third and fourth carbon budgets, both what the 2030 starting point should be and what the 2050 target should look like. The CBWG held a workshop to identify and discuss the modelling scenarios that would be used to align with these building blocks.

Table 2 Building blocks for Carbon budgets 3 and 4 from Vison for 2050 working paper

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

The Long-Term Strategy on Greenhouse Gas Emissions Reductions for Ireland states that reaching climate neutrality will mean that Ireland will have no further negative impacts on the climate system by mid-century. Whilst not prescriptive about how neutrality will be achieved, the recent update from June 2024[4] is clearer on the expectation of a neutrality definition that envisages deep cuts but not complete elimination or offsetting of remaining methane emissions. For this reason the modelling framework looks at 2050 scenarios that are consistent with net zero GHG emissions in 2050 as well as those that don't include biogenic methane emissions in the net zero calculation.

Pathways development and modelling

The modelling of carbon budget pathways for CB3 and CB4 consistent with the National Climate Objective goals 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; the TIM maintained by University College Cork, the FAPRI-Ireland model maintained by Teagasc and the GOBLIN model maintained by the University of Galway. Temperature impacts of modelled scenarios were assessed by a team from University College Dublin using Simple Climate Models (SCMs namely MAGICC7 & FaIRv2.1).

In addition to the core modelling, other model data was used as input to the Core models and used for feasibility/risk assessment work ancillary to the core modelling. The models involved here were the ESRI's I3E model (also used for macroeconomic analysis), the SEAI's National Energy Modelling Framework (NEMF) and the EPA Projections. Feasibility/risk assessment work was largely carried out by the SEAI using the NEMF. The FERS CBM model (an implementation of the Canadian Forest Service's Carbon Budget Model produced for Ireland by Forest, Environmental Research and Services) was additionally used in combination with GOBLIN to better ensure alignment with the accounting approach used for the EPA's Inventory and Projections.

It is worth noting that (in common with the EPA projections) there are underlying assumptions and important uncertainties to be aware of. These include:

[4] https://www.gov.ie/en/publication/e4e81-long-term-strategy-on-greenhouse-gas-emissions-reductions/

- Anticipated economic growth and demographic changes.
- Fuel prices from the European Commission recommended harmonised trajectories.
- Anticipated price trajectories for carbon tax.
- The EU-ETS carbon prices (based on the EU Reference Scenario).
- Anticipated progress in the implementation of energy related policies and measures relies on expert judgement.

Some notes and observations follow in relation to the Core models and modelling of temperature impacts:

TIM – TIMES-Ireland Model

TIM is the successor model to the Irish TIMES Model, which has been developed by the MaREI Energy Policy and Modelling Group (EPMG) at University College Cork since 2010 and funded through various projects by the EPA, SEAI, SFI and the NTR Foundation. It has played a significant role in informing the evidence base of Irish climate target setting, including as part of the first Carbon Budget process. TIM is and Energy Systems Optimisation Model (ESOM) that 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.

Eight TIM scenarios (TIM 1 to TIM 8) were provided by the modelling team looking at Energy Sector carbon budgets for the period. TIM 1 to TIM 5 allowed for energy system carbon budgets of 250, 300, 350, 400 and 450 Mt CO_2e over the period 2021 to 2050 and assuming a "business as usual" (BAU) energy demand growth. TIM 6 to TIM 8 allowed for 250, 300 and 350 Mt CO_2e energy system carbon budgets with a "low energy demand" (LED) growth profile. Some notes and observations on the TIM scenarios include:

- To put the carbon budgets in context, the Sectoral Emission Ceilings for the relevant energy sectors add up to ~275 Mt CO_2e over the period 2021-2030, less some part of the additional, currently unallocated savings assumed in that process. The EPA WAM scenario (achievement of which is still under significant risk as it contains measures that have not been implemented yet) from the latest projections projects 310 Mt CO_2e emitted from 2021-2030 and the WEM scenario 325Mt CO_2e. This means that **both the 250Mt and 300Mt budget scenarios for 2021-2050 would already be exceeded by 2030 and require negative emissions thereafter if emissions are in line with the EPA WEM or WAM scenarios and the 250 Mt budget scenario would have already been exceeded by 2030 even if SECs are achieved**.
- Stronger emissions cuts before 2030 are essential to meet the smaller carbon budgets. If emissions from 2021-2030 follow the trajectory in the EPA WAM scenario (achievement of which is still at risk) then the emissions cuts required thereafter to stay within budget reach apparently unfeasible levels, particularly from 2031-35. This would bring forward the year when net-zero emissions needs to be achieved by 5-8 years. This highlights the point that **full implementation of the WAM scenario is not sufficient and further measures are required.**
- The lower carbon budgets increase reliance on Carbon Dioxide Removals (CDR), with net zero emissions needing to be reached much earlier. For example CCS adoption in the cement industry would need to be in place as early as 2031 in the 250, 300 and 350 Mt CO_2e scenarios.
- At present, given the latest energy demand trajectory (and expansion of data centres etc.) 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 CBWG

however indicates that moderating final energy demand is necessary to meet most carbon budget scenarios, particularly in the case of overshoot. This will present a significant challenge to achieve in a country experiencing significant economic and population growth as well as fast growing energy demand from large energy users such as data centres.

- The assessment and risk scenario analysis provided by the SEAI by comparing TIM scenario budgets with the modelling used in their NEMF raises significant feasibility questions. Issues raised include how quickly gas can be phased out of the power sector, the pace of electrification anticipated in the transport sector and the likelihood of demand reduction measures taking effect as quickly as modelled in TIM LED scenarios.

FAPRI-Ireland Model

The FAPRI-Ireland Partnership, was established in the mid-1990s between Teagasc and the University of Missouri Food and Agricultural Policy Research Institute (FAPRI) to develop economic models to quantify the effect of policy reform on agricultural markets and farm income in Ireland. Teagasc developed the FAPRI-Ireland aggregate and farm-level models which have been used to examine numerous policy questions including the decoupling of direct payments, WTO trade agreements, expansion of the EU milk quota, national strategy planning such as Food Harvest 2020 and more recently environmental policy.

Nine scenarios (FAPRI 1-9) were provided by the Teagasc modelling team using their FAPRI model. These took the form of three different activity level projections (Base, Lower and Higher) cross-referenced with three levels of policy implementation (hence 3x3=9 scenarios in total). The policy implementation levels were (a) existing level of policy implementation (b) P1 – pathway 1 of MACC (ambitious mitigation) and (c) P2 – pathway 2 of MACC (very ambitious mitigation). Some observations follow in relation to the FAPRI modelling:

- Determination of anticipated progress in the implementation of Agriculture related policies and measures relies on expert judgement, i.e. is not based on an optimisation model as with TIM. The model relies on projections for medium-term developments in EU and World agricultural commodity markets and inherits uncertainties from this. The Teagasc modelling team highlighted in particular the difficulty in having any reasonable level of certainty regarding commodity prices in the long term, approaching 2050.
- The model assumes that agricultural policy continues as currently implemented and the Trade and Cooperation (Brexit) Agreement (TCA) reached between the EU and the UK governs UK-EU trade for the period. It assumes a lack of new bilateral trade agreements between the EU, UK and other countries.
- The most important difference between the activity level projections S1, S2 and S3 is in relation to the different numbers of bovine livestock and fertiliser use. S1 is a baseline projection with S2 projecting lower agricultural activity and S3 higher activity. All three scenarios see some continued expansion of the dairy cow numbers by 2030 (S1:-1.8m, S2:-1.7m, S3:-1.9m) and all three see a contraction of the number of suckler cows. Chemical fertiliser use in 2020 varies from a low of 304kt Nitrogen in S2 to a high of 419 kt Nitrogen in S3. The unabated S1, S2 and S3 scenarios aren't very likely given that mitigation measures are already being implemented but provide a without measures reference point.
- The S1 scenario, which likely most closely reflects a BAU situation and no implementation of MACC mitigation measures results in emissions remaining relatively stable out to 2030 and increasing slightly thereafter before stabilising again by 2050. There is a switch from beef to

dairy production being projected however with falling non-dairy cow numbers offsetting the increased dairy production.

- The estimation of the mitigation impact of P1 and P2 MACC pathways was largely based on the same approach as used for the EPA's GHG Inventory so estimates are likely to be quite well aligned with savings that would be realised in the Inventory if the mitigation actions are taken.
- P1 and P2 scenarios differ in the level of uptake of MACC measures primarily and also the reduction in livestock numbers due to diversification (reduction up to 366k in P2). Some key measures would include Dairy EBI, Earlier Slaughter ages (4 months earlier in P2), Clover and Multi-species sward uptake (1.83 Mha in P2), Feed additives and reduced crude protein intake and switching from CAN to stabilised urea fertilisers.
- The modelling looked at the impact of diversification measures in displacing livestock with forestry, anaerobic digestion (growing feedstock) and organic farming being the most impactful options.
- Looking at the results, the most ambitious scenario presented (S2 with P2 mitigation) sees an agriculture emissions reduction of 24% by 2030 and 48% by 2050 with total cumulative projected emissions of 477 Mt CO_2e from 2021 to 2050. **The S1 with P1 mitigation scenario (which is likely closest to the latest EPA projections WAM scenario) results in an emissions reduction of 15% by 2030 and 22% by 2050** and total cumulative projected emissions of 575 Mt CO_2e from 2021 to 2050.
- Reductions in emissions of different gases were also examined by the modellers with the **emissions reduction of Methane (CH_4) varying from -19% to -35% by 2050 (Scenario 1, P1 or P2) and that of Nitrous Oxide (N_2O) varying from -52% to -70% by 2050 (Scenario 1, P1 or P2).**

GOBLIN Model

The General Overview for a Back-casting approach of the Livestock Intensification (GOBLIN) model is a first version of a python-code-based bio-physical national model of the Agriculture, Forest and Other Land-Use (AFOLU) sector in Ireland. It has been developed by the University of Galway and represents the integration of a number of livestock, arable and bioenergy models.

The GOBLIN model is used to examine the interactions of the Agriculture and LULUCF sectors and in particular to explore scenarios that could deliver net-zero emissions (or climate neutrality) across the combined AFOLU sector. The GOBLIN team provided 13 scenarios (GOBLIN 1-13) for consideration with twelve scenarios corresponding to four different levels of Agriculture greenhouse gas emissions reduction by 2050 (-34%, -40%, -52% and -60%) crossed with three different forest management approaches (8kha per year, 25kha per year 50:50 conifer:broadleaf, 25kha per year 70:30 conifer:broadleaf). One additional scenario was produced with -52% Agriculture emissions and 17.5kha per year afforestation. Some observations follow in relation to the GOBLIN modelling:

- The GOBLIN scenarios were aimed at maintaining high bovine protein outputs but do see a this protein progressively coming predominantly from milk in the higher (especially -52% and -60%) emissions reduction scenarios. This is achieved by increasing dairy cow productivity strongly in a “sustainable intensification” approach.
- The modelling implies consolidation of farms with a land sparing approach that provides space for nature and the bio economy. **There would likely need to be significant changes in**

land management approaches with these scenarios, including diversification and multi-functional land use.

- The results indicate that achieving net zero greenhouse gas emissions (GWP100) is a massive challenge for the AFOLU sector. Even with 25 kha/yr and from 2030 and maximum abatement, net-zero GHG emissions are not achieved by 2050 in any of the modelled scenarios. However, if Methane is excluded and given a separate target then net zero of the remaining gases is possible.
- Commercial forestry has the potential to drive large downstream mitigation with the modelling indicating a substitution effect of up to 7 $MtCO_2e$ per year possible (not all in Ireland) in more ambitious afforestation scenarios. Storage of carbon in Harvested Wood Products and BECCS could also make an important contribution.
- The importance of long-term planning was emphasised by the modelling team, for example to avoid future carbon cliffs afforestation can't just take place to 2050 and then stop. It requires 50-100 year land sector planning for a climate neutral economy.

Modelling Temperature Impacts

The UCD Energy Institute team modelled the likely temperature impact of different carbon budget scenarios provided by the other modelling teams (TIM, FAPRI and GOBLIN), both to assess compliance with the National Climate Objective and compatibility with Paris Agreement goals. Modelling was performed in the FaIRv2.1 simple climate model (work was also done with the MAGICC7 SCM during the process which was found to be in good agreement to FaIR) as it was demonstrated to be in reasonable alignment with the CMIP6 model outputs used by the IPCC for their Shared Socioeconomic Pathways. This assessment would allow the ruling out of scenario combinations where warming impact does not stop by 2050.

- The modelling disaggregates the key greenhouse gases and models their warming impacts separately so it is not impacted by questions over metrics such as GWP100.
- The modelling approach is a 'constrained ensemble' where each scenario being run through and ensemble of model configurations constrained for compatibility with SSP126 (the IPCC Shared Socioeconomic Pathway designed with the aim of simulating a development that is compatible with the 2°C target). If there is 2/3 or better probability (based on the number of ensemble members) of neutrality by 2050 then that scenario is possible to consider further.
- Over 20% of the scenarios assessed achieved neutrality before 2046 with 2/3 probability, highlighting that there are a number of modelled options that could meet the National Climate Objective, though this assessment does not say anything about their relative feasibility.

Climate Justice and 'Paris Test'

Climate justice was examined from a number of perspectives, both global and local. Firstly it was looked at from the top-down global perspective of understanding what might a fair share of the remaining global climate budget for Ireland reasonably look like. The local element of climate justice involves ensuring that every climate action taken in order to meet our carbon budgets considers and ensures a just transition for all affected parties to the greatest extent possible.

The main philosophical considerations of Climate Justice and the Paris Test with regard to Carbon Budgets were presented to the CBWG with their implications for climate change and defining 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.

The CBWG separately heard evidence from the secretariat of the European Scientific Advisory Board (ESAB) on the assessment made for their 2040 target recommendation to the EU. Advisory board recommendations were outlined including targets, budgets and considerations of feasibility and fairness, with pathways identified to achieve at least 90% emissions reduction by 2040. Of particular note in relation to the budget discussion in Ireland was the comparison made by ESAB between 'fair' and 'feasible' budgets. They found that the lowest feasible budget estimates from the scenarios assessed were still higher than the equal per capita emissions allocations and other fair share estimates based on principles such as 'polluter pays' and 'ability to pay'. Whichever ethical principle was considered, there was a gap between the feasibility estimates and fair share estimates.

The ESAB recommendation was for *a "2040 emission reduction range of 90–95% compared to 1990, corresponding to a greenhouse gas budget of 11-14 Gt CO2e over the period 2030-2050".* This reflects a budget close to the minimum considered feasible. The recommendation to pursue the more ambitious end of the feasibility range was because this improves the fairness of the EU's contribution, and the Board deemed that addressing the feasibility/fairness shortfall was important as part of the EU's commitment to the Paris Agreement temperature goal. Discussions around the ESAB recommendations included emission reduction splits for different gases and sectors, noting that the ESAB report states that "*the capacity of the EU to remove carbon is limited, and hence a rapid reduction of non-CO_2 emissions, in particular from the agriculture sector, is critical to limit the reliance on carbon capture technologies*".

Insights from work done by the National Economic and Social Council (NESC) on approaching Just Transition in practice was presented to the CBWG, with a special focus on Just Transition on Agriculture and Land Use. This provided a list of Just Transition principles related to NESC recommendations around implementation, oversight and funding. The recommendations also apply a just transition lens to climate adaptation in the AFOLU sector and a wide scope in the monitoring of transition including economic, social and environmental aspects and data at a local scale in support of place-based transition.

Many of the NESC recommendations touched on communications and transparency aspects. This included transparency on the consideration of effort sharing between and within sectors but also on highlighting the opportunities and benefits as well as the cost of transition. The need for farm advisory services to scale up and more fully align with environmental objectives in order that ecological expertise can be provided at farm level was also highlighted. This relates to the need to avoid a one-size-fits-all approach in the design of responses and supports at local level.

Focused discussion on LULUCF emissions

The CCAC secretariat presented a paper that had been prepared for the Council on Agriculture and Land Use in Ireland to the CBWG, outlining the value of the sector to Ireland, measures of its sustainability, and demographics of farming in Ireland. Emission mitigation options for agriculture in Ireland were noted. Some potential impact of policy measures including nitrates, forestry, water table management and LULUCF were also outlined along with an explanation of the new EU LULUCF Regulation rules and targets.

Discussions included temporal dynamics of our land use, and the importance of baseline year in framing assessment. The value of historical perspective was noted, recognising the importance of context in agriculture, including the role of land as energy source, and historic emigration in Ireland. Recent structural changes impacting dairy and tillage farms were noted including expected global market growth for agricultural products. The importance of agriculture and land making a significant contribution to emissions reductions, notwithstanding historical context, and need to draw from a diverse evidence base to inform analysis was raised.

Focused discussion on international approaches to carbon budgets

An independent research study conducted for the CCAC examining Carbon Budgeting in the UK, New Zealand, the Netherlands, France, Finland and Denmark was presented to the CBWG. This examined the approaches to setting targets and trajectories where relevant, with potential lessons in an Irish context. The role of carbon budgets in attaining the goal of net-zero GHG emissions and equity principles were outlined. The main design elements of carbon budgets were presented, including the importance of the policy planning cycle. Some comparative data of the jurisdictions were presented along with potential lessons learned. Points of interest for discussion in the Irish context included the separate methane target for New Zealand, alignment with global carbon budget, and credibility around not-achieving carbon budgets.

Quantitative approaches to carbon budgeting for parties to the Paris Agreement were examined further by the CBWG at a later date, with a focus on the establishment of the Victorian Carbon Budgets in Australia including the main considerations and temperature alignment of pathways. Considerations were very similar to the approach taken in Ireland, including the probability of achieving temperature targets, conversion of global carbon budget into a GHG emission budget, and consideration of fair share contributions. A process for translating budgets to milestone targets was presented, along with the characteristics of Victoria's emissions. Discussions included land sinks, global carbon budget parameters, socio-political issues, economics and the Just Transition of decarbonising the electricity sector. Changes in the LULUCF sector were also raised including changes to forest management and the incorporation of non-CO_2 gases in a national carbon budget.

As noted above under Climate Justice, the CBWG also looked at the approach used by the ESAB for proposing 2040 targets, particularly in relation to the fairness/feasibility trade-off and the importance of land-management and technology deployment.

Focused discussion on methane

A background briefing note on methane was prepared by the secretariat and discussed by the CBWG along with further input from researchers focussed on both the physical science (using simple climate models – SCMs) and fairness/ethical considerations. Important considerations include the definitions of climate neutrality, different metrics for measuring the warming impact of methane, and the implications of methane reduction to policy targets.

The understanding of the global carbon budget as updated by the IPCC's sixth assessment report (AR6) highlights the need for net zero emissions of Long-lived greenhouse gases (LLGHGs) and for a strong, rapid and sustained reduction in Short-Lived Climate Forcer (SLCF) emissions such as methane. The AR6 definition of carbon budget relates to cumulative carbon dioxide emissions, constrained by assumptions regarding future scenarios of emissions of other greenhouse gases. This is different to the carbon budgets definition in the Climate Act, effectively an upper limit of cumulative emissions of all greenhouse gases, evaluated on the basis of the GWP100, allowable over the 5-year budget period.

AR6 notes that pathways consistent with the 1.5°C goal require between 40% and 75% reduction in the rate of global methane emissions. A large proportion of this mitigation can be achieved by tackling fossil methane emissions associated with energy (eg. fugitive emissions from oil and gas extraction) as well as emissions from the waste sector. However significant reductions to global agricultural methane emissions are also anticipated to be required.

Ethical considerations related to methane emissions include grandfathering issues, fairness of effort, the inclusion of value judgements and the implications of delayed action. The use of 'split gas' targets, effectively separate carbon budgets for LLGHGs and SLCFs, was examined considering the cases of New Zealand and France. New Zealand's approach sets a 24% to 47% reduction range for biogenic methane by 2050 compared to 2017, with a 10% reduction expected by 2030. It was unclear whether the CCAC can currently consider recommendation of a split gas approach given the definition of Carbon Budgets in the Climate Act, but a budget proposal can potentially be informed by different expected trajectories for different gases.

The choice of climate target, specifically the distinction between 'net-zero GHG' and Climate neutrality targets remains a key point to be addressed and has implications for the amount of carbon dioxide removals that will be required as noted above under the Vision for 2050 section.

Macroeconomic and socioeconomic impacts of carbon budgets

Assessment of the macroeconomic and socioeconomic impacts of carbon budgets require quantification of the projected impacts on employment levels, impact for public finances and implications of international climate action as international economic and macroeconomic action will also impact Ireland. Costs of climate action as investment in renewable energy were discussed along with those for reducing emissions in agriculture. Work on assessing the macroeconomic impacts of Carbon Budgets was performed by economists in the CBWG and by both the Central Bank and ESRI on behalf of the CCAC.

At a high level it was recognised that an important factor in determining the macroeconomic impact of climate actions is the current state of the economy. Given that Ireland has close to full employment currently, climate action investment will either divert resources from satisfying other needs or the resources will be acquired elsewhere (imported). Given that many of the necessary actions require some form of construction in Ireland, importation of goods, equipment and human resources won't suffice alone, therefore some trade-offs are expected to be required. Much of the cost is also like to be upfront or mature before the eventual benefits.

Model results for the different carbon budget scenarios (eg. TIM 350 Mt, 400Mt etc.) provide details of the technology requirements for the five-year periods allowing estimation of investment in new capacity needed which can then be expressed as a percentage of economic output (GNI*). This also needs to be compared to a counterfactual case where the status quo continues (eg. electricity continues to be largely generated from imported gas). In the Agriculture and Land Use scenarios the costs in the form of reduced outputs (due to lower fertiliser use, rewetting of some land etc.) needs to be compared to projected returns from new activity (eg. forestry and value chain of the harvested wood). Gaining an understanding of where the costs will fall (households, business, the State) was also discussed as an important aspect.

ESRI work on understanding the impacts of climate change in Ireland focussed on five impacts; coastal flooding, heat effects on labour productivity, human health, agricultural productivity and river flooding. The study indicated that Ireland will face significant impacts with coastal impacts the largest. With no adaptation the study suggests that total impacts will exceed 2.5% of GDP, however adaptation can significantly reduce the real GDP losses associated with a given level of climate change.

The work done by the Central Bank utilised their COSMO economic model to analyse the economic impact of transition-related investment on the Irish economy up to 2050, taking investment data provided by the TIM as input. The work sought to investigate the impact of capacity constraints in the labour market, with ~24,000 additional construction workers needed for energy investment up to 2030. In this capacity constrained model the impact of investment is projected to be inflationary in relation to wages, particularly in the construction sector.

While the macro-economic assessments presented to the CBWG provided some useful analysis, largely in terms of high-level output and labour market impacts, it was clear that a lot of this analysis was at an exploratory stage and needs further development. **Significantly more work is needed to fully understand the economic and socioeconomic consequences of both preparing for and adapting to the impacts of climate change and putting in place the measures required to mitigate greenhouse gas emissions.** This would include more granular sectoral detail (eg. for the Agriculture sector), econometric analysis linked to key proposed policies and measures as well as greater spatial impact analysis.

Biodiversity considerations

Through numerous discussions the CBWG the issue of both negative impacts and positive co-benefits of actions to mitigate climate change and improve biodiversity. An assessment of biodiversity considerations in the carbon budgets process was presented to the group with small scale studies and post hoc analysis of proposed carbon budgets on biodiversity being performed.

Previous work supported by the IPCC in 2020 highlighted that limiting global warming to ensure a habitable climate and protecting biodiversity are mutually supporting goals, and their achievement is essential for sustainably and equitably providing benefits to people. Despite the interconnectedness however, climate change and biodiversity concerns are rarely addressed in an integrated way in practice.

Several land- and ocean-based actions to protect, sustainably manage and restore ecosystems have co-benefits for climate mitigation, climate adaptation and biodiversity objectives. Measures narrowly focused on climate mitigation and adaptation can have direct and indirect negative impacts on nature and nature's contributions to people. International and EU action (such as the Nature Restoration Law) recognise the interconnectedness and need for policy target alignment.

The assessments presented to the CBWG looked at the alignment of existing national climate and biodiversity policy targets and at specific climate mitigation measures and categorised them according to whether there could be positive/negative/neutral biodiversity impacts, highlighting that the interrelationship is complex and conditions specific. This approach could feed into the goal of maximising win-wins for climate action and biodiversity in carbon budget process.

Results from the carbon budget pathway modelling suggest that substantial land use change will be required to facilitate changes to forestry, agriculture and the need for renewable energy generation to achieve climate targets. The evidence presented to the CBWG notes that there we can use our land 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 we have for Ireland's 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.

The evidence strongly points to the need for a National integrated land use strategy and also the need to avoid off-shoring bio-diversity impacts (eg. if the land needed to meet biofuels targets to 2030 is elsewhere what are the biodiversity and food security implications). A note of caution was also raised regarding the possible reversibility of measures to restore of carbon rich ecosystems impacted by climate change, including vulnerability to drought, wildfires, pest and disease.

Role of negative emissions

The CBWG examined the role of negative emissions in a number of contexts, including the role of land-based sinks. This included a presentation by a member of the CBWG on Carbon Dioxide Removal (CDR) and its integration in European Union Climate Policy. CDR was defined as being specific to the removal of carbon dioxide from the atmosphere by anthropogenic activities and durably storing it. Differentiation was made between CDR and other carbon management processes such as carbon capture and utilisation, and carbon capture and storage. The IPCC's sixth Assessment Report (AR6) has observed that CDR is required in all scenarios to counterbalance hard to abate residual emissions to achieve net zero GHG emissions and limit temperature increases.

The need for location specific variations of CDR were noted, with a range of CDR methodologies presented, and their requirement 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, including the application of CDR post net-zero. In discussions, long-term CDR planning for Ireland was considered difficult particularly difficulties of modelling CDR options to make informed choices for policy makers. CDR methodologies and their impact on global emissions, the use of climate models to test CDR assumptions, locational distribution of CDR potential, and negative emission trading were all discussed. The application of novel vs traditional CDR methodologies in Ireland, biodiversity impacts, overshoot scenarios, natural carbon removal process, and land-use budgets on national or international scales were all raised.

Traditional CDR methods include those related to forestry, peatland restoration and the production of durable wood products (which could include substitution of more carbon intensive materials like cement in construction). Novel CDR methos include options such as Direct Air Capture, Enhanced Weathering, Biochar and Bioenergy with Carbon Capture and Storage (BECCS). At present only a tiny fraction of CDR results from novel methods with much of the investment currently at the Research and Innovation stage still. It was highlighted that many of the novel CDR methods will need to be included in future modelling, even though in some cases still experimental, to better understand what their potential impact could be.