Climate Change Advisory Council

Carbon Budget Technical Report

October 2021

Table of Contents

Executive Summary

Ireland has committed to transition to a climate resilient, biodiversity rich, environmentally sustainable and climate neutral economy by 2050. To help achieve this challenging but necessary objective, the Climate Action and Low Carbon Development Amendment Act (2021) (the Amendment Act) provides inter alia for the establishment of carbon budgets as interim milestones on this trajectory.

The Amendment Act mandates the Climate Change Advisory Council to propose carbon budgets for each of the periods 2021-2025; 2026-2030; 2031-2035 (provisional) as soon as may be after the entry into force of the Act. The proposed carbon budgets should set Ireland on a pathway consistent with a sustainable economy and society where greenhouse gas emissions are balanced or exceeded by the removal of greenhouse gases by 2050.

The Council adopted this Technical Report at its meeting on 25th October 2021. The Council established a Committee on Carbon Budgets to support the preparation of its carbon budgets proposals. The work of the Committee and their analysis informed the deliberations of the Council and the calculation by the Council of the carbon budget proposals. This report describes the deliberations, reasoning and evidence behind the Council's carbon budget proposals.

Under the legislation, the proposed carbon budgets must provide for a reduction of 51% in the total amount of those greenhouse gas emissions (specified by the regulations) by 2030, relative to 2018. Total greenhouse gas emissions covered under the carbon budgets were 68.3 Mt CO_2eq in 2018. Therefore, the first two carbon budgets must be consistent with emissions of 33.5 Mt CO_2eq in 2030[1] as illustrated in Figure 0-1. This is a very significant challenge for our society and economy while we also grapple with other societal challenges such as the Covid pandemic, Brexit and housing.

The 51% target applies to greenhouse gas emissions attributable to industrial, agricultural, energy, land use and other anthropogenic activities in the State. This target does not include emissions from international aviation or shipping but this may be re-considered in the context of the next programme of carbon budgets and international developments in the interim. The 51% target is the primary constraint on carbon budgets over the course of the first two budget periods ending on 31 December 2030, relative to 2018. The provisional carbon budget proposed for 2031 to 2035 continues the trajectory towards climate neutrality by 2050.

[1] Emissions are evaluated using the GWP_{100} from IPCC AR5. See Table 2-1 Total emissions using AR4 values were 67.3 MtCO_2eq

The 51% target represents a significant challenge to all covered sectors. Strong, rapid and sustained reductions in emissions in all covered sectors and all gases are required to meet this challenge. The analysis indicates that, while different sectors will transition at different rates, the overall range of pathways to achieving the 51% target is narrow.

The proposed carbon budgets are built on the latest science, including from the IPCC Sixth Assessment Report Working Group 1 and were calculated using data from the latest EPA inventories and projections and are consistent with best practice on international reporting.

The approach taken to calculate the carbon budgets from the bottom-up was as follows. The 51% target is used to calculate the required level for total emissions in 2030, which is 33.5 Mt CO2eq Modelling by University College Cork, Teagasc and University of Limerick respectively informed the calculation by the Council of the carbon budgets. This modelling illustrated the quantity of greenhouse gases that would be emitted on different pathways towards meeting the overall 51% target by 2030. The amount of emissions allowed from each sector was aggregated for each scenario to give an economy wide[2] total for the scenario in each budget period. The total emissions from each economy-wide scenario, reaching 51% emissions reduction by 2030, were then averaged to give the final carbon budget amounts.

The Council proposes carbon budgets as presented in Table 0-1. These carbon budgets including the various scenarios were analysed against the criteria set out in the legislation as discussed later including an examination of the temperature impact of the different scenarios examined.

[2] Excluding International Aviation and Maritime emissions

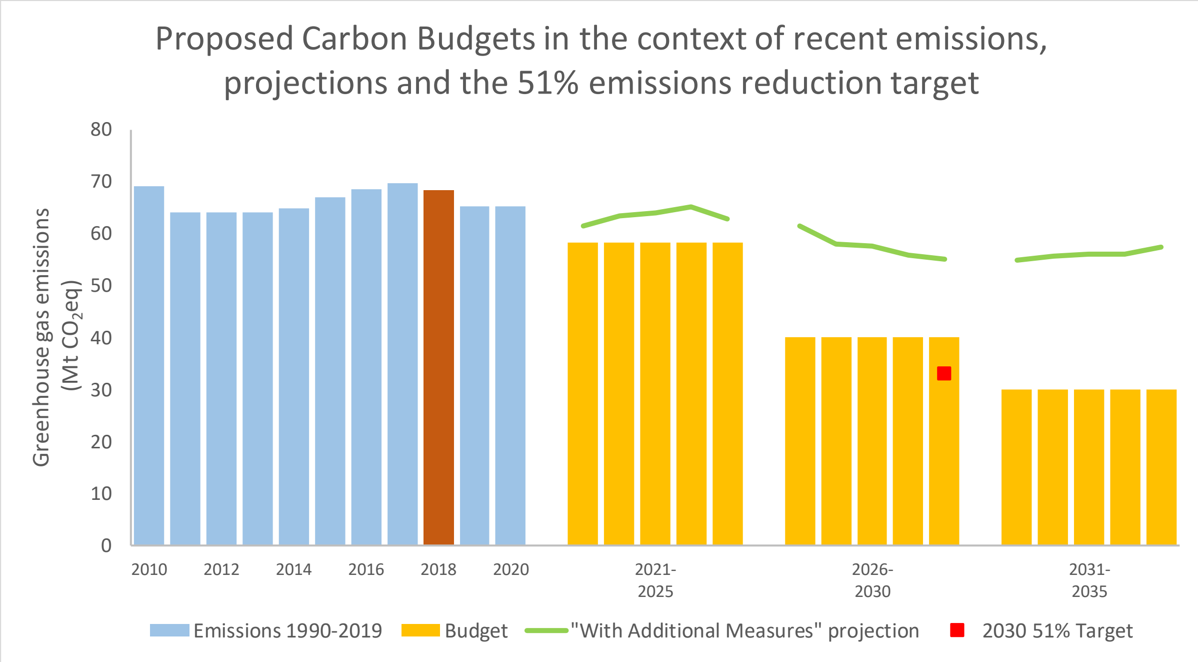


Figure 0-1 The proposed carbon budgets in the context of recent historic emissions, and the Environmental Protection Agency's "with additional measures" projections of emissions based on implementation of CAP2019, including LULUCF, excluding international aviation and navigation, and the annualised average emissions associated with the proposed carbon budgets. Sources EPA 2021, own work.

Table 0-1 Proposed Carbon Budgets of the Climate Change Advisory Council

	2021-2025 CB1	2026-2030 CB2	2031- 2035 (Provisional) CB3
	All Gases		
Carbon Budget ($Mt\ CO_2eq$)	**295**	**200**	**151**
Annual Average Percentage Change in Emissions	**-4.8%**	**-8.3%**	**-3.5%**
The figures are consistent with emissions in 2018 of 68.3Mt CO_2eq reducing to 33.5Mt CO_2eq in 2030 thus allowing compliance with the 51% emission reduction target.			

The proposed carbon budgets will require transformational changes for society and the economy which are necessary; failing to act on climate change would have grave consequences. The social and economic impacts can be mitigated by appropriate policies and supportive infrastructures e.g. for training; while opportunities arising from a green reputation, and innovation in products and services to support the low carbon economy should be seized. It is critically important that the potential for adverse impacts is identified, recognised and addressed. Individuals and communities at risk of loss of employment or disproportionate costs need to be identified and assisted in making the transition. The impact of these changes will require significant Government action with budgetary implications that need to be included in medium term planning.

Criteria of the Amendment Act

1. National Climate Objective

The proposed carbon budgets set Ireland on a pathway consistent with achievement of climate neutrality by 2050 with opportunities to achieve improvements in climate resilience, environmental sustainability and biodiversity. Analysis was carried out which showed that the proposed carbon budgets are consistent with achieving net zero of long-lived greenhouse gases (CO_2 and N_2O) and a significant reduction in methane emissions by 2050, thus establishing a climate neutral economy.

2. Consistency with the Regulation

In response to a request from the Minister, the Council provided advice on the formulation of the regulation. The proposed carbon budgets are consistent with that regulation, SI 531 of 2021, Climate Action and Low Carbon Development Act 2015 (Greenhouse Gas Emissions) Regulations 2021 adopted on 12/10/2021.

3. 51% Reduction by 2030

The proposed budgets have been calculated, in line with (Reg.531.2021) to allow compliance with the 51% emissions reduction target by 2030. The task is challenging. The modelling demonstrated that significant changes in society and the economy as well as a ramp up in investment would be required to meet the 51% target.

The most recent projections published by the EPA for LULUCF indicate that, with current policies and measures, net emissions for the sector will increase from 4.5 Mt CO2eq in 2019 to 7.1Mt CO2eq in 2030. This projected trend in sectoral emissions will need to be reversed. In the carbon budgets, the Council has assumed a 51% emissions reduction in the LULUCF sector in the period to 2030. This assumption of a 51% reduction in these emissions was employed in order to simplify the aggregation of total carbon budgets across all sectors including LULUCF. This does not imply that the Council endorses this scenario as the optimal reduction pathway for the sector. The 51% reduction implies net emissions of 2.4Mt CO_2eq in 2030. If this were not achievable then remaining sectors would require additional emissions reductions ambition.

4. Objectives of the United Nations Framework Convention on Climate Change and the Paris Agreement

The proposed carbon budgets are consistent with an appropriate contribution by the State to global efforts to limit climate change to well below 2^{o}C and pursuing efforts to limit the temperature increase to 1.5^{o}C as articulated in the UNFCCC and the Paris Agreement. The Carbon Budgets sit within an emissions trajectory which requires the 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.

5. Ireland's obligations under EU Legislation

The proposed budgets will enable full compliance with the State's current target of a 30% reduction by 2030 and are evaluated to be consistent with existing obligations and the proposed targets for Ireland under the EU Climate Law and its constituent parts including the Effort Sharing Regulation. There may be a requirement to make use of the existing flexibilities in order to remain in compliance (such as banking and borrowing) as the timing of implementation may see a misalignment between national and EU targets.

6. Biodiversity

Another part of the national climate objective relates to biodiversity. 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.

7. Use of latest Inventories, Projections and Best Practice Reporting of Emissions and Removals

The proposed carbon budgets were calculated using data from the latest EPA inventories and projections and are consistent with best practice on international reporting.

8. Scientific Advice including in Relation to Biogenic Methane

The proposed carbon budgets are consistent with the latest science, including from the IPCC Sixth Assessment Report Working Group 1 (AR6) whilst abiding by the legislated mandate and regulation (531.2021). 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_2 and N_2O) and for a strong, rapid and sustained reduction in methane emissions. Recent analysis from the United Nations Environment Programme

(UNEP) highlighted the need for methane emissions reductions globally and emphasised the role of mitigation options for methane emissions within the fossil fuel sector as a cost effective option. Emissions reduction from agriculture were seen as necessary but challenging. Additional research is required to enhance the mitigation options available. The legislation requires the Council to consider methane as part of the overall basket of greenhouse gases, using the standard GWP_{100} metric. Approximately 93% of Irish methane emissions come from livestock based agriculture which are particularly hard to mitigate without changing output levels. New methane based mitigation pathways (animal diet, additives and genetics) are currently being investigated, in Ireland and internationally, which may deliver methane reductions in future. The proportionate share of emissions reduction between different gases and associated sectors is a matter for government. However, Council notes the different emissions trajectories for each gas would have long term implications for Ireland's contribution to global warming.

9. Maximising employment, the attractiveness of the State for investment and long-term competitiveness of the economy

The proposed carbon budgets will have an impact on the economy but failing to act on climate change would have greater consequences. The negative impacts can be mitigated by appropriate policies and supportive infrastructures e.g. for training; while opportunities arising from a green reputation, and innovation in products and services to support the low carbon economy should be seized.

10. Climate Justice

Climate justice has national and international dimensions. Nationally, it is critically important that the potential for adverse impacts is identified, recognised and addressed. Individuals and communities who are vulnerable or at risk of loss of employment or livelihood, or disproportionate costs need to be identified and assisted in the transition. The importance of providing policy supports aimed at alternative forms of income for small and medium enterprises, farmers and other impacted households should be considered urgently.

It is the Council's view that the Paris Agreement represents the only international agreement on a fair approach to common but differentiated responsibilities and respective capabilities. An appropriate contribution to the Paris Agreement is an appropriate response to international climate justice.

People, nature, and infrastructure in Ireland are already vulnerable to a range of climate impacts today and these will only increase in the coming years as the climate continues to change. As already identified by the Council in its Annual Review 2020, increasing adaptation efforts will be required to ensure that societal, economic, and environmental goals remain achievable in the face of climate change.

1 Introduction

The recently published Volume I of the Sixth IPCC Assessment Report makes ever clearer the impact that greenhouse gases are having on climate. Human activities have already led and will continue to lead to more frequent and intense extreme heat and rainfall, increasing levels of drought and forest fire events, and cause our oceans to warm, acidify and lose oxygen. The report starkly concludes that unless there are immediate, rapid and large-scale reductions in greenhouse gas emissions, that limiting the temperature increase to 1.5C will be beyond reach. The case for significantly enhanced levels of climate leadership backed up by meaningful mitigation and adaptation actions is clear.

The commitment in the Amendment Act to reduce Ireland’s emissions by 51% by 2030 relative to 2018 and to transition to a climate resilient, biodiversity rich, environmentally sustainable and climate neutral economy by 2050 represents a serious ratchetting up of the level of national ambition in the fight against climate change. This target, which was agreed as part of the Programme for Government 2020, arose out of a desire to improve Ireland’s performance on climate action. Actions taken to date have failed to put Ireland on a transition towards the national climate objective, managing at best to stabilise the overall levels of emissions. Full and successful delivery of the carbon budgets informed by these commitments will place Ireland amongst the most ambitious and progressive of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) and its Paris Agreement. It will position Ireland as a leader in that forum and enhance its existing reputation as a small nation ‘punching above its weight’ in contributing positively to global peace and sustainable development.

Globally the term “carbon budget” is most often understood to refer to the total net amount of carbon dioxide (CO_2) that can still be emitted by human activities while limiting global warming to a specified level. Carbon budgets as a concept can have a relevance at a global, national, sub-national or even organisational levels. National emissions budgets are usually consistent with a contribution towards the global efforts to achieve a temperature objective taking into account the existing emissions levels and profile in that State and seek to bridge the gap between priority setting in the short term for climate action and the long-term outcomes of action on cumulative emissions and ultimately impact on climate. The proposals outlined below are consistent with this approach. The carbon budget is expressed as the maximum amount of emissions which can occur over a specific period of time. National carbon budgets are generally implemented by setting budgets for multiple periods of time, in order to provide greater certainty for decision makers and investors. In Ireland’s case, at any moment, there will be three carbon budgets, indicating the limit of emissions over three consecutive five-year periods beginning with the period 2021-2025. The budgets are binding for two periods, while the third budget is provisional. Under the legislation, Ireland's carbon budgets cover all greenhouse gases reported by the State under the UNFCCC and EU processes[3]. The different gases are denominated in terms of the conventional accounting metric, Global Warming Potential, GWP_{100}, using the values for GWP_{100} published in the IPCC Fifth Assessment Report[4]. The Amendment Act and the Regulations associated with same provide the legislative framework for what is included or excluded and what provisions are available to ensure compliance with the budgets over time.

Under the Amendment Act the Council is mandated to propose carbon budgets to the Minister of Environment, Climate and Communications as soon as may be after the coming into effect of the Act. Future carbon budget proposals will need to be made at least one year before the end of each of the current carbon budgets (i.e. the next proposal will be in 2024) and each proposal will always be made up of a programme of three carbon budgets for the State. The Act further mandates that the Council should consider a number of criteria in its deliberations. In March of 2021 the Council, in response to this responsibility, set up a Carbon Budget Committee to support its analysis of the issues and criteria that need to be taken into account.

The remainder of this chapter deals with the benefits of climate action and the current state of play in terms of our emissions profile. Chapter 2 outlines the carbon budgets themselves and some of the critical underpinnings of the calculations. Chapter 3 provides an overview of the modelling carried out to inform the proposals and an overview of the economic impacts of their implementation. Chapter 4 deals with the issues of EU targets and also how the scenarios analysed can be viewed in the context of Ireland's contribution to the temperature goals of the Paris Agreement. Chapter 5 provides an assessment of the role of different gases in contributing to the analysis whilst Chapter 6 investigates the potential for and importance of carbon dioxide removals. Chapter 7 provides a summary of the sectoral engagement that took place in June and July with Government Departments and other Agencies. Finally, Chapter 8 details the mandate and membership of the Carbon Budgets Committee whose work contributed so much to the preparation of this paper.

[3] This excludes International Aviation and Maritime emissions

[4] Other metrics such as GWP* have provided insights which inform analysis in this report where appropriate

1.1 Benefits of climate action

The prevention of climate change in itself is the most important benefit of global climate action. These benefits arise over decades and over all countries. The impacts of climate change are already felt across the globe and in Ireland. Ireland must play its part in the global effort to combat climate change.

The 2020 Lancet Countdown on climate change and health found that climate change has already produced considerable shifts in the underlying social and environmental determinants of health at the global level with effects often unequal, disproportionately impacting populations who have contributed the least to the problem[5]. During the past 20 years, there has been a 53.7% increase in heat-related mortality in people older than 65 years. This high cost in human lives is also associated with an economic cost with 302bn hours of potential labour capacity lost in 2019. Some of the worst affected countries saw losses of potential labour capacity equivalent to 4-6% of their GDP. The 2018 heatwave in Europe was estimated to have caused heat related mortality equivalent to 1.2% of EU Gross National Income (GNI). Research suggests that the projected decrease in temperature attributable mortality in winter months in Europe will be exceeded by the increase in temperature attributable mortality in summer months.[6] Increased risk of exposure to wildfires and floods, threats to global food security and the growth in climate suitability for disease transmission have all contributed to already profound impacts of climate change on human health. The new EU Adaptation Strategy published in February 2021[7] notes that in the EU economic losses from more frequent climate-related extreme events already average over €12 billion per year. This cannot be reversed but signifies the heavy cost of climate change before the globe even reaches 1.5 degrees warming.

Conservative, lower bound estimates show that exposing today's EU economy to global warming of 3°C above pre-industrial levels would result in an annual loss of at least €170 billion (1.36% of EU GDP).[8] However, economic analysis struggles to quantify and value systemic threats and risks such as

[5] Watts et al. (2021) The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. *LANCET*, 397(10269), pp. 129-170. [online] https://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(20)32290-X.pdf

[6] Quijal-Zamorano et al. (2021) Seasonality reversal of temperature attributable mortality projections due to previously unobserved extreme heat in Europe. *The Lancet Planetary Health*, 5(9), pp. E573-E575. [online] https://www.thelancet.com/pdfs/journals/lanplh/PIIS2542-5196(21)00211-4.pdf

[7] European Commission (2021) Forging a climate-resilient Europe – The new EU Strategy on Adaptation to Climate Change. COM(2021) 82 final. [online] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0082&from=EN

[8] European Council (2020). JRC Peseta IV. Projection of Economic impacts of climate change in Sectors of the EU based on bottom-up analysis. [online] https://ec.europa.eu/jrc/peseta-iv [accessed 15 June 2021].

climate change and therefore a typical cost benefit analysis is not appropriate where the action in question has implications for overall levels of economic growth and relative prices.[9] Some research argues that damages from climate change are probably underestimated and that future scarcities caused by the changing composition of the economy and climate change should lead to an increasing economic value of ecosystem services in future years, which if taken into account, provides strong justification for climate action[10]. At a more basic level, cost benefit analysis of climate change is difficult to complete because of gaps in data and knowledge. The short term costs of climate action are easier to quantify (e.g. how much wind power costs vs coal) and therefore are more completely represented than the harder to quantify benefits of avoided climate change which accrue over many decades, impact on areas that are hard to value (e.g. human lives, ecosystems) and rely on a counterfactual estimation of future impacts (what *would* happen with climate change vs what *would* happen without climate change). This context is important when considering the economic analysis put forward in subsequent sections of this report. While the Council places importance on transparency in the costs of climate action to Ireland, the Council is firmly of the view that ambitious climate action is a scientific and economic imperative.

In addition to the direct benefits of climate action in avoiding dangerous climate change, climate action itself can bring about more immediate indirect benefits. There are significant indirect benefits to ambitious mitigation which can accrue in this decade including benefits for human health, air and water quality, biodiversity and energy cost savings. We briefly explore a selection of the potential benefits below.

The Lancet (2021) noted that many carbon intensive practices and policies lead to poor air quality, poor food quality, and poor housing quality, which disproportionately harm the health of disadvantaged populations.[11] These impacts can be halted and reversed with well planned mitigation measures.

---

[9] Dietz, S. and Hepburn, C. (2010) On non-marginal cost-benefit analysis. Grantham Research Institute on Climate Change and the Environment Working Paper No. 18, p 28. [online] https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2014/02/Workingpaper18.pdf

[10] Sterner, T. and Persson, U.M. (2020) An Even Sterner Review: Introducing Relative Prices into the Discounting Debate. *Review of Environmental Economics and Policy*, 2(1). [online] https://www.journals.uchicago.edu/doi/abs/10.1093/reep/rem024?journalCode=reep

[11] Watts et al. (2021) The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. *LANCET*, 397(10269), pp. 129-170. [online] https://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(20)32290-X.pdf

Ireland has extremely high rates of respiratory illnesses, with the fourth highest incidence of Asthma[12] and the highest incidence of Cystic Fibrosis in the world.[13] Communicable illnesses from the common cold and seasonal flu, to SARS, Swine Flu, COVID-19 also attack the respiratory system. These illnesses are exacerbated by air pollution such as particulate matter (PM). Particulate matter in Dublin and smaller urban areas has been found to be largely driven by combustion of coal, peat and wood – normally for home heating. In some locations, this combustion, of solid fuel and in particular more smoky solid fuels such as bituminous coal, wet/green wood and peat, has driven regular exceedance of WHO guidance levels for $PM_{2.5}$.[14] Diesel cars represent the next biggest source of air pollution in urban areas. Analysis by the European Environment Agency (EEA) with the World Health Organisation (WHO) found that in Ireland approximately 1,300 premature deaths are attributable to $PM_{2.5}$ pollution, annually.[15] Climate action to reduce dependence on solid fuel heating and to move away from diesel vehicles would see significant health benefits. Research by UCC and UCD[16] estimated a net benefit in health and environmental impacts of €20 million per annum from 2030, as a result of the move from the business as usual (BAU) to a 22% reduction in emissions in the Effort Sharing Regulation (ESR) sector by 2030. A greater level of mitigation ambition, appropriately implemented, would be expected to bring greater air quality co-benefits. It would be important to ensure that these gains in air quality are not offset by localised increases in other air pollutants such as particulate matter where biomass (especially green/wet wood) is used inappropriately for home heating, particularly in an urban setting. The recently proposed Solid Fuel regulations will be a good start to managing the transition in this regard. Secondly, solid fuel use for primary home heating is predominantly associated with poorer households, rural households and older occupants. If solid fuel use is phased out without providing these vulnerable households with alternative, cleaner, low carbon heating, the health risk of living in underheated homes is high, as evidenced by the

[12] Asthma.ie, "Let me breathe - Government must fund free GP annual asthma review in Budget 2019," Official Website of the Asthma Society of Ireland, 2019. [online] https://www.asthma.ie/news/let-me-breathe-government-must-fund-free-annual-gp-asthmareview-budget-2019 . [Accessed 15 6 2020]

[13] CF Ireland, "Cystic Fibrosis Ireland - About," 2020. [online] https://www.cfireland.ie/. [Accessed 28 7 2020].

[14] Wenger, J., Arndt, J., Buckley, P., Hellebust, S., McGillicuddy, E., O'Connor, I., Sodeau, J. and Wilson, E. (2020) Research 318: Source Apportionment of Particulate Matter in Urban and Rural Residential Areas of Ireland (SAPPHIRE) (2013-EH-MS-15), Environmental Protection Agency. [online] https://www.epa.ie/publications/research/air/Research_Report_318.pdf

[15] Environmental Protection Agency (2020) Transport emissions result in an exceedance of an EU limit for air pollution in Dublin, 24 September 2020. [online] https://www.epa.ie/news-releases/news-releases-2020/transport-emissions-result-in-an-exceedance-of-an-eu-limit-for-air-pollution-in-dublin.php

[16] Kelly, A., Chiodi, A., Fu, M., Deane, P. and Ó Gallachóir, B.P. (2017) Research 212: Climate and Air Policy in Ireland: Synergies and Tensions – A GAINS Ireland and Irish TIMES analysis (2013-CCRP-MS.14), Environmental Protection Agency. [online] https://www.epa.ie/publications/research/climate-change/EPA_Research-212_webEssentra.pdf

phenomenon of excess winter mortality[17]. Thus addressing the building fabric and developing alternative heating systems particularly for vulnerable households will be of utmost importance. Solid fuel use for heating as a secondary home heating source is far more prevalent across all households and regions. Specific policy actions to communicate with and engage these households towards cleaner and more efficient heating is key.

Poor building stock exacerbates (or perhaps in some cases is the direct cause of) respiratory and some cardiac conditions due to cold, damp, draughts, and mould. Fossil fuel heating further compounds the problem because of carbon dioxide, carbon monoxide gases, and particulates (smoke & soot), decreasing the indoor air quality.[18] These impacts are usually felt most by the poorest and most vulnerable sections of society. Again, ambitious climate action which improves building quality through building fabric upgrades can significantly improve health outcomes. A Catalonian study concluded that renovating 1.5 million dwellings would save the Spanish public administration €555m in healthcare and labour costs savings annually. A Welsh case study found that admissions to hospital fell by between one quarter and one third across the retrofitted homes, depending on the measures that had been installed.[19]

Analysis suggests that it is possible to implement carbon budgets while protecting and enhancing biodiversity.[20] However, inappropriate mitigation measures have the potential to undermine or threaten biodiversity. Care must be taken to identify and implement policy 'win-wins' to achieve this with particular attention given to the siting of energy infrastructure, appropriate species mix in forestry and the location of vulnerable species. Sustainable development of the agriculture and land use sector can deliver important win-win opportunities while the Common Agricultural Policy may be used to support improved management of livestock farming alongside provision of ecosystem services. More efficient use of and reduction in the application of nitrogen would bring climate, biodiversity and water quality benefits.

In summary there are a wide range of benefits, both direct and indirect. from taking climate action. Because of the complexity of the systems, the sheer variety of types of action that are required, and the potential for other impacts it is difficult to put a single value or even range of values on the

---

[17] Clinch, J.P. and Healy J.D. (2000) Housing standards and excess winter mortality. *Journal of Epidemiology & Community Health*, 54(9), 719-720. [online] https://jech.bmj.com/content/54/9/719
[18] IERC (2021) Creating Shared Value for all: The multiple benefits of a retrofit renovation wave in Ireland, International Energy Research Centre (IERC), Ireland. [online] http://www.ierc.ie/wp-content/uploads/2021/04/IERC-Retrofit-Co-Benefits-Paper_Final_Digital.pdf
[19] IERC (2021) ibid.
[20] Gorman et al. (2021) Small Scale Study of the Impacts of Climate Change Mitigation Measures on Biodiversity. In press.

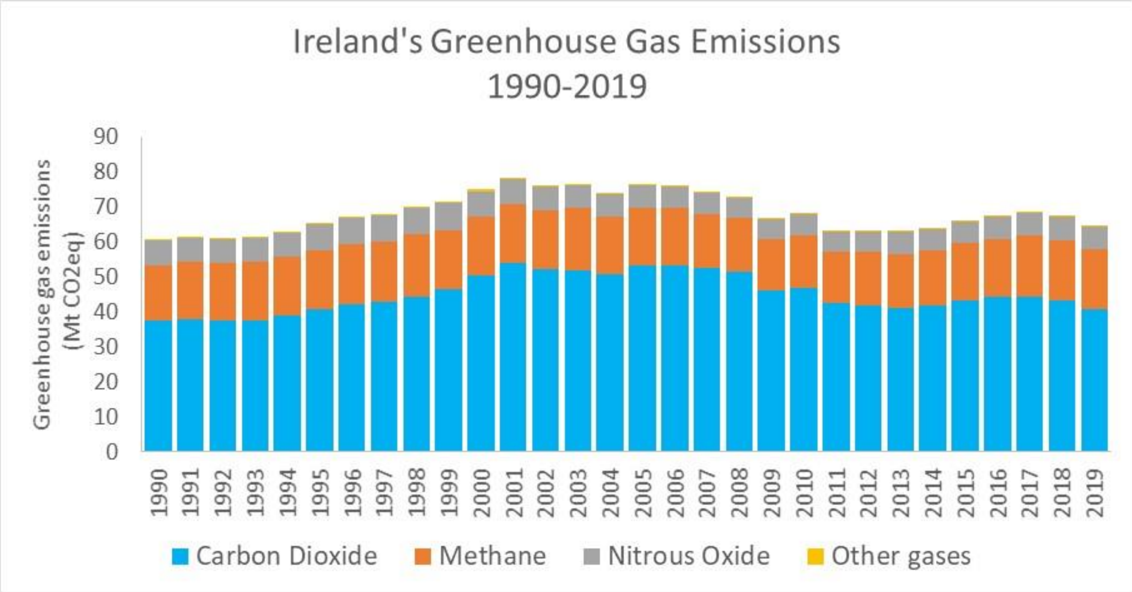
benefits in total, an issue that is widely acknowledged. Nonetheless it is clear that beyond the scientific imperative there is a wide range of economic and societal benefits that arise from taking a comprehensive course of action to address our emissions in a planned and urgent manner.

1.2 Where we are now

In 2018, Ireland's greenhouse gases emissions including Land Use, Land Use Change and Forestry (LULUCF) totalled 68.3Mt CO2eq, see Table 1-1.[21] Emissions fell to 66.3 Mt CO2eq in 2019, and are estimated to have fallen further in 2020, largely due to the impact of measures to manage Covid-19[22] evaluated on the basis of AR5 values for GWP_{100}, as specified in the (Reg.531.2021).

It is useful to review some important aspects of greenhouse gas emissions in Ireland compared to the EU as a whole, see Figure 1-1. Ireland's gases emissions including LULUCF, in 2018, consisted of carbon dioxide (63.1%), methane (25.6%), nitrous oxide (10.0%), with other minor gases contributing 1.4%. This profile is in strong contrast to the emissions profile for the EU as a whole, where carbon dioxide accounted for 79.0% of emissions, methane 12.5%, nitrous oxide 5.7% and the minor gases just 2.8% of emissions.

[21] This excludes international aviation and maritime emissions.
[22] Emissions are evaluated using the GWP_{100} from IPCC AR5. See Table 2-1 Total emissions using AR4 values were 67.3 $MtCO_2eq$



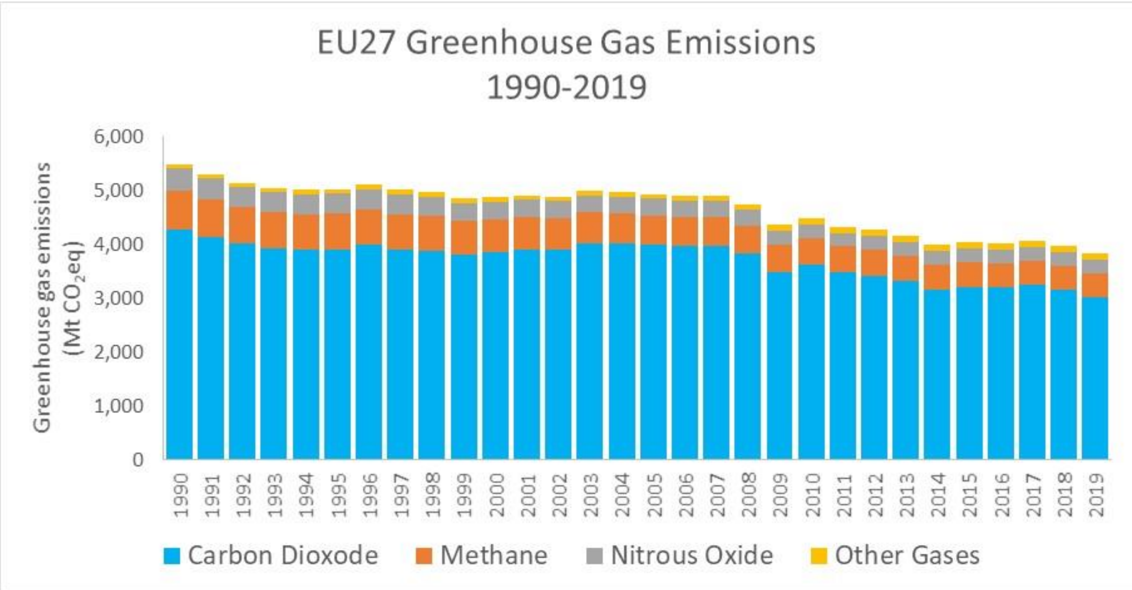


Figure 1-1 Historical emissions of greenhouse gases in Ireland and the EU27 from 1990-2020, Source EUROSTAT 2021, EPA 2021

The differences in emissions profiles is a reflection of the relative size of different sectors in Ireland's economy compared to the EU as a whole, as shown in Table 1-1 and Table 1-2. For example, heavy industry is a prominent component of the EU economy, with large energy and process emissions associated with these activities, whereas Ireland's industrial sector is small. Ireland is also heavily dependent on fossil fuels to meet our energy needs, accounting for 89% of energy supply in 2018, compared to 71% across the EU27, with an additional 19% of the EU supply coming from nuclear power.[23]

[23] Eurostat (2021) based on data in Energy balances. [online] https://ec.europa.eu/eurostat/web/energy/data/energy-balances

Table 1-1 Breakdown of emissions and removals by sector in Ireland in 2018.

2018			Mt CO_2eq
Energy			37.0
Industrial Processes			3.2
Agriculture			22.3
Land Use, Land Use Change and Forestry			
	Emissions	9.6	
	Removals	-4.8	
	Net LULUCF		4.8
Waste			1.0
Total Emissions			68.3

Another area of important contrast is the prominence of the Agriculture sector in Ireland as a source of emissions most notably of both methane and nitrous oxide. In 2018, across the EU, agriculture accounted for 11.0% of total emissions, 52% of methane emissions, and 73% of nitrous oxide emissions. Conversely in Ireland, agriculture accounted for 32.6% of total emissions, 90% of methane emissions and 88% of nitrous oxide emissions. This is due to the number of cattle in relation to the population. A third point of contrast between the EU and Ireland emission profiles is the magnitude of emissions and removals associated with Land Use, Land Use Change and Forestry (LULUCF). At EU level, in 2019, the LULUCF sector reported a net removal of 243 Mt CO_2eq, approximately -6.4% of total emissions from all other sectors. Whereas in Ireland, LULUCF was a net source of emissions of 4.8Mt CO2eq, or 7% of total emissions, and reported net emissions from management of wetlands and grasslands have always been reported as greater than the removals from forestry, as can be seen in Figure 1-2. Grasslands are a source due to the national land drainage carried out in the 1950s to 1970s with further drainage works continuing to occur at a farm level. The change in accounting method from Net-Net (which measures improvement relative to a baseline rate of emissions) to Gross-Net accounting (which reflects the actual physical balance of sources and sinks) now places a large emphasis on the emissions from the c.350,000 hectares of these soils. This change is arising in order to simplify the accounting systems and to enhance environmental integrity and the EU proposes to adopt the same changes from 2026..

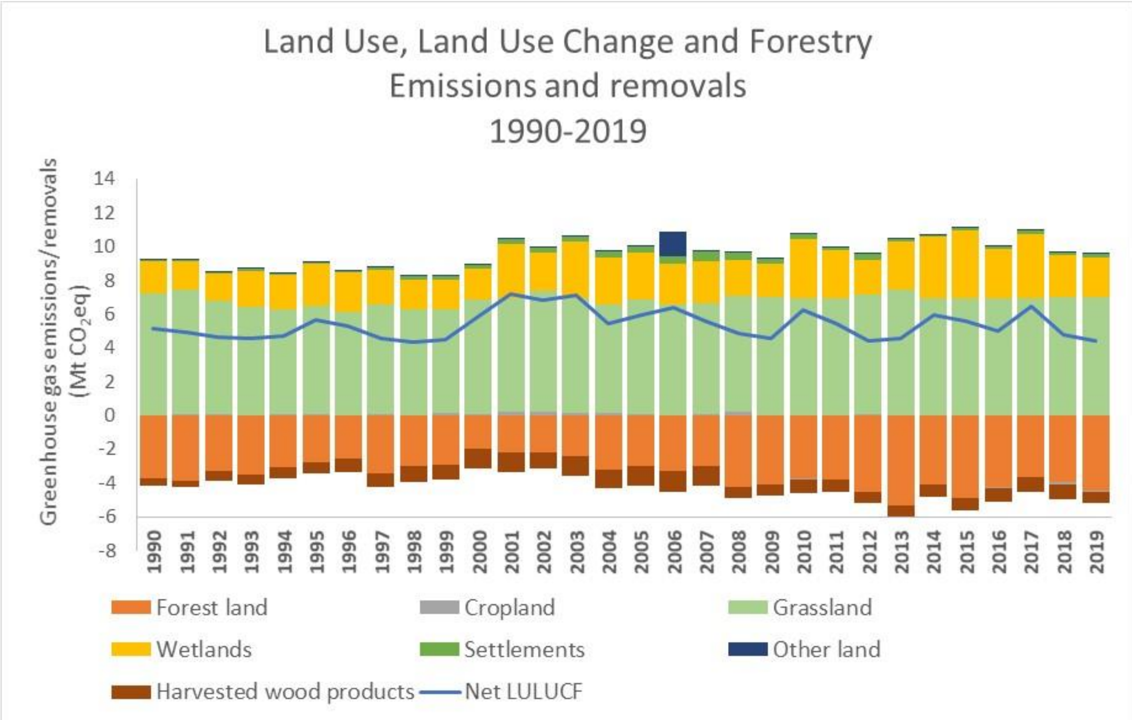


Figure 1-2 Historic emissions and removals associated with Land Use land Use Change and Forestry in Ireland 1990-2019. Source EPA (2021)

Table 1-2 Comparison between the share of greenhouse gas emissions by sector in Ireland and the EU evaluated using AR5 values for GWP_{100}. Source Eurostat (2021), EPA (2021)

Sectoral Share of Total greenhouse gas emissions in 2018 Including Land Use, Land Use Change and Forestry		
	Ireland	EU
Energy	54.2%	82.3%
Industrial Processes	4.7%	9.4%
Agriculture	32.6%	11.0%
Land use, land-use change and forestry	7.0%	-6.4%
Waste	1.4%	3.7%

Given the prominence of non-CO_2 greenhouse gases and LULUCF in Ireland's emissions profile, and their close association with agriculture in Ireland, the role of agriculture and land use in carbon budgets was considered in great detail, while noting the requirements set in the legislation with respect to the target for 51% emissions reduction by 2030 and the national climate objective and the regulation specifying use of the GWP_{100} metric.

Current projections of greenhouse gas emissions out to 2030 and 2040 are shown Figure 1-3. The projections are produced by the EPA on the basis of successful implementation of all measures included in the Climate Action Plan 2019. In the event that all measures in the "With Additional Measures" projection (WAM) were fully implemented on schedule, and, in the event that Ireland can use full access to the available flexibilities of the Effort Sharing Regulation, Ireland would achieve emissions reduction in line with our current EU targets to 2030. However, post 2030, there are currently insufficient policies and measures in place, or in the pipeline, to avoid market forces from driving greenhouse emissions across the economy upwards again. Furthermore, EU goals to 2030 have been revised and targets for Member States are under negotiation with the strong likelihood of increased ambition to 2030. For further detail on Ireland’s current and future proposed emissions targets in the evolving EU context see Section 4.1.

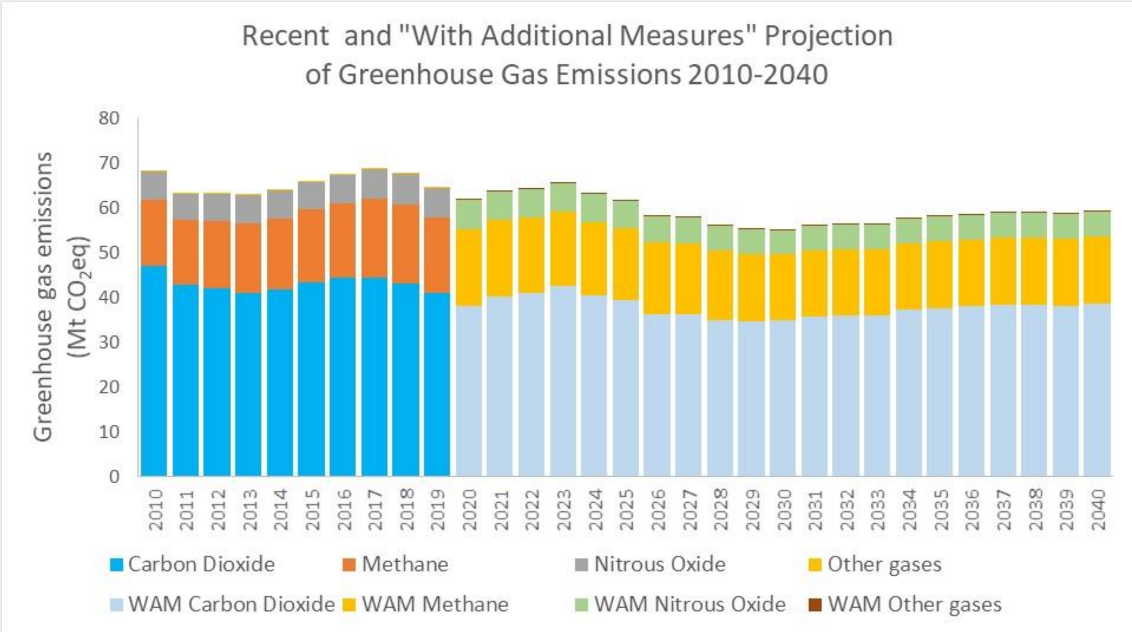


Figure 1-3 Emissions of greenhouse gases in Ireland from 2010-2020, and “With Additional Measures” Projection from 2020-2040. Source EPA 2021

2 Our Carbon Budgets

The Amendment Act mandates the Climate Change Advisory Council to propose economy wide[24] carbon budgets for each of the periods 2021-2025; 2026-2030; 2031-2035 (provisional). The proposed carbon budgets should set Ireland on a pathway consistent with a sustainable economy and society where greenhouse gas emissions are balanced or exceeded by the removal of greenhouse gases by 2050 and remain net zero or net negative thereafter. Under the Act, it is the role of Government to consider the Council's proposals and to adopt the carbon budgets or revise as appropriate. Once the carbon budgets have been passed by the Oireachtas, it is the Minister's responsibility to set sectoral emissions targets ceilings consistent with the carbon budgets.

Under the legislation, the proposed carbon budgets must provide for a reduction of 51% in the total amount of those greenhouse gas emissions using the GWP_{100} metric (as specified by the regulations) by 2030, relative to 2018. Total greenhouse gas emissions in 2018 covered under the carbon budgets were 68.3 Mt CO2eq. This value is consistent with but different to what was reported in the most recent EPA submission to the UNFCCC in April 2021 due the application here of the GWP_{100} values published in the IPCC AR5[25]. See Table 2.1. Therefore, the first two carbon budgets must be consistent with emissions of at most 33.5 Mt CO2eq in 2030. The 51% target applies to greenhouse gas emissions attributable to industrial, agricultural, energy, land use and other anthropogenic activities in the State. As specified in the Regulation this target does not include emissions from international aviation or shipping. The 51% target is the primary constraint on carbon budgets over the course of the first two budget periods ending on 31 December 2030, relative to 2018.

Analysis of carbon budget scenarios was sought to inform considerations of feasibility, competitiveness impacts, implications for investment, distributional impacts, jobs and climate justice. The results of the modelling do not imply an endorsement or recommendation of the Council for particular mitigation strategies but rather illustrate the scale of the challenge and also establish appropriate mitigation pathways consistent with the legislated level of ambition including a 51% reduction in greenhouse gas emissions by 2030 relative to 2018. Modelling of scenarios and analysis of the results allows consideration of different mitigation options that may be applied to reduce emissions in line with carbon budgets, their potential, their costs, their interactions and their possible implications. The aim was to inform society wide carbon budgets that are consistent with our international climate commitments and are achievable and to develop an evidence base to address the mandated criteria in the legislation. There is no single model in Ireland that captures in

[24] Excluding International Aviation and Maritime emissions

[25] See Table 2-1 Total emissions using AR4 values were 67.3 $MtCO_2eq$

sufficient detail the technical information on mitigation options across all sectors. Modelling of carbon budget scenarios by three groups; University College Cork (UCC) TIMES Ireland Model (TIM), Teagasc Food and Agriculture Policy Research Institute(FAPRI) Ireland model and University of Limerick (UL) Goblin model was carried out. A brief description of these models is provided in Section 3.1. The scenarios and model runs were calibrated to and informed by data from EPA inventory and projections.

The Regulation (S531.2021) requires the Council propose carbon budgets for all greenhouse gases reported by the EPA[26] under the UNFCCC on the basis of Global Warming Potential values evaluated over 100 years, GWP_{100}, published in the IPCC Fifth assessment report (AR5). This ensures consistency with the EU who have adopted these values for reporting going forward from 2021 and is also consistent with UNFCCC reporting practices. All figures presented in this report have been adjusted to reflect the adoption of the AR5 GWP_{100} values, unless otherwise stated. The main impact of this adjustment is to increase the reported value of CH_4 and decrease the reported emissions of N_2O relative to CO_2 emissions.

Table 2-1 Selected Global Warming Potential values for key gases from IPCC Forth Assessment Report (AR4) and Fifth Assessment Report (AR5)

	AR4	AR5
Carbon Dioxide	1	1
Methane	25	28
Nitrous Oxide	298	265

The carbon budget scenarios considered represented different mitigation efforts across sectors that could be consistent with meeting the overall national 51% emission reduction target in line with the Council's legislative mandate. The Council has considered a number of core scenarios which explore a range of different mitigation reductions across sectors. Different levels of mitigation in the broader energy sector (electricity, heat, transport and industry) were modelled by TIM. Different levels of mitigation effort were modelled in the agriculture and land use sector by both the Teagasc FAPRI-Ireland model and the Goblin model. Appropriate combinations of scenarios from each model gave an overall economy wide[27] scenario for meeting the 51% reduction target by 2030. Each scenario represents different sharing of effort across sectors with Exx-Ayy representing a scenario where the

[26] This excludes International Aviation and Marine emissions
[27] Excluding International Aviation and Maritime emissions

Energy sector (heat, transport, electricity) reduces emissions by xx% while the Agriculture sector reduces by yy% and the LULUCF sector reduces by 51%, adding up to an overall reduction of 51% from 2018 levels, which can be seen from Figure 2-1.

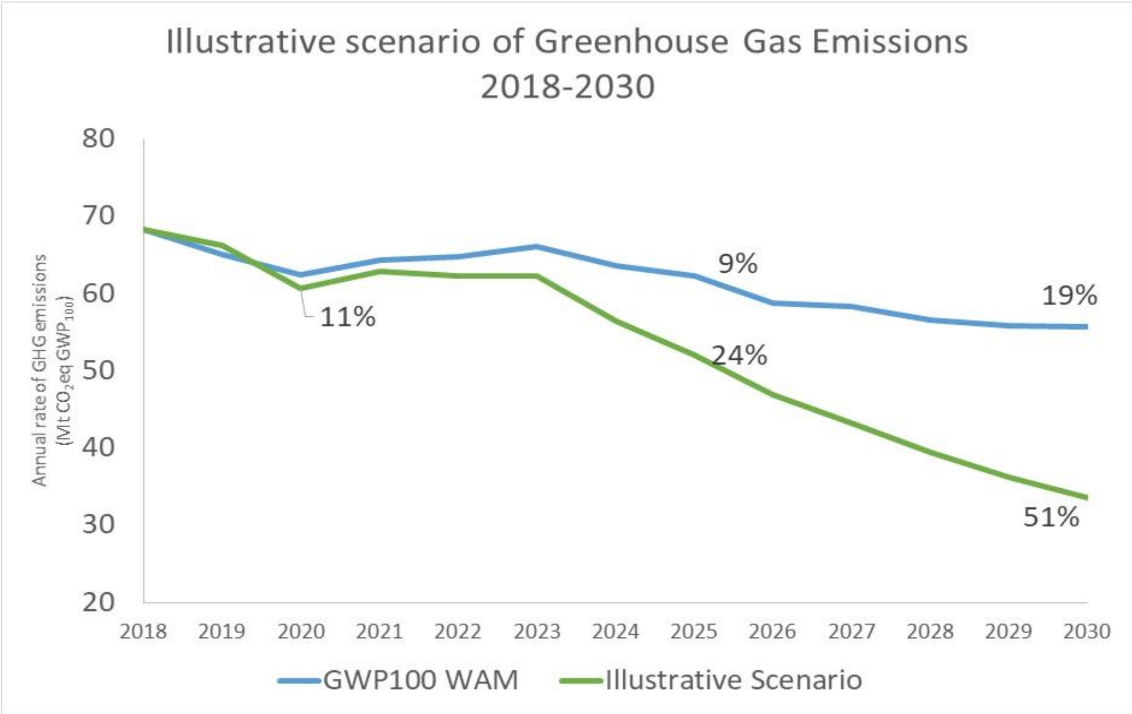


Figure 2-1 The total annual greenhouse gas emissions associated with an illustrative scenario explored for Council, also included for comparison are the emissions Projections for the " With Additional Measures" 2020-2040 from the EPA (2021)

It is necessary to consider how emissions might develop in the period post 2030 in order to establish a basis for proposals for the provisional third carbon budget for the period 2031-2035. In the period after 2030, emissions are constrained to achieve climate neutrality by 2050. Any residual emissions of CO_2 and N_2O (and relevant industrial gases) are balanced by removals. Post 2030, it is assumed that CH_4 emissions are decreasing at a rate of approximately 3% per decade, which is understood to stabilise the impact of those emissions on climate. Figure 2-2 shows cumulative emissions to 2050 for each of the scenarios and a comparison with the current "with additional measures" projection.

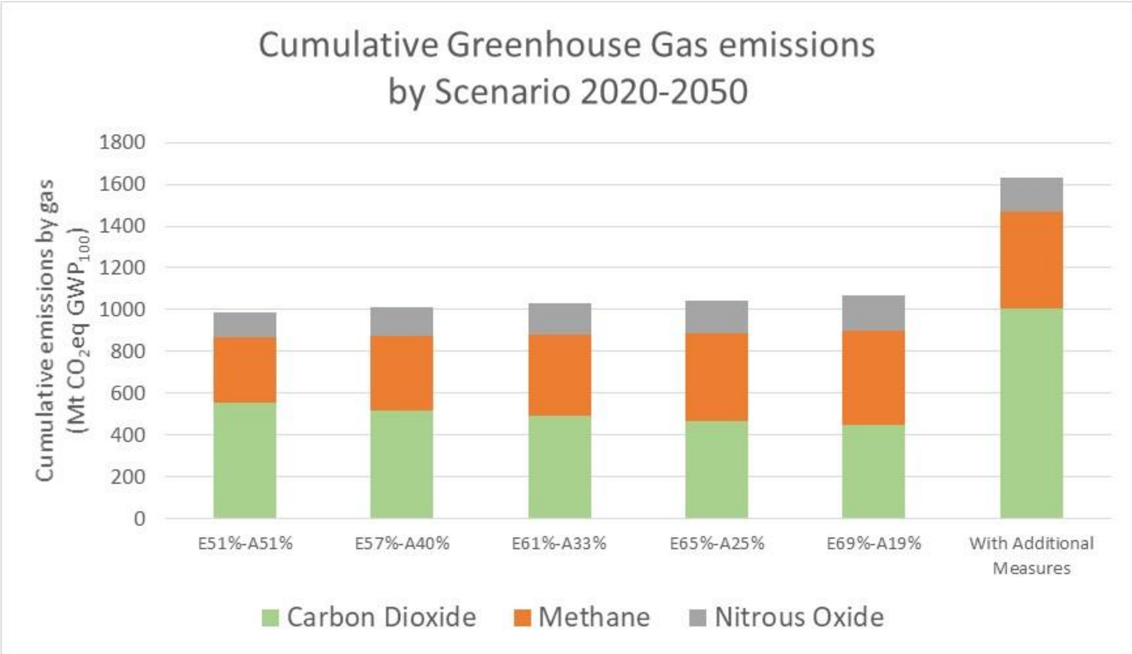


Figure 2-2 Share of cumulative emission by gas on the basis of GWP_{100}, for each illustrative scenarios and the "With Additional Measures" projection from EPA 2021.

In the period after 2030, activities integrated into the TIM model are constrained to achieve net zero emissions by 2050. Figure 2-3 provides an illustrative example of the changes in emissions from each sector modelled by TIM in the period out to 2050. After 2030 emissions of industrial gases are assumed to progress on a linear path to net zero emissions by 2050. Post 2030, emissions of CH_4 and N_2O not included in TIM are assumed to reduce at a rate of 3% per decade. In order to achieve the objective of climate neutrality by 2050, it is assumed that any residual emissions of greenhouse gases which may contribute to warming are balanced by removals. The removals necessary for balancing of residual emissions for activities covered by TIM are shown in Figure 2-4. It is worth noting the residual emissions in 2050 across the TIM Energy sectors are very similar, what differs between scenarios is the pace at which the sector reaches these residual levels of emission.

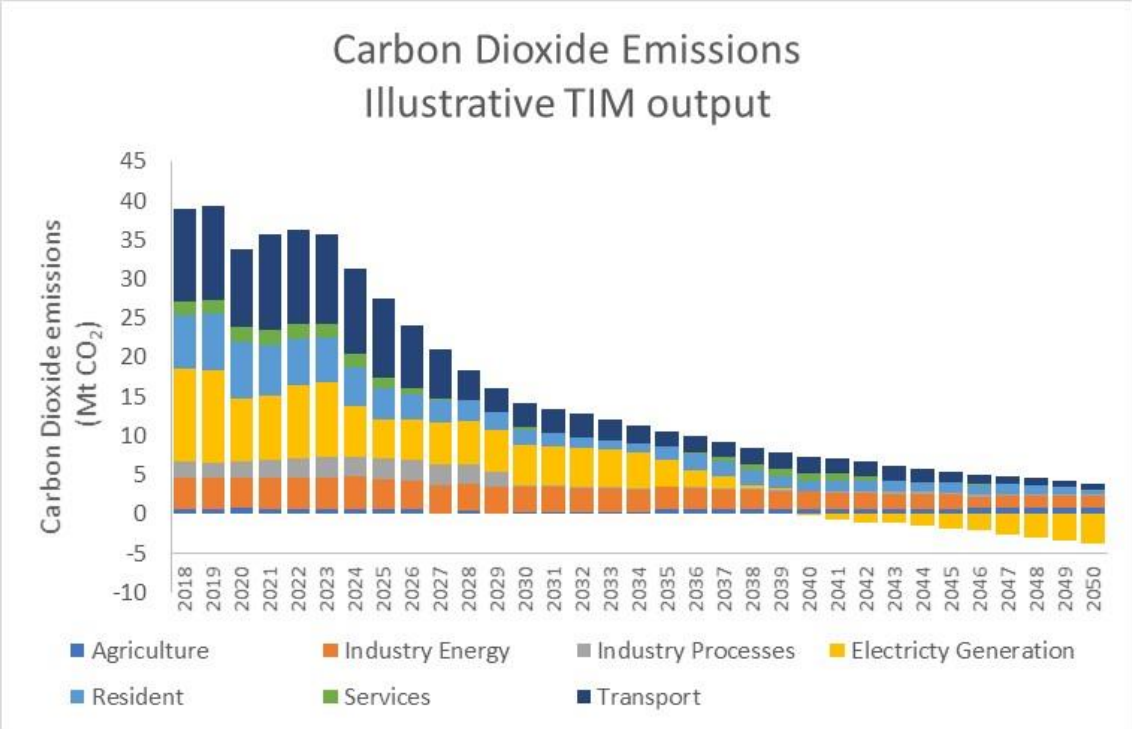


Figure 2-3 Illustrative example of the pattern of emissions reduction and removals deployment in TIM modelling to 2050.

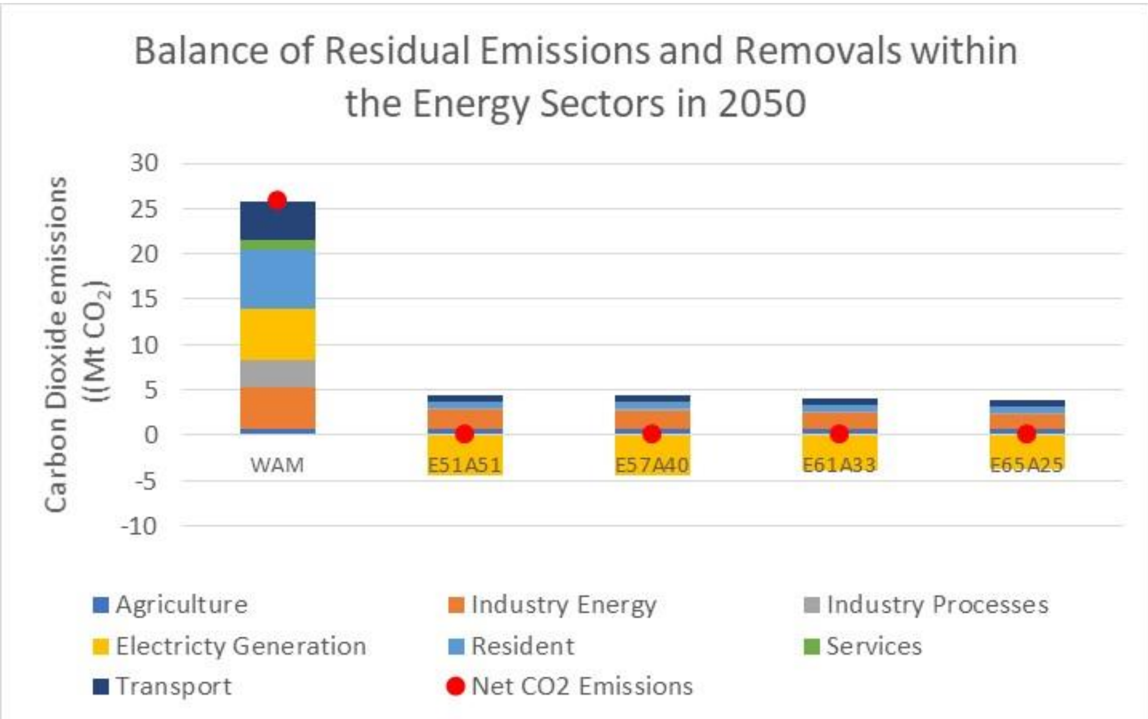


Figure 2-4 TIM model balance between residual emissions and removals with the Energy sector in 2050.

In addition to the core scenarios a set of scenarios was developed to explore the speed and scale of change required across the energy sector to meet the 51% mitigation target, and to discover the potential costs associated with delivering the 51% target at different speeds of reduction. Early action scenarios were modelled as a linear pathway from 2020 to 2030 while late action or ‘no constraint’ scenarios were only constrained to meet the 51% target by 2030. These scenarios are illustrated in Figure 2-5 below.

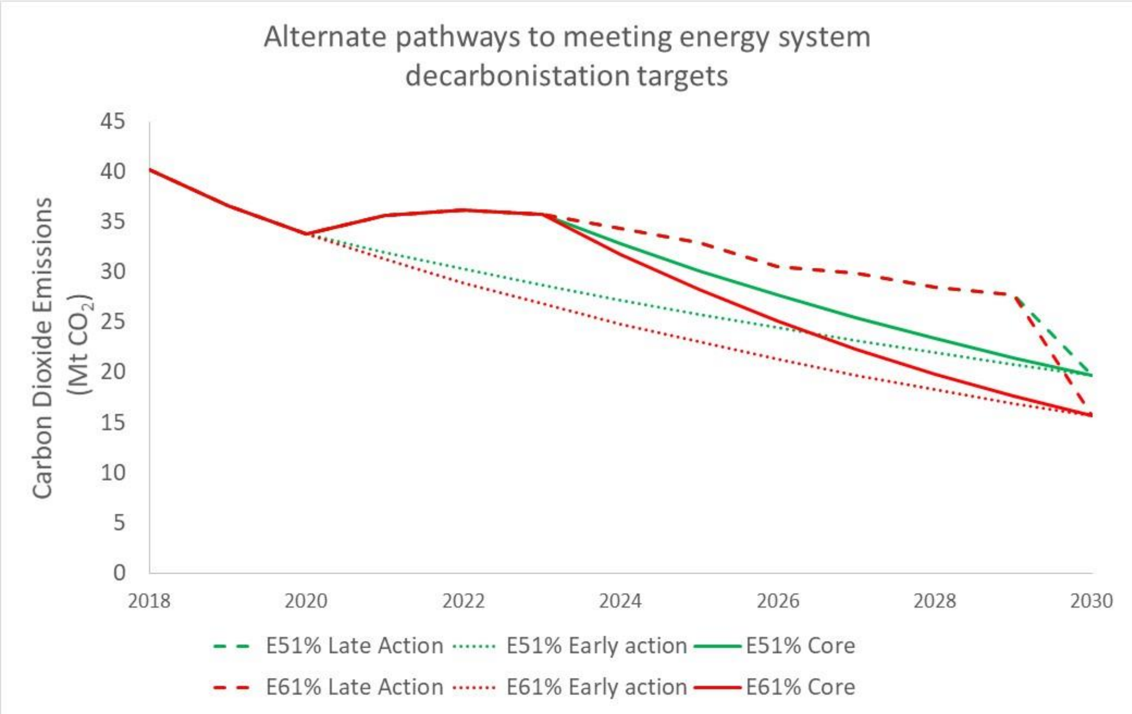


Figure 2-5 Comparison between TIM model outputs for selected core, early action, and no constraint scenarios

The model was unable to find a technological option within the State to meet 51% reductions in the context of late action scenarios. Further, it was considered that the early action scenarios created an unachievable task for the first budget period due to the time already elapsed and the lead in time required for deployment of technologies or changes in behaviour at scale. Notably, the electricity sector requires large scale deployment of enabling infrastructure including offshore wind and grid upgrades to deliver ambitious mitigation. Decarbonisation of the electricity sectors is the foundation for the decarbonisation of other sectors such as heat and transport. The necessary legislation that enables planning and licensing for this kind of development, especially for offshore wind, is yet to be adopted by the Oireachtas. As such within a two-year time frame it is not appropriate to assume significant and immediate reductions in energy emissions.

This further analysis therefore demonstrated that the core scenarios represent the more feasible, cost-effective approaches. Delivering more mitigation in CB1 is not feasible due to technology constraints, while delivering less mitigation in CB1 makes the task of complying with the 51% emission reduction target by 2030 infeasible.

Within the legislation each carbon budget is a five-year cumulative limit to all covered emissions in that period.[28] This allows for interannual variations which can arise for non-policy reasons e.g. a cold winter which may lead to increased emissions from heat demand. Such variations are transient and not indicative of long-term trends and will tend to average out. The 2021 Act has a specific target for a reduction of 51% in emissions in 2030 compared to 2018. The Act importantly does not determine the pathway to meet that 2030 target. For example, the energy modelling shown in this technical report highlights that a linear pathway is technically unrealistic and economically inefficient way to meet this. The proposed 5-year budgets therefore are designed to and would enable the target emissions in 2030 to be met in a manner that is technically feasible and has less impact on society as a whole. However, given that action slowly ramps up across the decade and given the time-lag between policy implementation and actual emissions reductions this requires substantial interventions to start immediately.

A number of sensitivity scenarios were tested to explore the role of technologies and energy sources such as the timing of carbon capture and storage availability, the extent of availability of renewables such as offshore wind, the levels of bioenergy and green hydrogen and the level of energy service demand. Greater availability of energy sources and carbon capture and storage is important but the greatest impact on overall costs of transition was the level of energy service demand (i.e. heat, light, transport) with lower costs seen in a scenario of low energy service demand. Furthermore, greater reliance on electricity as the energy vector for transport and heating, along with growing electricity demand from population growth and data centres illustrates the importance of continuing to push energy efficiency alongside technological (e.g. demand response, system services) and behaviour change as a means to reduce the cost of transition.[29] Continued support for research, demonstration and deployment of key zero emission technologies will also be important.

The modelling showed that there are numerous possible pathways consistent with meeting the 51% emission reduction target. A distinction was noted between the possibility to achieve emissions through technical or behavioural solutions versus situations lacking that possibility where a reduction in activity was required to achieve the emissions reductions.

The scenario pathways for emissions reduction within Agriculture are informed by analysis from Teagasc. The modelling undertaken to explore pathways for LULUCF examined linear and non-linear

[28] The regulation specifies that we include all sectors except international aviation and maritime
[29] The 2021 Eirgrid All Island Generation Capacity Statement suggests an increase in electricity demand of 18% to 43% in its low and high demand scenarios respectively.
Eirgrid and SONI (2021) All-Island Generation Capacity Statement 2021-2030. [online] https://www.eirgridgroup.com/site-files/library/EirGrid/208281-All-Island-Generation-Capacity-Statement-LR13A.pdf

pathways. It was considered that a linear pathway was unfeasible because of the time lag between action and the impact on emissions as well as the difficulty of ramping up activities in a very diverse sector. The analysis of net carbon (see Section 3.1.3) and biodiversity impacts (see Section 3.1.4) shows that afforestation and re-wetting needs to take place on the appropriate land. It will take time to identify these lands at the appropriate scale and implement the measures. Therefore, the assumed pathway for this sector is of mitigation beginning in 2021 and accelerating up to 2030. Actions have already started in reducing emissions, particularly in relation to re-wetting peatlands. The most recent projections for the LULUCF sector indicate the emissions/removals to 2030 are currently on a challenging trajectory for delivering additional mitigation. This assumption is relaxed in the period to 2050, where it is assumed that additional removals within LULUCF can be ramped up along a linear pathway after 2030 until removals balance the residual emission of N_2O, see Figure 2-6. The assumption that LULUCF delivers the removals is made for simplicity and does not preclude the possible deployment of other removal technologies to achieve the same end. Residual emission of N_2O within agriculture is expected to be the dominant driver for the need for removals for non-Energy activities. It is important to note that, this approach, which balances residual emissions against on-going removals, is contingent on implementation of action to ensure reduction in emissions from current land use and ensuring the sequestration required in the long-term.

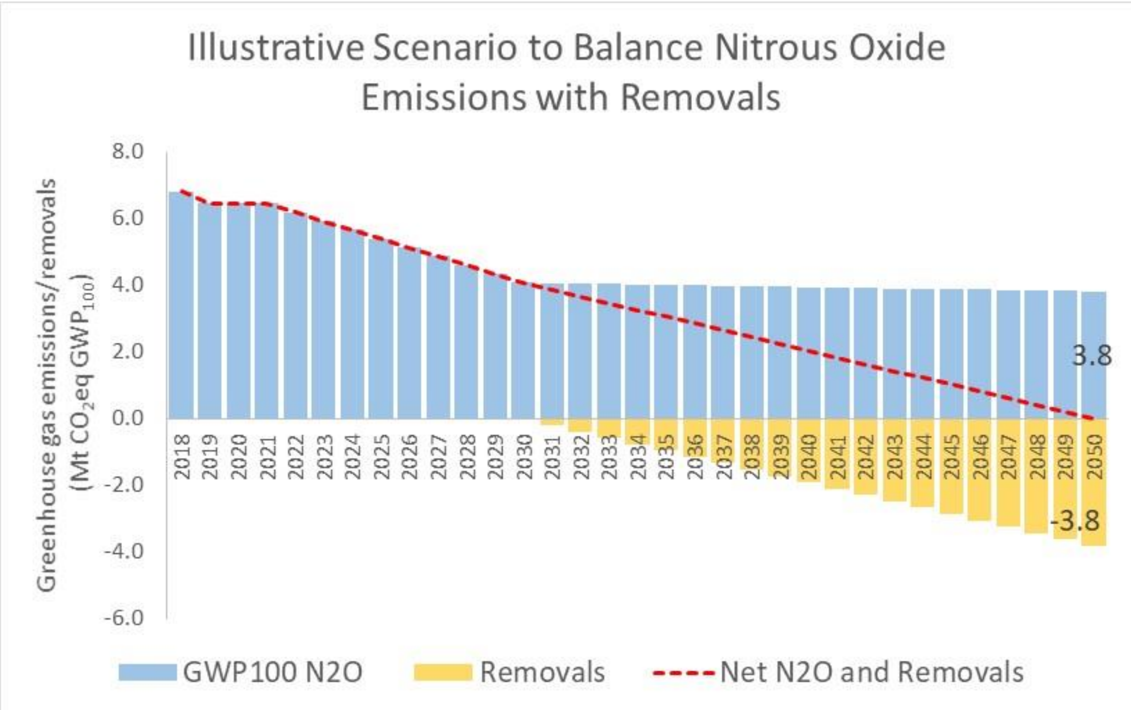


Figure 2-6 Illustrative scenario for Nitrous Oxide emissions and from 2031 ramping up of the capacity for removals to balance emissions by 2050

The Council did not choose a preferred scenario but rather used all scenarios to inform its carbon budget proposals. The emissions associated output from these scenarios are summarised in Table 2-2. While the modelling of Scenarios 1 and 5 provides quantified solutions, the modelling groups communicated serious caveats/reservations as to the practical feasibility of these scenarios. Scenario 1 resulted in costs that were extremely high for the agriculture sector. Scenario 5 resulted in marginal costs of abatement that were extremely high for the energy sector. Both of these scenarios are seen to have ramifications for the broader economy. As noted in Section 4, Scenario 5 may also not be compliant with meeting a national contribution to Paris Agreement goals. Overall, this analysis highlights that while a range of options exist to meet the carbon budget targets it will be necessary for all covered sectors to realise increased ambition.

Given the distinct characteristics of the three main sectors the timing and the rates of emissions reduction to 2030 are not identical. Whilst linear pathways were considered as a starting point for deliberation, changes to these pathways were necessary across each sector. This was largely attributable to the time-lag between making decisions and investments on the one hand, and on the other hand, seeing the emissions reductions come into effect. It should also be recalled that the first year of the first carbon budget period is almost over. Therefore, the Council does not believe that a 7% per annum reduction in the first carbon budget period is appropriate. However, the carbon budget programme for the decade requires immediate action and investment in the first period in order to deliver the accelerated reductions (in excess of 7% per annum) in the second carbon budget period required to meet the 2030 target of a 51% reduction relative to 2018.

Table 2-2 A summary of the core scenarios modelled. Each scenario represents different sharing across sectors with Exx-Ayy representing a scenario where the Energy (heat, transport, electricity) reduces emissions by xx%, while the Agriculture sector reduces by yy%, and LULUCF sectors reduce emissions by 51% (across all scenarios)

Mt GWP100 AR5	**2021-2025 All gases CB1**	**2026-2030 All gases CB2**	**2021-2030 All gases Total**	**2031- 2035 All gases CB3**	**2021-2035 All gases Total**
Scenario 1: E51-A51	295	200	495	148	643
Scenario 2: E57-A40	296	200	496	150	646
Scenario 3: E61-A33	296	200	496	151	647
Scenario 4: E65-A25	297	202	499	152	652
Scenario 5: E69-A19	292	202	494	152	646
Average[30]	**295**	**200**	**496**	**151**	647

Table 2-3 presents the proposed carbon budgets based on the analysis undertaken. Figure 2.7 shows these carbon budget proposals in the context of recent historical emissions and current projections of emissions to 2035. Before finalising these carbon budget proposals an analysis was undertaken of the implications to satisfy that the criteria were met in line with the legislation. This analysis is presented in the following chapters.

Table 2-3 Proposed Carbon Budgets of the Climate Change Advisory Council

	2021-2025 CB1	**2026-2030 CB2**	**2031- 2035 (Provisional) CB3**
	All Gases		
Carbon Budget (Mt CO_2eq)	295	200	151
Annual Average Percentage Change in Emissions	-4.8%	-8.3%	-3.5%
The figures are consistent with emissions in 2018 of 68.3Mt CO_2eq reducing to 33.5Mt CO_2eq in 2030 thus allowing compliance with the 51% emission reduction target.			

[30] Rounding errors may occur in process of calculating averages

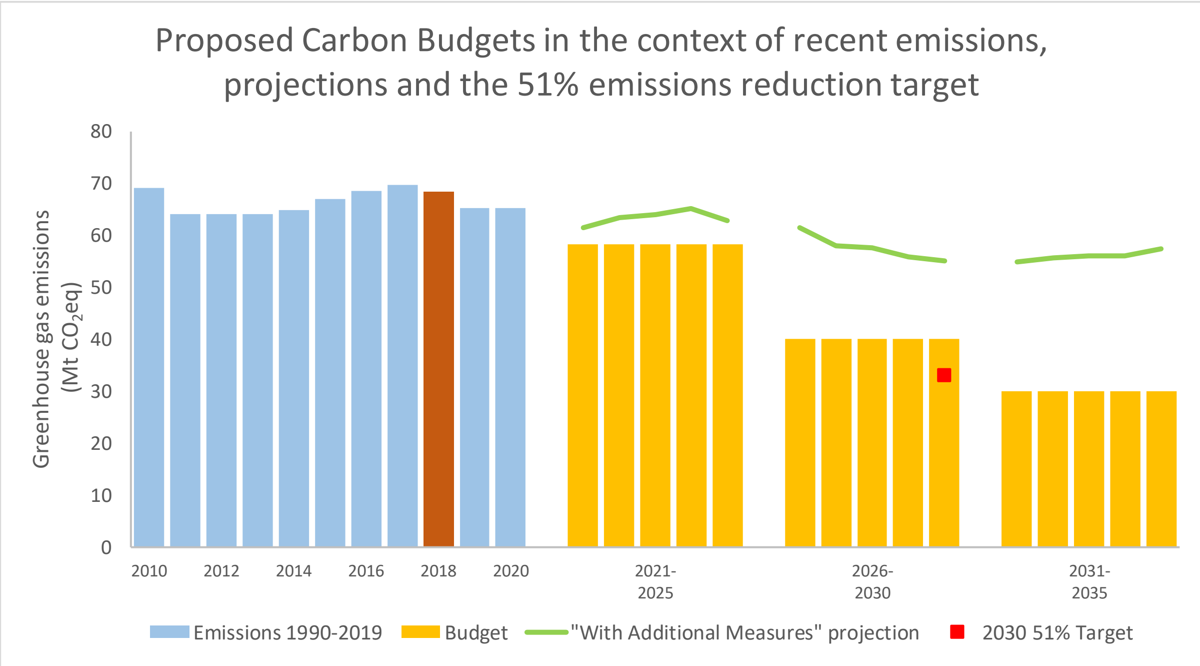


Figure 2-7 The proposed carbon budgets in the context of recent historic emissions, and the "with additional measures" projections of emissions based on implementation of CAP2019 Source EPA 2021.

3 Assessment of the Impacts of Carbon Budgets

Based on the scenarios presented in chapter 2 and building on the results of the modelling, the impacts of the carbon budgets were assessed against the criteria laid out under the legislation. The Council is not responsible for proposing sectoral emissions ceilings, but does point out that the allocation between sectors will have implications for the impacts on society and the economy. As the modelling illustrated the type and magnitude of action that would be required to meet the carbon budgets, it was possible to look at the potential levels of investment required and the impacts on sectors and the wider economy of different scenarios. This additional analysis allowed an initial assessment of the implications of the carbon budgets for employment, investment, competitiveness and climate justice in line with the legislation. The results of this analysis are presented here.

3.1 Implications for Action

3.1.1 Energy

UCC employs the TIMES Ireland Model (TIM) to explore mitigation and energy sector scenarios out to 2050. The TIMES modelling tool is used by many governments and researchers around the world to explore mitigation in the energy sector. Most notably the UK Committee on Climate Change uses the UK TIMES Model (UKTM) to help it develop the carbon budgets for the UK.[31] TIMES is an optimisation model which means that rather than attempting to replicate or predict behaviour and choices, the model instead takes the role of a rational central planner; choosing deployment of (and investment in) technologies and measures in order to meet a given level of energy service demand (for heat, for private car miles, for lighting etc.) at the lowest financial cost while respecting any emission reduction targets or carbon budgets set in a given scenario. More detail on the model is available on the associated website where the functionality of the model and the list of assumptions are detailed and results from multiple scenarios are graphed and available to download. [32]

The modelling demonstrated that significant changes in society and the economy would be required to meet the carbon budgets. Across all scenarios modelled, it is clear that the short time-horizon to

---

[31] Committee on Climate Change (2015) Chapter 3: The cost-effective path to 2050 In: Committee on Climate Change (2015) *The Fifth Carbon Budget – The next step towards a low-carbon economy*. 47-75. UK. [online] https://www.theccc.org.uk/wp-content/uploads/2015/11/Fifth-Carbon-Budget_Ch3_The-Cost-effective-path.pdf

[32] Olexandr Balyk, Andrew Smith, Vahid Aryanpur, Ankita Gaur, Jason McGuire, Xufeng Yue, James Glynn, & Hannah Daly. (2021). Carbon Budget Scenarios for Ireland's Energy System, 2021-50 (v1.0) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.5517363
Energy Policy & Modelling Group (EPMG) (2021) Carbon Budget Scenarios for Ireland. [online] https://tim-carbon-budgets-2021.netlify.app/results

2030 requires a faster energy system transition than the natural renewal of many technologies, so early retirement will be needed in some cases. Overall, use of fossil fuel falls from 90% of primary energy demand in 2018 to 49-54% in 2030.

The carbon budget scenarios for the energy sector suggest a need to maximise the electrification of cars and vans with an associated requirement for expansion of charging infrastructure. The scenarios see a range of between 600,000 to 1,500,000 battery electric vehicles by 2030 to meet targets along with 130,000 battery EV vans. The more ambitious scenarios for the energy sector would effectively mean all new car registrations would have to be battery electric vehicles before 2030 with significant early scrappage of ICE vehicles. Additional biofuel blending will also be necessary. A reduction in transport demand and mode switching from private car transport to public and active transport could reduce the costs of transition as well as having important co-benefits related to improving health and easing congestion. Land use planning and public transport infrastructure would have an important role to play in this.

The modelling suggests a complete removal of coal and peat for residential heating and up to 600,000 retrofits between 2020 and 2030. For reference the recently published Housing for All Strategy committed to the retrofit of 500,000 houses to B2 or cost optimal standard by 2030, of which 35,000 would be houses owned by local authorities[33]. This would mean an 80% reduction in kerosene use and large scale electrification for home heating. Heat pumps or electrification are also foreseen for space heating in the commercial sector. District heating can be an important pathway for residential heating in urban areas. The modelling also foresees fuel switching for industrial heat and emissions savings in the cement sector from carbon capture and storage in the period to 2030.

The requirement for electrification in transport and heat leads to a significant increase in electricity generation and installed capacity in all scenarios. The scenarios see approximately 7GW installed capacity of onshore wind in 2030. Natural gas remains on the grid as a significant source of electricity in all scenarios. Levels of offshore wind vary under the scenarios from 1.6GW up to a maximum of approximately 7GW installed capacity depending mostly on electricity demand levels. Demand management, particularly through energy efficiency measures will be crucial to control costs. The additional demands on the electricity system from the electrification of transport and heat will lead to requirements for grid reinforcement. Abundant clean electricity is crucial to

[33] Department of Housing, Local Government and Heritage (2021) Chapter 5. Supporting the Four Pathways: Enabling a Sustainable Housing System In: *Housing for All – a New Housing Plan for Ireland*. [online] https://assets.gov.ie/197162/b407f940-db3e-44dd-b4aa-4cca97c3b397.pdf

underpin the achievement of the carbon budgets and the 51% target. Almost every sector relies on an increasing supply of it to decarbonise.

3.1.2 Agriculture

A range of agricultural emission reduction scenarios were explored using the Teagasc FAPRI-Ireland model. These are set out in Table 3-1. Scenarios A, C, D and E were undertaken initially at the request of the Department of Agriculture, Food and the Marine (DAFM) and this set of scenarios was augmented by the preparation of the Teagasc FAPRI-Ireland Scenario F. A scenario that explored the impact of a stabilised dairy herd was also undertaken for DAFM (Scenario B) and presented at a meeting of the Carbon Budget Committee. The scenarios in Table 3-1 correspond closely, but do not exactly map to, the scenarios examined by the UCC TIM.

Modelling analysis in energy and agriculture generally tends to focus on the potential impact on existing systems and practices, however, it should be noted that opportunities for diversification of agricultural income streams and activities will emerge as a part of transition and development of the broader green and circular economy, including forestry, renewable energy and niche premium market development. While some diversification opportunities are emerging, it will be critical to explore their scalability, to develop these more fully and to offer supports to enable such transitions. It will also be important to consider the risk to soil carbon stocks and sinks in any land-use change.

Emissions reductions in agriculture can be achieved when farmers adopt actions to reduce emissions which have been identified through Teagasc research. The following actions are included in the scenarios modelled;

a) Accelerated gains in the genetic merit of dairy cows (as measured by the Dairy EBI),
b) Improved beef genetics (maternal traits and liveweight gain),
c) extended grazing,
d) improved nitrogen (N) use efficiency,
e) clover inclusion in forage,
f) altered fertilizer formulation,
g) improved animal health,
h) altered crude protein in pig diets,
i) altered slurry spreading techniques,
j) Use of slurry amendments during storage,
k) use of sexed semen,
l) pasture nutrient management (optimising pH, fertilisation, etc.),

m) cover crops and straw incorporation in tillage

The range of actions to be deployed to reduce emissions is large however the scope to mitigate emissions of methane are likely to particularly challenging over the first two carbon budget periods. In 2018 Teagasc identified 25 measures to reduce agricultural and land GHG emissions[34] and further actions are currently being explored in ongoing Teagasc research programmes. The implementation of these actions as well as those currently under development will require support from Government and the agri-food industry. The reflection of all of these measures within the emissions inventories prepared by the EPA will also represent a very significant challenge.

Table 3-1 Agricultural GHG emissions reduction scenarios analysed using the Teagasc FAPRI-Ireland Model

	Change in Agricultural Emissions vs 2018 (with all MACC/Ag Climatise Measures implemented)
Scenario A: Business as Usual (BAU)	-17%
Scenario C	-20%
Scenario D	-33%
Scenario E	-40%
Scenario F	-55%

Within the scenarios prepared for the Carbon Budget Committee, agricultural emissions are not offset by sequestration actions provided by the Land Use, Land Use Change and Forestry (LULUCF) category. This aligns with current EPA National Emissions Projections which project the LULUCF sector being an overall source in 2030.

The analysis of the impact of possible carbon budgets for Irish agriculture used the Teagasc FAPRI-Ireland model to simulate a Business as Usual (BAU) scenario, which includes implementation of mitigation measures identified in the Climate Action Plan 2019, and alternative scenarios wherein the agricultural emissions reduced by predetermined amounts relative to the 2018 Base level. The reductions in agricultural emissions within each of the scenarios were the product of the mitigation delivered by the measures outlined in the Teagasc Marginal Abatement Cost Curve (MACC) report and DAFM Ag Climatise report and reductions in agricultural activity levels.

Given that 85% of Ireland's agricultural GHG emissions are associated directly or indirectly with bovine agriculture, changes in agricultural emissions over and above those delivered by mitigation measures are driven by changes in bovine agricultural activity levels. Bovine activity levels are fundamentally determined by developments in the dairy cow and other (aka suckler) cow breeding

[34] Lanigan, G.J. and Donnellan, T. (2018) An Analysis of Abatement Potential of Greenhouse Gas Emissions in Irish Agriculture 2021-2030. Teagasc, Carlow. [online] https://t-stor.teagasc.ie/handle/11019/2092

inventories. The alternative scenarios analysed by Teagasc altered the economic incentives to which farmers of dairy and other cows respond within the Teagasc FAPRI-Ireland partial equilibrium model of the Irish agricultural economy. Within the Teagasc FAPRI-Ireland model progressively larger negative subsidies were introduced so as to “engineer” a reduction in the volume of bovine agricultural activity required to lower agricultural emissions to target levels determined by the carbon budget scenarios.

The BAU projection of agricultural activity levels is the same as that provided to the EPA by Teagasc. These BAU projections (conditional forecasts) provide the agricultural activity basis of the projections of agricultural GHG emissions published by the EPA (EPA, 2021). The projections are conditional on projections of medium-term EU and world price developments and developments in the Irish, EU and Global economy. These exogenous economic drivers are assumed to not change between the BAU scenario run of the Teagasc FAPRI-Ireland model and the alternative carbon budget scenarios.

The BAU scenario shows the anticipated level of emissions in the absence of policy and other actions to reduce GHG emissions. It suggests that increased dairy activity would largely be offset by reductions elsewhere in the bovine sector, leaving the total cattle population largely unchanged in the period to 2030. GHG emissions would increase in the short term before declining slightly towards the end of the decade reflecting the changing breed composition of the Irish bovine inventory.

The alternative scenarios modelled using the Teagasc FAPRI-Ireland model illustrate the impact of a GHG emissions reduction. As noted above some of the decline in emissions arises from the implementation of mitigation measures. As in the energy system scenarios analysed using the UCC TIM, technological and biological constraints limit the scope for emissions mitigation that is feasible in the medium term. Most of the reduction in agricultural GHG emissions, particularly in Scenarios D, E and F arise from reductions in bovine agricultural activity levels. With reductions in beef and dairy activity levels, unless other income streams are developed, agricultural output value and agricultural sector income are also reduced. The more ambitious the agricultural GHG emissions reductions scenarios considered, the larger the negative impact on agricultural output value and on agricultural sector income. The acceleration of technology development leading to additional mitigation possibilities and increasing the rate of technology adoption could help to avoid the need for a reduction in bovine agriculture activity levels. Teagasc (and other researchers) are investigating a range of technologies that could deliver additional mitigation in the future, but which still require further development before deployment.

Projections for the Dairy and Other (suckler) cow inventory vary widely under the set of 4 increasingly ambitious agricultural GHG reduction targets implied by the carbon budget scenarios. The larger the reduction in agricultural GHG, the larger the reduction in activity levels within the dairy and beef sectors. Under the Carbon Budget Scenarios where agricultural GHG are required to reduce by 30% or more, suckler cow inventories decline from just above 1 million head in 2018 to circa 200,000 head by 2030. There is a larger spread in the magnitude of the reduction required in dairy cow numbers across the scenarios analysed. To achieve a 51% reduction in agricultural GHG emissions (to be approximately pro rata with Energy System emissions reductions of 51%) requires that dairy cow numbers are reduced to circa 650k head by 2030 compared to just over 1.4m head in 2018 and a BAU level of over 1.6m head (see Figure 3-1). Less ambitious agricultural GHG reduction targets such as in Scenario D where agricultural GHG fall by 33% required dairy cow inventories to reduce to circa 1.2m head. The spread in the range of reductions required in the dairy and suckler herds in response to the different scenarios is not prescriptive, rather it illustrates that different combinations of reductions in dairy and suckler numbers could deliver the emissions reductions in the various scenarios.

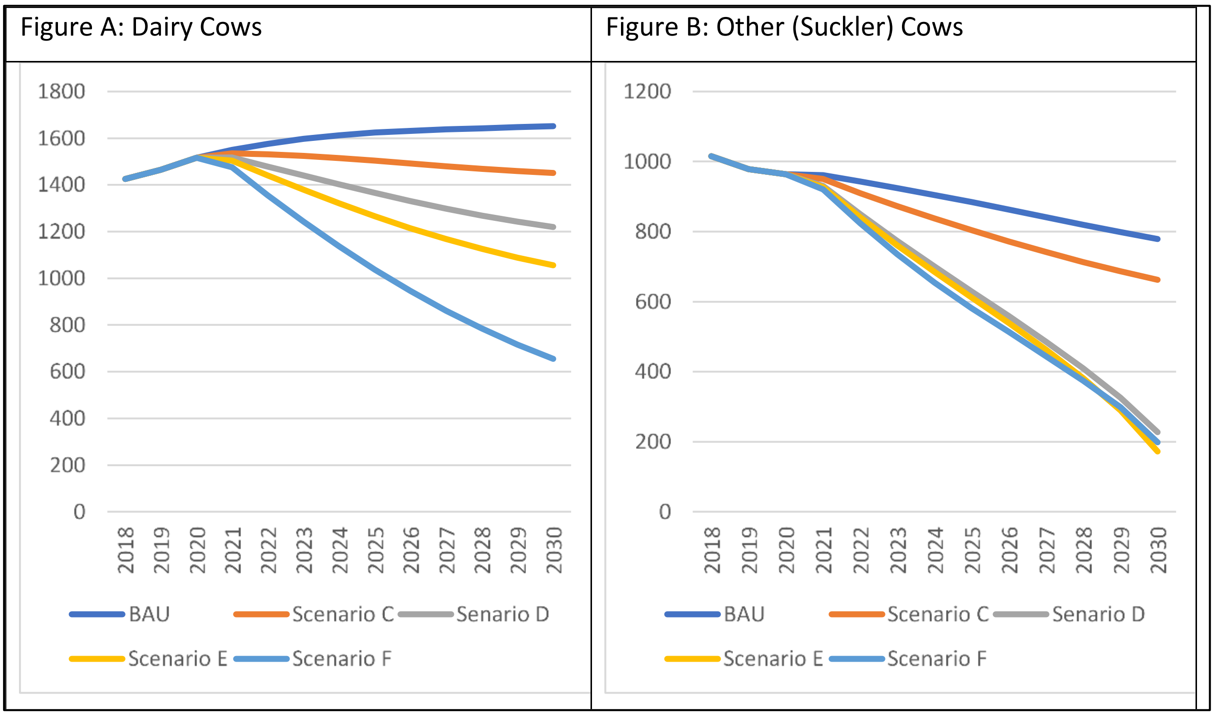


Figure 3-1 Teagasc FAPRI – Ireland modelling of projected animal numbers under different scenarios. (Source: Teagasc, 2021)

Teagasc analysis of the agricultural GHG reduction scenarios led to the conclusions that

- Only relatively small reductions in agricultural GHG emissions can be achieved by currently proven technical mitigation alone and that under all scenarios analysed these alone are insufficient to leave Agriculture within any of the core carbon budget scenarios considered.
- Progressively larger reductions in agricultural GHG emissions require both actions to achieve technical mitigation and actions to reduce livestock agricultural activity with reductions in beef and/or dairy activity contributing increasing shares of the reduction in agricultural GHG across the progressively more ambitious carbon budget scenarios.

3.1.3 Land use, Land use Change and Forestry

In the most recent EPA inventory, LULUCF was a net source of 4.8Mt CO_2eq in 2018. The most recent projections published by the EPA for LULUCF indicate that, with current policies and measures, net emissions for the sector will increase from 4.5 Mt CO_2eq in 2019 to 7.1Mt CO_2eq in 2030. In order for net emissions for LULUCF to achieve a 51% reduction, this projected trend in sectoral emissions will need to be reversed. In section 3.1.3.2, the options to achieve a 51% reduction by 2030 in the emissions from LULUCF were examined based on modelling work from Teagasc and University of Limerick (UL). The UL Goblin model was used to estimate the amounts of afforestation and rewetting that would be required to get this 51% reduction, while the Teagasc modelling examined the mitigation potential of a number of other options. [35] The 51% reduction target is in line with the overall economy wide reduction required by the Amendment Act (2021). [36] If a different sectoral target for LULUCF was applied by the Government, this would require more or less afforestation, rewetting, etc to reach the target.

Grassland is the largest net source of emissions within the LULUCF sector, estimated at 7.0Mt CO_2eq, in 2018. The main source of emissions is the drainage of an estimated 337kha of organic soils, which emit 8.3Mt CO_2eq. This is partially balanced by a reported removal by mineral soils of 2.0Mt CO_2. The illustrative scenario shown in Figure 3 1 assumes rewetting of over 110,000 hectares of drainage organic soils, see Table 3 2. This illustrates the scale of the challenge.

Wetlands are also a net source of emissions within the LULUCF sector, estimated at 2.5Mt CO_2eq, in 2018. The main source of emissions is the drainage of an estimated 75.6kha of peatland for peat

[35] Donnellan and Lanigan (2021) https://www.climatecouncil.ie/. Forthcoming.

[36] Excluding International Aviation and Maritime emissions

extraction. The illustrative scenario assumes 90% of peatlands currently used for peat extraction are rewetted.

The Forest Land category was reported as a net removal of 4.0Mt CO_2eq in 2018. Forest Land is projected to switch from a net removal to a net source of emission in the period to 2030. This is due to a legacy of high afforestation rates in the 1980's and 1990's coupled with a failure to achieve targeted afforested rates in recent decades.

The Harvested wood products category was reported as a net removal of 0.8Mt CO_2eq in 2018. The magnitude of the removal is related to the volume of wood harvested and the end-product derived from this wood. Processing of wood into durable products extends the time over which the carbon absorbed by the trees is taken out of the atmosphere. It is an important aspect of material substitution and sustainable resource management. It is projected that HWP removals will increase over the period to 2030.

The National Inventory undergoes continual update and revisions to take account of improved scientific understanding and improved activity data. Normally, these changes are marginal. However, there is large uncertainty in estimates of emissions and removals in the LULUCF sector and recent research suggests that significant changes in the inventory will be implemented in the coming years. For example, the EPA is considering the findings from a recent study of the impact of the afforestation of peatlands in Ireland. The research suggests that the loss of carbon from drained organic soils under forestry has been underestimated, and by extension the removals associated with these forest areas have been overestimated. 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).

3.1.3.1 LULUCF Accounting: Moving from Net-net to gross-net accounting

Very large differences in net sequestration outcomes from LULUCF activities are associated with the use of different accounting approaches. The current system for LULUCF accounting, the net-net accounting system expresses emissions and removals relative to a baseline or reference period. [37] Conversely, the gross-net accounting system encompasses the full suite of emissions associated with a given emissions category. This is the accounting approach for carbon budgets mandated under Regulation 531.2021. The EU has proposed that the LULUCF sector transition to a gross-net system in order to simplify the accounting system, enhance the environmental integrity and eventually merge

[37] Hanrahan, Donnellan and Lanigan (2021) https://www.climatecouncil.ie/. Forthcoming.

LULUCF with agriculture into a single AFOLU sector and the modelling in the next section (3.1.3.2) is on the basis of the gross-net accounting system.

Under the net-net accounting system LULUCF is projected to be a carbon sink of -17.5 MtCO_2eq and -11.85 MtCO_2eq respectively for Carbon Budget 1 and Carbon Budget 2. Under a business as usual (BAU) scenario and the gross-net accounting system, the LULUCF sector is projected to be a carbon source of +29.5 Mt CO_2eq and +32.3 Mt CO_2eq respectively for Carbon Budget 1 and Carbon Budget 2. The large discrepancy is mainly due to the fact that under the 'net-net' system, the majority of emissions from managed organic soils are incorporated into the baseline, so that only emissions or removals that are additional relative to that baseline are counted.

Using revised projections (incorporating higher emissions factors for forestry on organic soils as discussed above) the whole LULUCF sector is projected to be a larger carbon source for the commitment period in the absence of corrective measures (+45.6 Mt CO_2eq and +52.6 Mt CO_2eq for Carbon Budgets 1 and 2 respectively). This is due to forestry being a small carbon sink for Carbon Budget 1 of -4.2 MtCO_2eq but a carbon source of +4.9 MtCO_2eq in Carbon Budget 2.

3.1.3.2 Analysis of pathways to 2030

As discussed in the introduction to section 3.1.3, the most recent projections published by the EPA for LULUCF indicate that, with current policies and measures, net emissions for the sector will increase from 4.5 Mt CO2eq in 2019 to 7.1Mt CO2eq in 2030. In order for net emissions for LULUCF to achieve a 51% reduction, this projected trend in sectoral emissions will need to be reversed. For instance, this would mean moving from a current annual afforestation rate of approximately 2,500ha per annum with an accelerated ramp up beginning immediately, reaching 20,000ha per annum in 2028 and continuing thereafter up to 2050 with attention needing to be paid to the potentially significant impact on biodiversity and water quality.

In the carbon budgets the Council has assumed a 51% emissions reduction in the LULUCF sector in the period to 2030. This assumption of a 51% reduction in these emissions was employed in order to simplify the aggregation of total carbon budgets across all sectors including LULUCF. This does not imply that the Council endorses this scenario as the optimal reduction pathway for the sector. Inclusion of LULUCF in the budgets occurred late in the process of agreeing carbon budget proposals and further work is required to ascertain optimal pathways and robustly assess feasibility. The 51% reduction implies net emissions of 2.4Mt CO_2eq in 2030. If this were not achievable then remaining sectors would require additional emissions reductions ambition.

Options exist across all land use categories to reduce emissions and enhance removals. Independent analysis from the Sequester project and Teagasc suggest multiple pathways exist for achieving 51% emissions reduction within the LULUCF sector to 2030 on a gross-net basis. Emissions reductions of 51% within the LULUCF sector while very challenging are possible. These pathways, involving significant implementation of rewetting of peatlands, improved management of mineral and organic soils under grasslands, cropland management, increased afforestation will require action by Government that effectively encourages the identified land use actions.

The SeQUEsTER project team in University of Limerick were asked to explore the role of emissions and mitigation in land use in achieving climate neutrality targets for 2050, and how these align with carbon budgets, using the GOBLIN model. The modelling is not intended to recommend sector-specific targets, but to inform deliberation on implications for national and EU legislative compliance, LULUCF accounting, carbon budget feasibility, competitiveness, investment and employment. In this context, there remains considerable uncertainty around emissions and emission removals by agriculture, LULUCF and the combined Agriculture, Forestry and Other Land Use (AFOLU) sectors.

An illustrative scenario involving land use change and change in land management consistent with a 51% reduction by 2030 in net emissions in LULUCF using UL GOBLIN model is shown in Figure 3-2 and Table 3.2. Based on this scenario, the cumulative emissions for the two carbon budget periods, consistent with a reduction of 51% in net emissions are shown in Table 3.3.

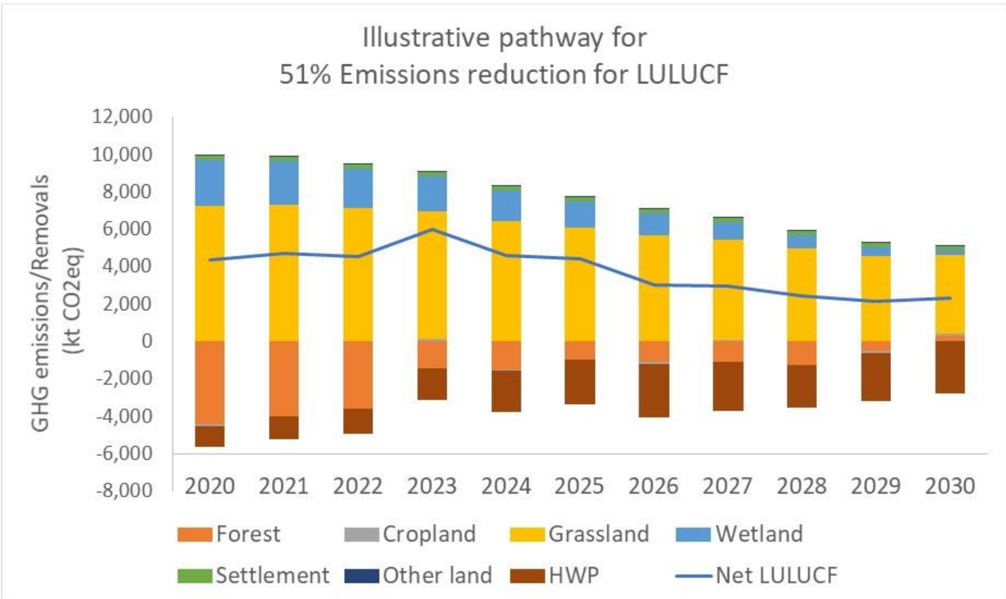


Figure 3-2 Illustrative pathway towards a 51% emissions reduction LULUCF by 2030, relative to 2018, using Goblin model outputs.

Table 3-2 Illustrative Scenario area of land use change or change in land management consistent with a 51% reduction in net emissions in LULUCF using UL GOBLIN model*

Illustrative Scenario Area of land use change or Change in land management			
51% Goblin	2021-2025	2026-2030	Cumulative 2021-2030
Afforestation (ha)	46,500	92,500	139,000
Grassland re-wetting (ha)	43,601	69,000	112,601
Peatland rewetting (ha)	27,839	34,798	62,637
* Other options (such as improved management of mineral and organic soils under grasslands, and cropland management) which were not included in this modelling would reduce the amount of afforestation and rewetting required to achieve the assumed 51% reduction target.			

Table 3-3 Cumulative emissions over the carbon budget periods on the basis of the Illustrative Scenario shown in Figure 3-2

Period	**2021-2025**	**2026-2030**	**Cumulative 2021-2030**		**2018**	**2030**	**% reduction**
51% LULUCF (Mt CO_2eq)	24	13	37		4.8	2.4	51.0%

In addition, to the impact of the measures analysed using the GOBLIN model (Table 3-2) the adoption of other agricultural management measures could contribute to sectoral emission abatement. Teagasc in conjunction with FERS Ltd have estimated that better management of 450,000 ha of mineral grassland soils as well as increased cover cropping and straw incorporation on 100,000 to 150,000 ha could deliver up to 0.45 Mt CO_2eq per annum.

The rewetting of grasslands in particular will have an impact on their use in agriculture and the spatial concentration of these soils types in certain regions will have potential implications for rural development. Currently Teagasc research finds that approximately 40% of organic grasslands are farmed under specialised cattle systems, 30% are farmed by specialised sheep production systems, 25% by dairy farm systems with the remainder in tillage production. On average cattle and sheep production systems are already relatively low intensity systems and with management of the water table and other management interventions agricultural activity could continue on rewetted land albeit at likely lower levels of intensity. The Teagasc National Farm Survey has consistently shown that most income on Irish dry-stock[38] farms is made up of payments under Pillars I and II of the Common Agricultural Policy (CAP). Continuing these payments, if that land was rewetted, and ensuring it remained eligible for CAP payments would be important to minimise the negative income impacts for most farmers with rewetted land. For more intensively farmed land on organic soils under dairy and tillage production systems rewetting would more significantly curtail their current land use practices and the income losses could be significant.

[38] These relate to the non-breeding beef farm enterprises

Ongoing research is focusing on how such lands can be farmed. Policy will have to consider compensating farmers and land owners for the income foregone from land rewetting.

The transformation of Ireland's landscape has potential important impacts on biodiversity, these are discussed in more detailed in section 3.1.4 stressing the importance of an integrated approach to land use planning that takes explicit account of the impact of different land use measures on biodiversity and does this at a spatially meaningful scale.

In addition, the scale of change will require a strong level of social acceptance especially with respect to re-wetting of peatlands and grasslands as well as afforestation. There will be a need for public and community engagement to ensure robust policy design and successful implementation of measures. Regions with high concentration of peatlands and organic grassland that would be rewetted (for example the midlands) would require advanced planning, including a hydrological assessment, and targeted measures including open dialogue with impacted communities, support measures including retraining, reskilling and entrepreneurial activities, and for farmers, support for sustainability measures that could be applied and alternative income sources.

The analysis of different scenarios suggests significant changes in the use and management of current grasslands, and to a lesser extent, croplands, would not support the same level of agriculture activity. This implies a reduction in agricultural output with potential loss of income, the implications of which are explored in section 3.2.2. This could be addressed through appropriate supports and market development. In the longer term, afforestation involves the exchange of agricultural output for forestry output. The overall impact on income will be determined by the specific circumstances at farm level and the range of options available. Coherent and targeted land use policies which recognise this complexity will be required.

3.1.3.3 Scenarios for Land Use to 2050

Significant afforestation will be necessary to achieve climate neutrality by 2050. This will contribute important removals to balance residual emissions in achieving the transition to a low carbon economy. The scale of afforestation required demands urgent action in the period to 2030.

For simplicity, the modelling did not consider any requirement to balance on-going methane emissions with removals, as it is assumed that the rate of methane emissions will, at a minimum, be managed in a manner consistent with the stabilisation of the climate response to methane emissions.

Figure 3-3 displays the simple balance of emissions and removals (excluding CH_4) across agriculture, organic soils under grassland, wetlands and forestry associated with climate neutrality in AFOLU in

2050. Indicative scenarios are based on forestry removals needed to exactly balance residual emissions from AFOLU sources. Scenarios considered included where agriculture emissions are reduced by 25% (Ag-25) to 75% (Ag-75), whilst all exploited wetlands are rewetted and 25-75% (R-25 to R-75) of organic soils under grassland are rewetted. This mix of scenarios offer insight to illustrate interactions and trade-offs across activities. Total removals required range from 3.8 to 11.4 Mt CO_2eq. annually, for Ag-75,R-75 to Ag-25, R-25 respectively. See Chapter 6 for greater detail on this analysis.

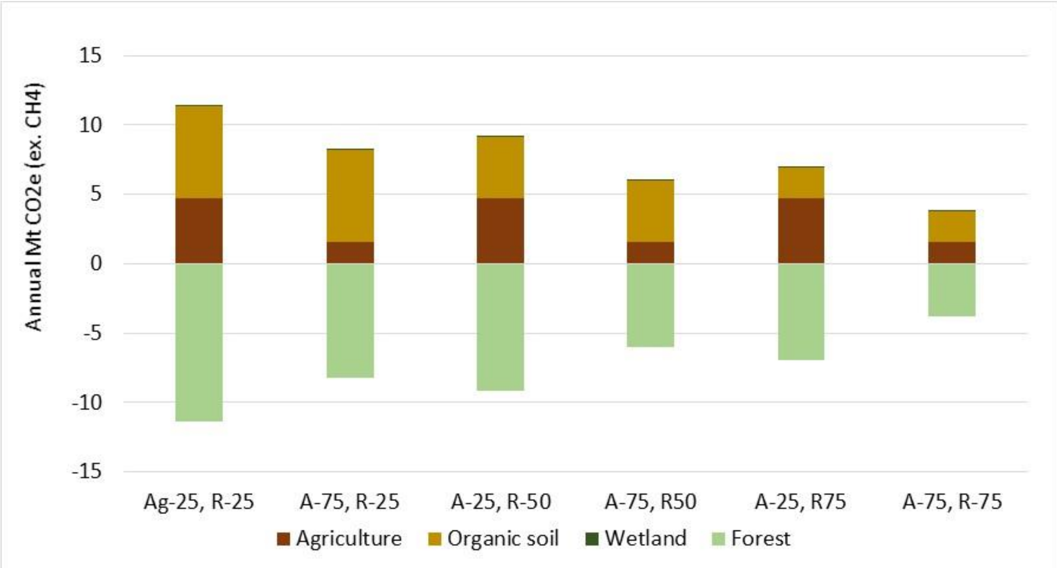


Figure 3-3 Combinations of CO_2 equivalent (excluding CH_4) emissions and removals in 2050 across agriculture, organic soils under grass, wetlands and forestry compatible with climate neutrality in the AFOLU sector

Climate neutrality will require simultaneous high levels of ambition across agriculture, agricultural land management, organic soil rewetting and afforestation. Forestry is the primary, scalable CO_2 removal measure in the near term for Ireland – and will therefore be required to offset any residual AFOLU emissions in order to achieve climate neutrality in the sector. However, afforestation needs to be properly planned to ensure it does not result in unintended emissions or negatively impact biodiversity or water quality and should not, for example, be undertaken on peatlands which would turn a present-day carbon sink into a future carbon source.

Depending on the level of ambition in mitigation of AFOLU emission sources in the period to 2050, AFOLU climate neutrality is likely to require sustained average rewetting rates for organic soils under grassland of over 8 kha per year, and sustained average afforestation rates somewhere between

13kha and 33 kha per year, considerably higher than the Ag Climatise[39] target of 8 kha/yr, and over 4 times higher than has been achieved in recent years. There is a considerable time-lag between forest planting and increased rates of CO_2 removal. Nevertheless, actions which achieve high levels of rewetting and afforestation in the next decade are urgently required to realise benefits in due course. Timely forest planting will be imperative to provide “headroom” for agricultural activities and residual organic soil emissions within the envelope of AFOLU climate neutrality by 2050. However it is imperative that afforestation is carefully implemented and is appropriate both in terms of species mix and location.

Harvested wood product (HWP) carbon storage, future bioenergy carbon capture & storage (BECCS) and product substitution from cascading wood value chains have been excluded from the current analysis. Recent work has shown these processes have the potential to more than double net GHG mitigation compared with terrestrial carbon storage alone over a 100-yr period of two commercial forest rotations[40] . The indicative commercial forestry scenarios explored here could therefore support long-term climate neutrality across the wider Irish economy, generating significant new (bio)economic activities & employment.

GHG mitigation and carbon sequestration activities in the AFOLU sector will be integral to Ireland’s transition towards climate neutrality, presenting opportunities for farmers to diversify income via, inter alia, carbon farming and commercial forestry.

3.1.4 Biodiversity

Biodiversity is under serious pressure in Ireland. Additional negative biodiversity impacts cannot be absorbed. Therefore, actions to mitigate climate change must avoiding putting additional pressure on vulnerable ecosystems.

The impacts of climate measures on biodiversity are context dependent. This requires assessment on a case by case basis to determine how to implement “the right action in the right place”. Changes in land management, particularly drainage, to facilitate expansion of livestock farming may be bad for carbon, water and biodiversity.

Analysis suggests that it is possible to implement carbon budgets while protecting and enhancing biodiversity. Care must be taken to identify and implement policy ‘win-wins’ to achieve this with

[39] Department of Agriculture, Food and Marine (2021) Ag Climatise – A Roadmap towards Climate Neutrality. [online] gov.ie - Ag Climatise - A Roadmap towards Climate Neutrality (www.gov.ie)
[40] Forster et al. (2021) Commercial afforestation can deliver effective climate change mitigation under multiple decarbonization pathways. *Nature Communications*, 12(3831). [online] https://www.nature.com/articles/s41467-021-24084-x

particular attention given to the siting of energy infrastructure, appropriate species mix in forestry and the location of vulnerable species. Sustainable development of the agriculture and land use sector can deliver important win-win opportunities while the Common Agricultural Policy may be used to support improved management of livestock farming alongside provision of ecosystem services. More efficient use of and reduction in the application of nitrogen would bring climate, biodiversity and water quality benefits.

The high rates of change in land management and land use change required to achieve the level of removals implied in each of the mitigation scenarios in section 3.1.3 carry significant risks to biodiversity and water quality but also present opportunities. Successful implementation of climate action on the scale required will require a strategic and integrated land use planning approach at both national and local scales. The synergistic benefits of climate mitigation measures in the protection and enhancement of biodiversity, air and water quality, flood alleviation and other ecosystem service provision must be considered as part of this integrated approach and adverse impacts of land use change on vulnerable habitats such as those associated with wetlands, uplands and high nature value grassland and forest land must be avoided.

It will be important that where biofuels are employed to reduce greenhouse gas emissions that strong and robust sustainability criteria are applied to support domestic and international biodiversity objectives.

3.2 Economic Analysis

The task of decarbonising Ireland is a major challenge, and it will affect all aspects of our lives. Achieving a successful outcome will take time, but there is a strong legal commitment to making major progress by 2030, reducing emissions by 51% compared to 2018 levels. The payoff for this transformation of our economy will be Ireland's contribution to halting global warming by 2050. It will have other potential benefits in terms of biodiversity and human health. However, to make it happen will require a major increase in investment in decarbonising the economy. This investment in the domestic economy may result in additional economic activity and employment as discussed in section 3.2.3. Some of the investment may also be recouped in savings in fuel and via economic co-benefits such as from improved health and air quality. However, there will be additional expense which requires redirecting resources that could have been used for investment to reach other goals or to fund household consumption and other current government expenditure. Obviously, there will be significant implications for employment, output and the competitiveness of the economy.

In addition, the necessary economic changes will have implications for those working in different sectors, for different households, communities and businesses. The negative impacts can be mitigated by appropriate policies and supportive infrastructures. It will be the role of public policy to ensure a just transition, ensuring that the burdens and benefits of the transformation in our economy are shared fairly across society.

3.2.1 Investment Required for Transition

The TIM model is able to provide us with an assessment of the costs involved in the different mitigation scenarios in the energy sector. Table 3-3 shows the comparative upfront investment costs required under different scenarios. The no mitigation scenario is used only to illustrate the level of investment that would be expected to occur in order to replace end of life assets to maintain existing service levels and to meet any expected growth in demand. The 'additional cost' imposed by climate action in any other scenario can be seen by subtracting the 'no mitigation' scenario costs. The total additional upfront investment cost over the decade beginning in 2021 would be from about €19bn - €50bn in the WAM and 51% scenarios respectively with investment in transport and residential sectors together making up about €3bn - €18bn under each of those scenarios. There is a significant increase in costs if the energy sector ambition rises to a 61% cut in emissions with the additional upfront investments costs rising by another approximately €32bn over the decade.

Table 3-4 *Illustrative comparison of the average annual lump sum investment cost in millions of Euro across all energy demands over the decade 2021-2030 as reflected in the TIMES Ireland Model for a No Mitigation scenario, the With Additional Measures scenario ((corresponding to actions planned under the Climate Action Plan 2019), and scenarios of 51% and 61% emissions reduction by 2030 from 2018 levels. These figures do not include the cost of finance. Source: UCC (2021).*

2021-2030	Annual Average Lump Sum Investment (€m)			
Scenario	No Mitigation (BAU)	With Additional Measures	51% Reduction	61% Reduction
Industry	0	68	235	235
Power	675	1,845	2,929	3,249
Residential	978	1,178	2,211	2,906
Services	493	737	1,004	1,185
Supply	8	172	281	280
Transport	3,371	3,458	3,908	5,809
Total	5,524	7,457	10,568	13,768

If we take €5bn as the average per annum upfront investment required over the decade under a scenario of 51% reduction in emissions by the broader energy sector, this would represent approximately 1.3% of GDP or 2.4% of GNI* based on the 2020 national accounts from the CSO. As a comparison, the financial crisis caused GNI* to fall by 9.7% from 2008 to 2009.[41] In a 2018 analysis, the impact of Brexit was estimated as a reduction of 4.3% in GDP in 2030 when compared against a non-Brexit baseline.[42]

3.2.2 Output Changes

The core scenarios of the TIM model assume an increasing level of energy service demand[43] out to 2050, implying no required or assumed direct change in economic output as a result of the carbon budget scenarios.[44] On the other hand, many of the carbon budget scenarios modelled for the agriculture sector directly assume or use a change in output, primarily in the livestock sector, as a tool to meet mitigation goals. We describe those changes here.

While reducing bovine agricultural activity delivers an environmental benefit in terms of reduced agricultural emissions, the consequence of such changes, in the absence of alternative agricultural opportunities or income streams, would be lower agricultural output, lower agricultural incomes and reductions in employment in agriculture.

---

[41] Central Statistics Office (2021), Annex 2. Modified Gross National Income at Constant Market Prices (chain linked annually and referenced to year 2019) N2025. [online] www.cso.ie

[42] From a report prepared for the Irish Government: Copenhagen Economics (2018), Ireland & the Impacts of Brexit: Strategic Implications for Ireland Arising from Changing EU-UK Trading Relations. [online] https://www.copenhageneconomics.com/dyn/resources/Publication/publicationPDF/8/428/1520263183/copenhagen-economics-2018-ireland-and-the-impacts-of-brexit.pdf

[43] Energy service demand is the demand for heat, transport, light etc. Energy demand reflects the quantify of electricity/fuel required to meet the energy service demand.

[44] Second order impacts on economic output are considered as part of the macroeconomic analysis in section 3.2.5

Table 3-5 summarises changes in bovine activity and GHG emission changes under the scenarios analysed relative to the BAU scenario. The economic impact on agricultural output value and GVA are shown in Table 3-6. Farm level impact is not estimated here but is dependent on individual farm circumstances.

Table 3-5 Animal Number and GHG emission changes under the scenarios analysed

	2030	2030/ 2018		2030	2030/ 2018		2030	2030/ 2018
	Cattle (m head)			Cows (m head)			GHG (Mt)	
BAU	7.10	-2%		2.43			20.61	
Scenario C	6.43	-11%		2.11	-13%		16.10	-20%
Scenario D	5.88	-19%		1.84	-24%		14.97	-33%
Scenario E	4.66	-36%		1.23	-50%		12.18	-40%
Scenario F	3.84	-47%		0.85	-65%		9.51	-55%

Table 3-6 Changes in Agricultural Output Associated with Different Levels of Mitigation relative to Business As Usual scenario Source: Teagasc (2021)

Emissions Reduction	Scenario C (E70:A20)	Scenario D (E61:A33)	Scenario E (E57:A40)	Scenario F (E51:A51)
	Change in Output at Basic Prices (€m relative to BAU)			
Milk	-478	-557	-1,400	-3,028
Cattle	-255	-541	-1,124	-1,347
Agriculture	-719	-1,894	-2,451	-3,687
	Change in Output Value relative to BAU (% change in 2030)			
Milk	-14	-30%	-41%	-68%
Cattle	-10%	-37%	-45%	-54%
Total	-7%	-19%	-25%	-38%
	Change in Agricultural Operating surplus/GVA (€m)			
Agriculture	-301	-862	-1,038	-1,887
	Change in Agricultural Operating surplus/GVA relative to BAU (% Change in 2030)			
Agriculture	-9%	-25%	-30%	-55%

Since agriculture is heavily linked to the food processing industry, any negative impact on agricultural output will cascade into the food processing industry. The linkages between agriculture and the food industry and other economic sectors mean that there would also be negative consequences for the wider economy.

In the absence of macroeconomic analysis that incorporates information about bovine agriculture specific output adjustments required to achieve the national target of 51% reduction in GHG emissions by 2030, the Teagasc analysis of the potential downstream employment impacts of the reduction in bovine agricultural activity are presented. Teagasc estimates based on published research (Millar et al, 2018) on the links between economic activity in agriculture and the wider economy, suggest that the negative employment impacts on food processing of the output shocks in Cattle and Milk Output alone would be negative and much greater than suggested in the analysis by McKinsey & Co. which was based on a lower rate of emissions reduction by 2030.

Table 3-7 summarises the estimated employment output and employment impacts arising from the shocks to Cattle and Milk Output. Note that the total output value shocks for the agriculture sector as a whole will differ given the presence of other agricultural activities, where opportunities for diversification should be explored.

Table 3-7 Output and Employment Impacts of Agricultural GHG Emission Reduction Scenarios

	Scenario C (E70:A20)	Scenario D (E61:A33)	Scenario E (E57:A40)	Scenario F (E51:A51)
	Change in Output Value €m relative to BAU			
Milk	-478	-557	-1,400	-3,028
Cattle	-255	-541	-1,124	-1,347
Sum	-733	-1098	-2524	-4375
	Implied Change in Total Economy Employment			
Milk	-2,878	-3,352	-8,425	-18,222
Cattle	-2,871	-6,107	-12,681	-15,192
Sum	-5,749	-9,459	-21,106	-33,414

Based on this analysis, Teagasc came to the following conclusions;

- The large reductions in bovine agricultural activity implied by the core carbon budget scenarios have progressively larger negative impacts on agricultural output value and agricultural sector income.
- Large changes in bovine agricultural output volume will have large knock on consequences for economic activity levels and employment in the Food processing sector and for the wider Irish economy.

The Department for Agriculture Food and the Marine is currently preparing its Strategic Plan for the Common Agriculture Policy for Ireland 2023-2027. This is very relevant to achieving ambitious mitigation while respecting climate justice. In its Annual Review 2020 the Council recommended that income support payments from the Common Agricultural Policy should better support and encourage farmers to reduce emissions and/or use their land more profitably, while providing additional positive environmental outcomes. The critical role of farmers in the management of carbon stocks such as wetlands, grasslands and forestry should be acknowledged and farmers should be incentivised to adopt measurable and verifiable practices that sequester carbon. Additional resources should be allocated to support necessary investment in innovation, research and knowledge transfer to enable the long-term climate sustainability and resilience of Irish agriculture and land use.

3.2.3 Employment implications

The legislation requires that the carbon budgets take into account, insofar as is practicable, the need to maximise employment, the attractiveness of the State for investment and the long-term competitiveness of the economy.

Ireland is fortunate to have had historically low unemployment figures prior to the Covid-19 pandemic. Nevertheless, job losses and unemployment have huge impacts on the quality of life of individuals and in communities. Figure 3-3 summarises CSO statistics on employment in Ireland up to 2018 prior to the Covid-19 pandemic and associated impacts.

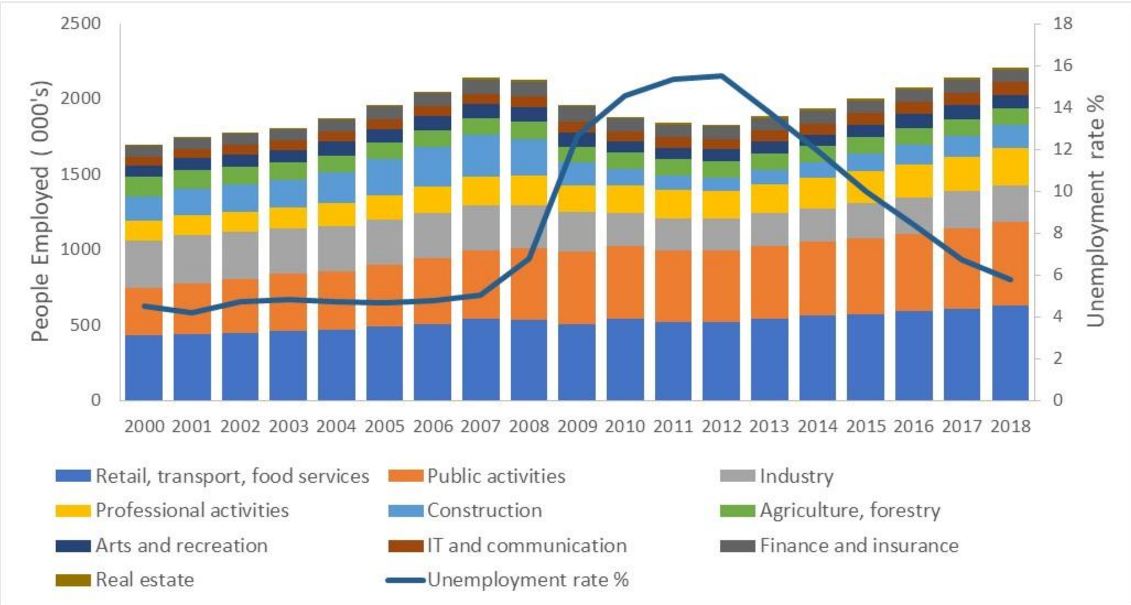


Figure 3-4 Employment by economic sector in Ireland 2000-2018. Source: Eurostat 2021

The jobs market could be affected by the carbon budgets in a number of ways. Jobs could be created in sectors providing low carbon solutions due to increased demand. Jobs could be lost in higher carbon sectors where demand for those products or services reduces. Jobs could also be lost or gained due to impacts of the carbon budgets on overall economic activity.

The need to maximise employment suggests a strong emphasis on avoiding job losses as well as promoting efforts for new job creation. There will undoubtedly be changes to jobs markets in the State arising from the scale of the changes required in all covered sectors of the economy. It will be important to identify jobs at risk so that workers and communities can be prepared, for example through upskilling, retraining and redeployment for new employment in a low carbon economy.

Analysis by Teagasc of the carbon budget scenarios suggests, that without intervention, potential job losses in the agri-food sector would be between 6,000 and 13,000 in a scenario of 20% emissions cuts to between 21,000 and 45,000 job losses in a scenario of 40% emissions cuts in agricultural emissions.[45] This is consistent with research by NESC identifying the agri-food sector as one of the most impacted sectors in terms of employment from the low carbon transition.[46]

Jobs and communities that are more associated with fossil fuel based technologies are also particularly vulnerable. The extent to which these communities or workers can readily switch to low or zero carbon alternatives will vary. Some positive examples are the plumbing and electrical trades, where renewable energy systems already form part of apprenticeship training.

While some jobs are vulnerable in a low carbon transition, other jobs will be created. The investment required in new energy systems, renewable energy and home retrofits will require thousands of workers to deliver. The extent to which jobs are created will depend in part on the extent to which technologies, components or services are sourced domestically or imported. It will be important for development agencies to maximise the employment potential in Ireland from the emerging opportunities due to the low carbon transition. Stanley et al (2021) found that approximately 6000 FTE jobs would be required in the construction sector to deploy an additional 3.5GW of onshore wind, while 7.3GW of offshore wind would require 33,000 FTE (it should be noted that in this context an FTE is a full time equivalent position for one year. So, employment numbers quoted here could be considered one year contracts rather than permanent positions. Therefore 6000 FTE positions could be equivalent to 1200 people working full time for five years). Solar power leads to less employment in Ireland per €m invested as most of the investment goes towards components which are normally imported as demonstrated in Figure 3-4. Investment in retrofits would lead to almost 40,000 FTE in construction. Retrofit could further result in a requirement for up to 33,000 FTE in manufacturing if materials and components were produced in Ireland. This increased demand for construction workers needs to be managed in the context of government policy to deliver increasing numbers of new homes over the decade. Thus it will be important to acknowledge that inflationary pressures may arise in some sectors with potential implications for enterprise, particularly exports, and for delivery of mitigation options.

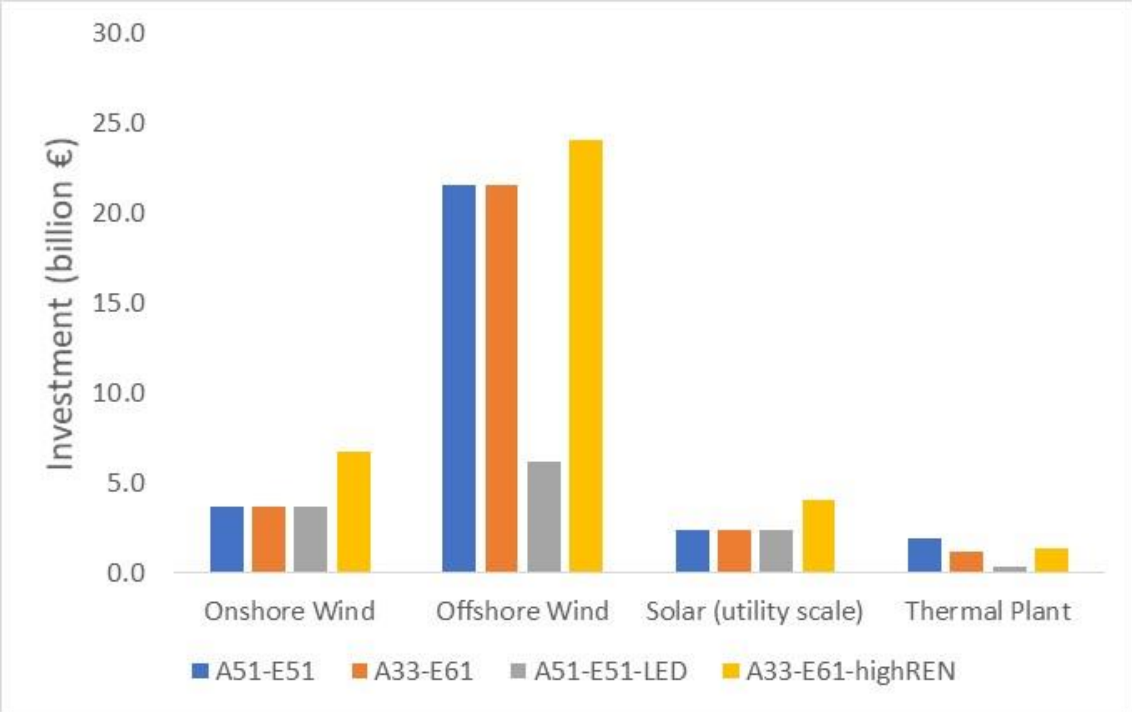
An effective training and reskilling infrastructure will be crucial to deliver the skilled workers required in sectors such as the construction and trades industries otherwise supply constraints and inflationary pressures may impact on the ability to implement the carbon budgets and reach our 51% target. An effective training and reskilling infrastructure will also be important to support

---

[45] A scenario of 55% emissions cuts in agriculture was estimated by Teagasc to lead to between 33,000 and 75,000 jobs losses. This impact on employment contributed to the Committee's identification of the A51-E51 scenario as unfeasible.

[46] National Economic & Social Council (2020) *Addressing Employment Vulnerability as Part of a 'Just Transition' in Ireland*. Tech. rep. 149. [online] http://files.nesc.ie/nesc_reports/en/149_Transition.pdf

climate justice and a just transition, assisting workers who might lose their jobs to prepare for alternative employment.



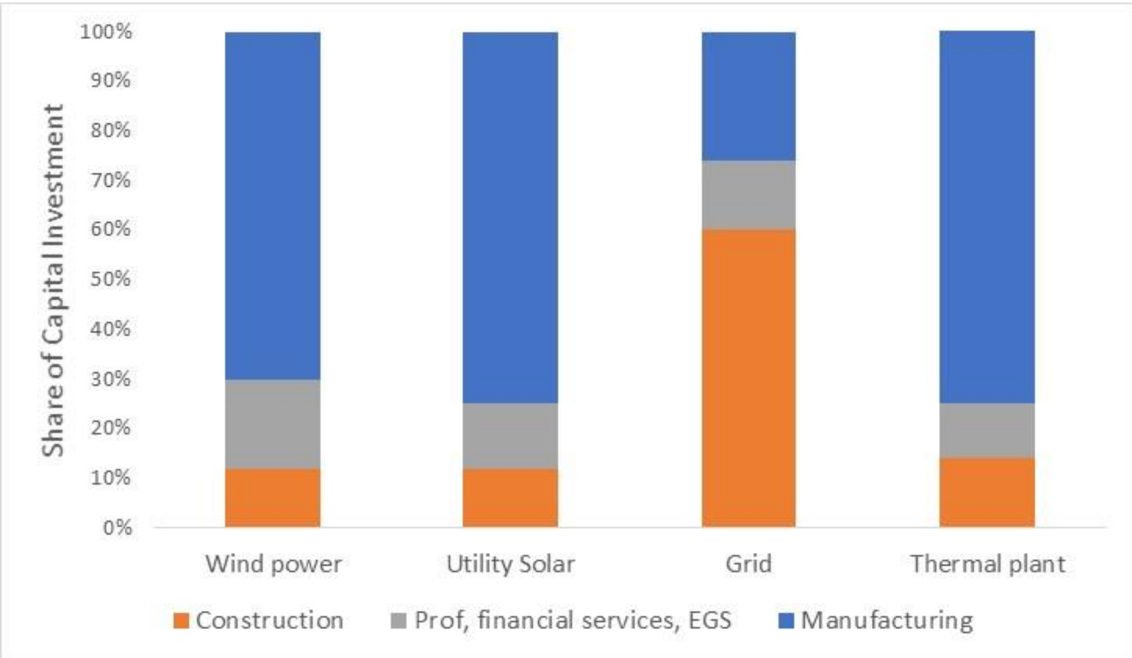


Figure 3-5 Capital investment in power generation and the sector where expenditure flows, Sources UCD analysis of TIM-Ireland 2021 and SEAI 2015 data

Businesses, particularly small and medium sized enterprises (SMEs), and farmers will also need to be prepared for the low carbon economy of the future by enhancing their resilience, reducing risk and ensuring their business / farm is successful in a decarbonised world. Policy supports, incentives, technological support and innovation will be essential. For farmers innovation and incentives encouraging additional and alternative income streams need to be urgently rolled out. The importance of providing policy supports aimed at alternative forms of income for small and medium enterprises, farmers and other impacted households should be considered urgently.

The balance of job losses and job creation is hard to predict and will be critically dependent upon the overall effectiveness of preparations for transition, including an effective training and reskilling infrastructure.

3.2.4 Attractiveness of the State for Investment and Long-term Competitiveness

Increased ambition in controlling and reducing greenhouse gas emissions in Ireland could have both positive and negative impacts on the attractiveness of the State for investment and on long term competitiveness.

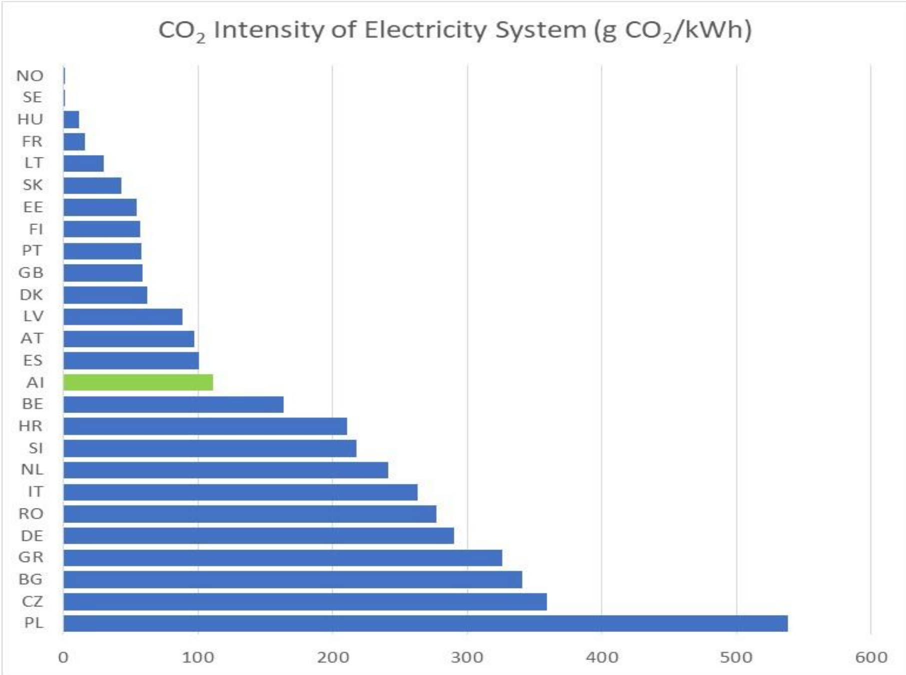
Demonstrating progress in the low carbon transition can be important for Ireland's trading partnerships and for continued success in attracting foreign direct investment and in selling Irish produce on international markets where environmental credentials are increasingly important.

Delivery of the increased ambition evident in the proposed carbon budgets could enhance Ireland's reputation as a modern and green location for business, bringing increased attractiveness for investment among those companies and businesses eager to demonstrate their green credentials to a global market. The establishment of Ireland as a Green/Sustainable Finance hub leading, developing skills and deploying innovative finance solutions to support transition and longer-term change could also further enhance Ireland attractiveness for investment. Greater ambition can also drive innovation and efficiency that could give Irish business and industry a competitive advantage in a world where all countries will require access to decarbonisation solutions in the coming decades.

Increases in costs due to the low carbon transition may have an impact on competitiveness and investment where the cost changes experienced in Ireland are experienced to a lesser or greater degree in other countries. To date investment in renewable electricity has, if anything, saved electricity consumers' money (di Cosmo, 2014 and IWEA, 2018) due to savings in fuel costs. It is not clear the extent to which household's electricity bills would continue to reflect savings. Analysis by McKinsey for the Council finds that increased ambition to 2030 would lead to an increase in business electricity rates of 2-3 cent per kilowatt hour which they suggest is broadly in line with other

European countries.[47] These changes may be significant in manufacturing subsectors with single digit margins. For example, in food manufacturing, electricity prices may add 0.7-1.5% to the cost of a unit of production (or up to 1.2-2.5% if a producer also electrifies their gas use). Analysis carried out for the Electricity Association of Ireland, as shown in Figure 3-6 suggests that Ireland could have one of the lowest wholesale electricity prices, on an All Island basis, among European countries in 2030, which could give rise to a competitive advantage in this sector while achieving carbon intensity of just over 100g CO_2 eq per kilowatt hour.[48]

[47] McKinsey paper forthcoming on council website.
[48] Electricity Association of Ireland (2021) Our Zero Emission Future. [online] https://www.eaireland.com/wp-content/uploads/2021/06/Our-Zero-e-Mission-Future-Report.pdf



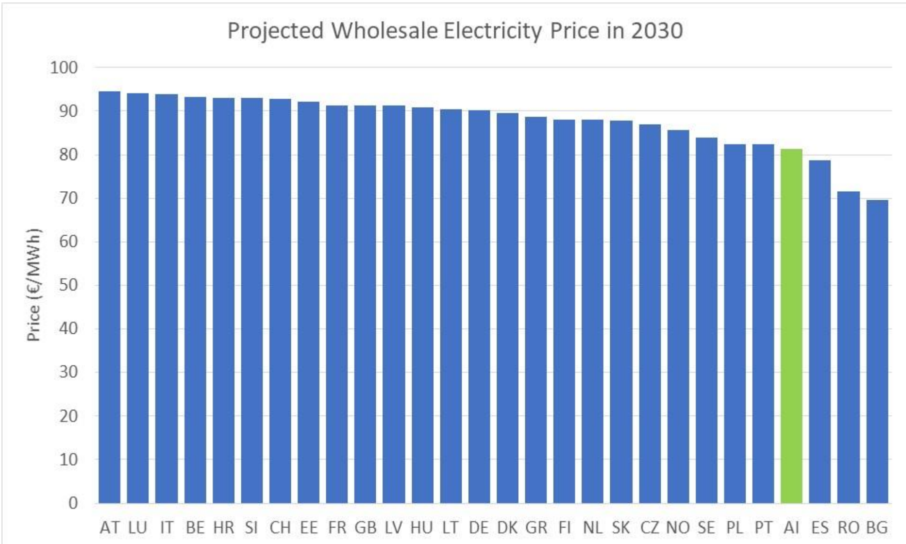


Figure 3-6 How modelling of the All-Ireland (AI) electricity system compares in Carbon Intensity and whole electricity prices to other EU countries. Source: Electricity Association of Ireland 2021[31]

The comparison with Ireland's trading partners and competitor countries is the important issue rather than any arbitrary comparisons with other countries with whom we do not compete. OECD countries (which includes EU Member States, USA and the UK) buy 88% of Irish exports.[49] Ireland is not alone in acting on climate change. EU Member States and the UK have taken on similarly ambitious goals in the coming decades with a determination to make an appropriate contribution to efforts towards the 1.5C Paris Goal. EU ETS sectors under the fit for 55 package will take on a greater

[49] Central Statistics Office (2021) Table TSA10: Value of Merchandise Trade. [online] https://data.cso.ie/table/TSA10

level of ambition than the 51% target mandated for the Council’s carbon budget proposals. Ambition in the USA is also increasing[50].

Analysis by McKinsey, illustrated in Figure 3-7, suggests that opportunities exist for Ireland to further develop exports arising out of the low carbon transition. They suggest that Ireland is fundamentally well-equipped to develop export markets in alternative proteins, dairy and the bio-economy in the short-term, heat pump manufacture in the mid-term, and carbon credits and carbon management longer term. Whilst Ireland is assessed as intrinsically well placed, realisation of these opportunities will be highly contingent on strategic actions taken by Irish businesses and policy makers.

3 – Investment / competitiveness attractiveness: Ireland is well placed to export emerging agriculture products in the near-term as well as energy, buildings end products longer term

▲ Estimated start date ● Highly relevant ○ Moderately relevant

		Possible export timeline			Competitive strengths			
	Export opportunities	2021-25	2025-30	2030-35	Existing adjacent industry	Natural resources	Relevant skills	Target customers
Agriculture	Alternative proteins end product and ingredients	▲			●	●	●	Global
	Low-carbon dairy end product	▲			●	●	●	Europe
	Carbon credits	▲			●	●		Global
	Bioeconomy products		▲		○	●		Europe
Energy	Green hydrogen end product			▲	○	●		Europe
	Green electricity end product			▲	○	●		Europe
Buildings	Heat pumps end product		▲		●			UK
Industry	Lower-carbon cement know how		▲		●		●	Global
Transport	Sustainable aviation fuels end product and know how[1]			▲	●	●	●	UK
Professional services and IT	Green finance products and services	▲			●	n/a	●	Europe
	Low-carbon data management	▲			●		●	Global

1. Contingent on there being sufficient available land for bioenergy crops, which may require further land uses changes given the competing needs for bioenergy crops
Source: McKinsey analysis

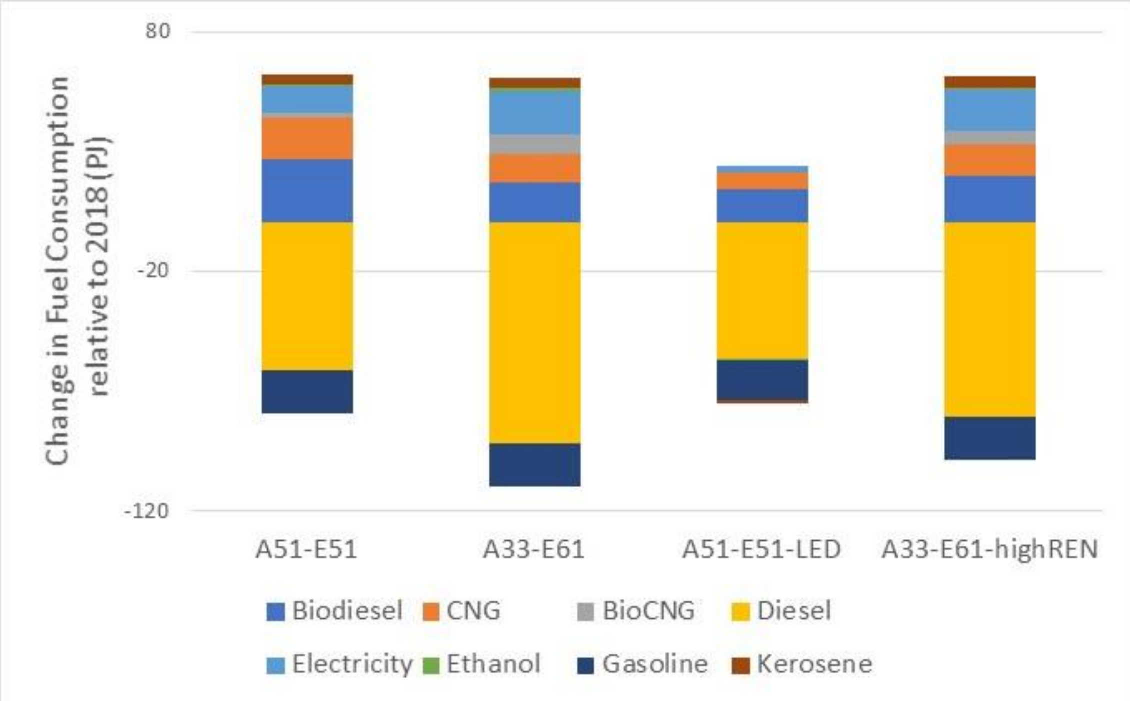
Figure 3-7 Quantitative framework evaluating potential export opportunities for Ireland

3.2.5 Macroeconomic implications

For the world to reach the goals set in the Paris agreement, a step change in climate investment will be taking place across the world over the coming decade. The benefits will accrue in Ireland and elsewhere in a rapid reduction in emissions of greenhouse gases. However, as in Ireland, this redirection of resources to necessary investment is likely to be only partly offset by a reduction in expenditure on fossil fuels.

[50] Reuters (2021) Factbox: United States, other countries, ramp up climate-change ambition, 22 April 2021. [online] https://www.reuters.com/business/environment/united-states-other-countries-ramp-up-climate-change-ambition-2021-04-22/

Ambitious mitigation aiming towards net zero by 2050 entails a significant shift away from fossil fuels towards renewable energy. This brings significant reduction in fuel costs. Figure 3-8 illustrates the scale of the shift.



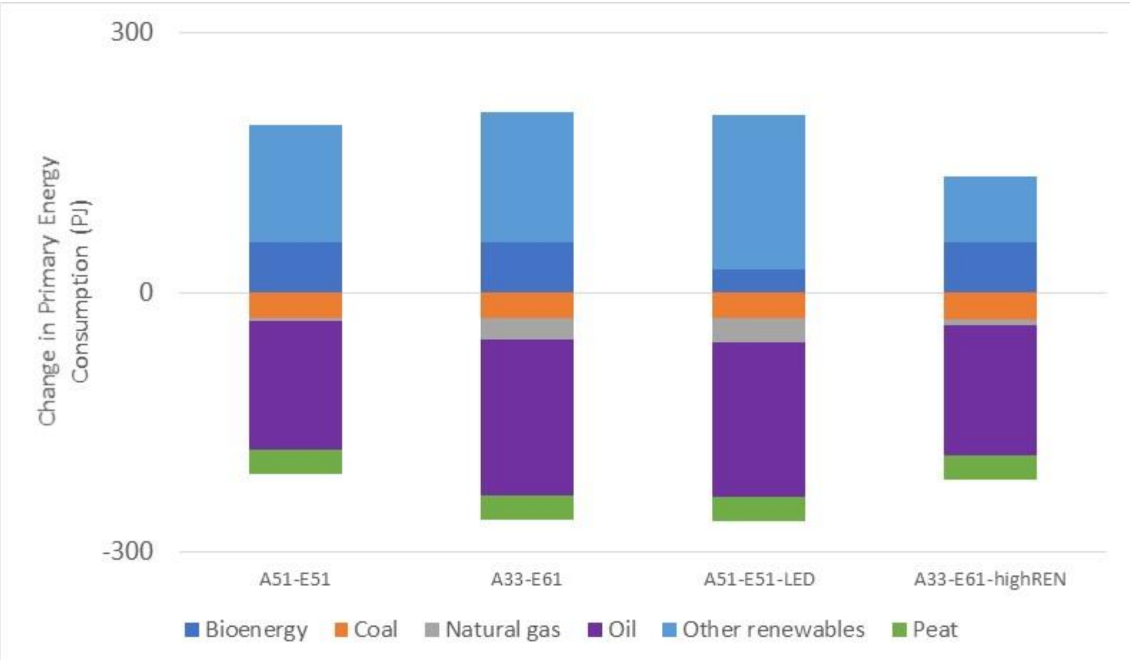


Figure 3-8 Fuel consumption in the transport sector and primary energy consumption in all covered sectors, 2030 relative to 2018. Source: TIM 2021

Analysis of the TIM scenario results discussed in section 2 and 3 suggests that moving from a no-mitigation scenario to a 51% emissions reduction scenario in the energy sector would see variable costs savings of about €9bn over the decade to 2030. The variable cost savings are greater in the following decades up to 2050 and also increase with greater levels of mitigation ambition in the energy sector.

In the medium term, the difference between the cost of the investment and the savings on fuels will have to be met by redirecting resources from other uses in the economy. It is this reduction in resources for other uses which will represent the cost of the necessary changes in our economy. In some countries and some economic sectors, the fuel savings may be close to the cost of the investment, whereas in others the net "cost" will be quite significant. This process will be replicated across the world economy, as outlined in a paper by Pisani-Ferry, 2021[51].

The analysis of Pisani-Ferry and others suggests that internationally investment in tackling climate change could amount to 2% or more of GDP in the countries that take action. If there is widespread implementation of the Paris Agreement goals across the world, a 2% rise in investment, with no direct effect on savings, will result in a rise in interest rates. In turn this will slow investment elsewhere in the economy, with potential longer-term impact on output. The potential rise in interest rates will also affect governments that are highly indebted and will make borrowing by governments to finance the investment less attractive. In turn, a higher level of interest rates is likely to adversely affect employment growth in the medium term.

The additional investment, through increasing the demand for investment goods such as solar panels and wind turbines, will lead to increased output and employment in the affected sectors. The scale of this benefit depends on the extent to which technologies are imported or indigenously manufactured. However, the funding of the investment will also see a reduction in investment elsewhere and/or a reduction in consumption. To the extent that the investment results in a reduction in expenditure on fossil fuels the negative effects of the funding will be limited in countries such as Ireland that don't produce fossil fuels. Obviously, those employed in producing fossil fuels and related products and services are likely to see a reduction in employment. However, to the extent that the investment is not offset by savings in expenditure on fuel, there will have to be cutbacks either in other investment or in consumption. This reduction in other expenditure will see small losses of employment spread across many sectors. There could be bigger effects if the

[51] Pisano-Ferry, J. (2021) *Climate policy is macroeconomic policy, and the implications will be significant*. No. PB21-20. [online] https://www.piie.com/publications/policy-briefs/climate-policy-macroeconomic-policy-and-implications-will-be-significant

level of output in the economy changes as a result of the necessary changes in the structure of demand.

The innovation, driven by the need to develop and deploy new technologies, could have a long-term positive effect on world output. However, there are a number of ways in which there could also be a significant negative impact on output. For example, where parts of the capital stock are written off prematurely (e.g. fossil fuel electricity generation stations, and fossil fuel cars) there is likely to be a loss of productive capacity.

The long-term effects on economies will depend on their structures and how efficiently they prepare for and tackle the challenge. While output in many economies may not be greatly affected, as climate friendly investment substitutes for other forms of expenditure, there will still be real costs for individuals, governments, and society from the need to use resources for climate goals rather than meeting the existing needs of household and government consumption. There will also be real gains for sectors that are important in the decarbonisation process.

Analysis prepared for the Council by McKinsey suggested that up to 50% of the measures they examined for the low carbon transition to 2030 could have a standalone business case due for example to fuel savings or fall in technology costs. The cost of such measures should be borne by the private sector. Where the required mitigation measures to achieve targets don't have a standalone business case, where a market failure may exist, governments will have to take action to ensure that the investment takes place. This support can take a number of different forms: subsidies to make the investment attractive to households and companies; green finance and investment solutions tailored to support consumer and business transition; taxes can be raised on carbon emissions and related activities to make the necessary investment commercially viable; or the state can regulate to require the private sector to undertake the necessary investment. Where the state subsidises, shares risk or provides grants for mitigation actions, the state will have to secure sufficient levels of funding in the government budget whether through a reduction in fossil fuel subsidies, an increase in taxation, or government borrowing (with a longer term commitment to pay back from the government budget in future years).

If the government chooses to fund much of the investment through higher taxation, there will be an additional loss of output, reflected in analysis provided by the ESRI. As first shown internationally in Pigou, 1928, this additional loss of output is due to the shadow price of public funds exceeding the revenue actually raised: taxes tend to reduce output by more than the amount actually raised in tax, while the spending of the taxes may not provide offsetting benefits. The latest estimate of the shadow price of public funds is incorporated in the Public Expenditure Guidelines, 2019 where the loss of output from raising taxes is assumed to be 130% of the revenue raised. Thus, if much of the investment is financed by taxation, this would be a clear drag on the economy until the transition to a net-zero carbon economy is completed. Given the potential investment requirement and economic impact, public financing will not be sufficient. Optimisation of Ireland's access to the EU Green Deal aligned with increased engagement with private capital markets in innovative financing solutions, ranging from green and social bonds, impact investing funds to green consumer lending could leverage on public finance and reduce the funding gap and drag on the economy.

3.2.5.1 Distributional Impacts

Addressing climate change requires expenditures across all of society and the economy. This implies that all households and businesses will need to make investments. In particular households will need to make investments in more sustainable transport options and also to upgrade the energy efficiency and energy technologies in their homes. Some households will be better able to finance this transition than others.

In the A51-E51 scenario deployment of electric vehicles is assumed to be slightly higher than in the base case, involving an additional €800 million a year in investment, primarily by the household sector.

However, in the A33-E61 scenario the stock of Electric cars by 2030 is assumed to be around 800,000 higher than in the A51-E51 scenario. To reach this number of EVs it would be necessary to scrap early 800,000 older fossil fuel cars. This would represent a real loss to the affected households as, while the new EVs which they would have to buy would be much less costly to run, this would not offset the loss from the early scrappage of their existing car.

While regulation could force early scrapping, unless carefully designed it could end up focussed on generally poorer households with older fossil fuel cars. This would be difficult to achieve and could be widely seen as unfair. Given the commitments to a just transition: if there had to be scrappage of 800,000 cars the losses to households affected would be large. If these losses had to be substantially covered by the state, this would place a serious additional burden on the public finances. Unless Ireland increases its involvement in manufacture of electrical vehicle components there would be very limited offsetting bonus in terms of new output.

In the case of the household sector, the A51-E51 scenario assumes households will spend an additional €1.2 billion a year on retrofitting their houses and in the A33-E61 scenario they are assumed to spend an additional €1.9 billion a year, see Table 3-4 for the projected annual average upfront investment costs across sectors for the decade 2021-2030.

While this investment will substantially reduce each affected household’s expenditure on energy through switching to electricity (for more efficient heat pumps), they will still have a significant bill for electricity for heating. A paper by Coyne and Denny, 2021, using detailed Irish data, shows that even after a major retrofit to bring a house to at least a B2 standard, Irish households continue to spend more on energy than would be predicted by engineering models.

In 2018 households with gas central heating spent around €1000 a year and oil households spent closer to €1500 a year on fuel for heating. While all expenditure on fossil fuels will end if a heat pump is installed, there will still be a significant bill for the albeit limited amount of electricity used by the heat pump. Even for oil households, the likely savings in fuel costs from a retrofit will go nowhere near paying for the cost of a full retrofit. Even without discounting, the fuel cost savings would take many decades to recoup the capital cost.

This suggests that the targets for retrofit will not be met unless the state pays for the bulk of the costs. In any event the state will have to pay for retrofitting the social housing stock which it owns. If two thirds of the cost of the retrofits assumed here were to fall on the state, this would require the spending of between €1 billion and €1.5 billion a year over the period 2026-2030 to achieve the necessary target on retrofits.

3.3 Climate Justice

The legislation requires that the carbon budgets should have regard to climate justice. Climate Justice is not defined in the legislation. A paper by Dr Tara Shine for the Council in 2019 suggests that 'Climate justice links human rights and development to achieve a human-centred approach, safeguarding the rights of the most vulnerable people and sharing the burdens and benefits of climate change and its impacts equitably and fairly. Climate justice is informed by science, responds to science and acknowledges the need for equitable stewardship of the world's resources.'[52]

Climate Justice is understood to include both international and national dimensions. The UNFCCC is the international vehicle for pursuing justice on climate issues. The Paris Agreement is an international treaty ratified by 190 countries and the European Union and represents the only truly international agreement on what is a fair way to approach common but differentiated responsibilities and respective capabilities. Climate Justice is referenced in the Paris Agreement and was a key driver in the negotiation of many of its features. Adherence to the provisions of the Paris Agreement and an appropriate contribution towards its goals is the most appropriate way to assess efficacy with respect to international climate justice. Section 4.2 describe how these carbon budgets represent an appropriate contribution to achievement of the ultimate objective of the UNFCCC and the mitigation goals of the Paris Agreement. It is not within the scope of the carbon budget process to address other aspects of adherence to the provisions and the spirit of the Paris Agreement e.g. international adaptation and climate finance. Addressing these other features of the Paris Agreement would be a significant contribution to international climate justice.

Nationally, compliance with the carbon budgets will undoubtedly bring changes to lives and livelihoods. For many, these changes will be positive and beneficial. However, it is critically important that the potential for adverse impacts is recognised and addressed.

Individuals and communities at risk of loss of employment or livelihoods need to be identified and prepared for the transition. The best and most just way to support people who will lose their jobs is to provide infrastructure for upskilling and retraining so that they can re-enter employment in the low carbon economy. This will also support the delivery of the carbon budgets by addressing constraints in supply chains. It will also be important to recognise the potential impact on vulnerable households of the costs of the low carbon transition and to mitigate this through appropriate supports. For example, an ambitious low carbon transition will see a movement away from travel by

[52] Shine, T. (2019) Climate Justice and Carbon Budgets. [online] https://www.climatecouncil.ie/media/climatechangeadvisorycouncil/contentassets/publications/Shine%20(2019)%20Climate%20Justice%20and%20Carbon%20Budgets.pdf

fossil fuel powered cars towards active (walking or cycling) and public transport and battery electric vehicles. For vulnerable households living in isolated areas, active and public transport may not be realistic options, but battery electric vehicles may be more expensive than what they can afford in the absence of additional supports. A low carbon transition will also require greater energy efficiency in heating homes and a switch away from fossil fuels to renewable energies. While this would bring overall benefits in the long run to society and households, both through energy cost savings and less tangible benefits such as improvements in health and comfort, the required investment may be out of reach of the most vulnerable households who often live in the poorest quality homes in the absence of additional supports.

Finally, as the government will be required in a lot of cases, to step in to encourage, facilitate or incentivise the low carbon transition this will place a greater demand on the exchequer. Government will need to develop innovative means to access low cost approaches to financing the transition but Ireland may also have to be prepared for the need to increase taxes to support the transition and the consequences this would have on the economy.

4 International Perspective

4.1 EU Requirements

The legislation requires that the carbon budgets be consistent with any mitigation or adaptation commitments entered into by the European Union in response or otherwise in relation to the objective specified in Article 2 of the UNFCCC. This is understood primarily to refer to commitments expressed in the Nationally Determined Contribution of the EU to the Paris Agreement, under the UNFCCC[53].

The European Climate Law, which entered into force in July 2020, writes into law the goal for the EU economy and society to become climate-neutral by 2050. The law also sets the intermediate target of reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. In October 2020 the EU submitted an update to the Nationally Determined Contribution (NDC) of the EU to the Paris Agreement, under the UNFCCC setting out that "The EU and its Member States, acting jointly, are committed to a binding target of a net domestic reduction of at least 55% in greenhouse gas emissions by 2030 compared to 1990." The EU NDC provides details on actions taken to implement the NDC including: the EU Emission Trading System (EU ETS), the Effort Sharing Regulation (ESR) and the regulation on emissions and removals from land use, land use change and forestry (LULUCF).

In order to make a comparison between EU targets and the national carbon budgets, it is necessary to also take account of the different approach to LULUCF, by first considering only those elements of the carbon budgets covered under the ETS and ESR as currently structured. Table 4-1 shows the proposed carbon budgets excluding provisions made for the on-going emissions from LULUCF in the period to 2030, that is covering ETS and ESR.

[53] While Regulation XXX excludes International Aviation and Maritime from the calculations, notable EU policy development include proposals for the inclusion of international shipping in the EU ETS and the ReFuelEU proposal which will involve all aviation emissions.

Table 4-1 Proposed Carbon Budgets 1 and 2 excluding provisions made for LULUCF.

Proposed Carbon Budgets	**2021-2025 All gases CB1**	**2026-2030 All gases CB2**	**2021-2030 All gases CB1 + CB2**
Carbon Budget **excluding LULUCF** (Mt CO_2eq)	**271**	**188**	**142**
Carbon Budget provision for LULUCF (Mt CO_2eq)	24	13	**9**

Ireland currently has obligations under each of the three instruments; the EU ETS, the ESR and the LULUCF regulation. Ireland's current target under the ESR for non-ETS greenhouse gas emissions is a reduction of 30% by 2030 relative to 2005. This target is part of the previous EU-wide target of a 40% reduction in greenhouse gas emissions by 2030 relative to 1990.

Revisions to the three instruments, which were proposed by the European Commission in July of this year, are currently being negotiated with all EU Member States to reflect the increase in the EU's overall ambition to a reduction in emissions of at least 55% from 1990 levels by 2030. The proposed emission reduction target for greenhouse gas emissions covered by the EU ETS across the EU is 61%. The European Commission has proposed a 42% ESR target for Ireland by 2030 which is at the upper end of the range of targets for EU Member States which lies between 10% and 50% (see Figure 4-1).

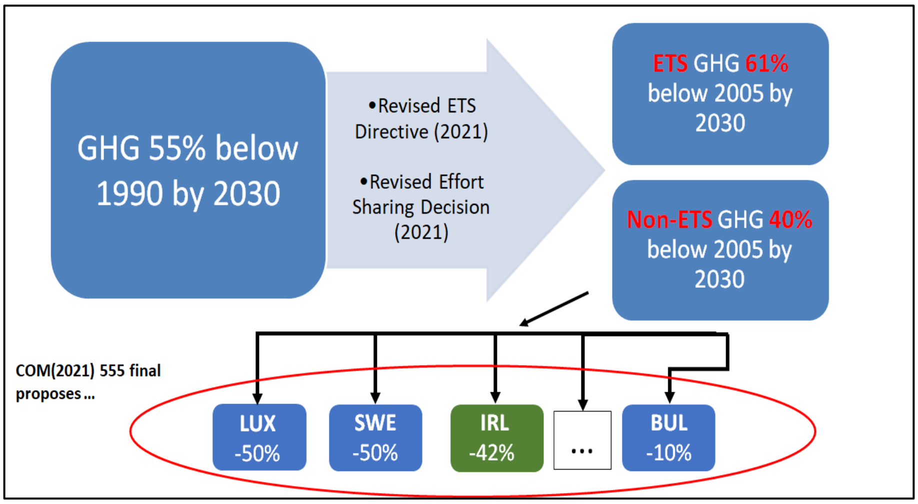


Figure 4-1 Proposed EU "Fit for 55" targets

The European Commission has proposed to introduce a separate target for LULUCF. The package envisages a transition from Net-Net Accounting for the period 2021-2025 to Gross-Net Accounting for the period 2026-2030. According to the proposal from 2031 onwards it is anticipated that emissions from Agriculture and LULUCF would be integrated into a single sector and the amended Regulation would aim towards the objective to achieve climate neutrality in this combined sector by 2035. This 2035 target relates to the EU in aggregate. The contribution of individual member states to this overall goal is not predetermined and will likely vary depending on the land use characteristics of each member state. The EU legislated targets for 2030 are defined with existing reporting protocols using GWP_{100}. Recent projections from the EPA indicate that only with full implementation of measures contained within the Climate Action Plan 2019 and full use of the two main flexibilities available Ireland would meet the existing EU targets. These flexibilities relate to a write-off of ETS allowances and in respect to credits arising from LULUCF activities which are available for use subject to the so called “no-debit” rule. The proposed change in approach, from Net-Net to Gross-Net accounting for the period 2026-2030 in the EU would make gaining access to these LULUCF credits more difficult. (See also Section 3.1.3)

Based on preliminary analysis provided by Professor Brian Ó Gallachóir, the carbon budgets proposed here are broadly consistent with the new EU proposed targets for Ireland. That is if the carbon budgets are delivered in full this would imply a high probability that the new ESR targets would also be met. Given that the EU ETS targets are set at a collective level for the EU as a whole it is not possible to calculate an exact comparison, and as such the following analysis cannot be determined to be definitive. However, for the purposes of illustration, Professor Ó Gallachóir’s presentation simply assumed that ETS emissions in Ireland develop in line with the European Commissions Impact Assessment analysis of the 61% target in order to make a meaningful comparison. (see Figure 4.2 for an illustration of the sectoral split of the EU budget).

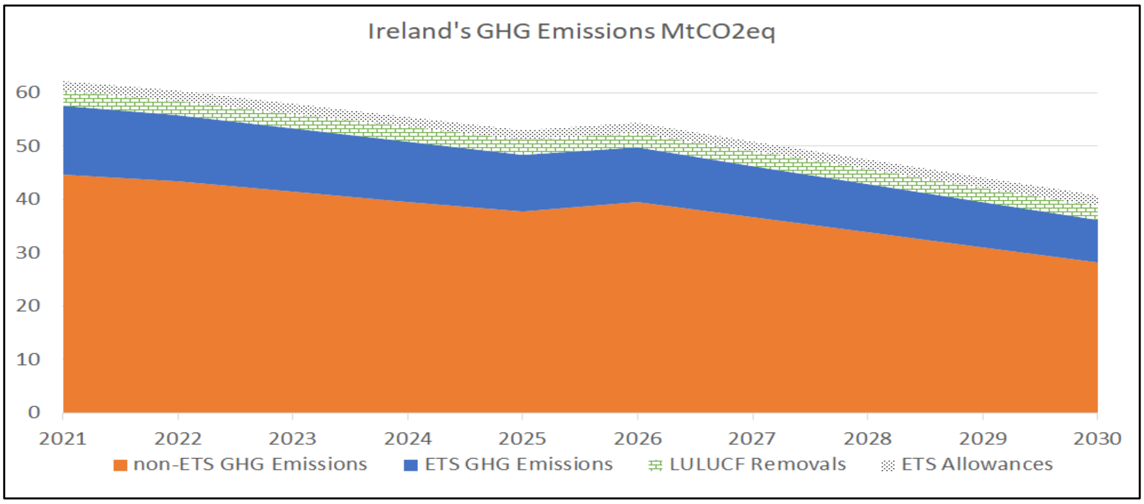


Figure 4-2 Estimating Ireland's equivalent greenhouse gas emissions budget arising from EU Fit for 55 Proposals

Allowing for this significant uncertainty the only case in which there might be concern of a major misalignment between the proposed EU targets and the proposed carbon budgets would be in the event that the proposed national carbon budgets were to be significantly higher than the estimated EU budget for Ireland.

Tables 4-2 and 4-3 summarise the EU budgets based on the EU Fit for 55 package. The first table assumes that no use is made of either of flexibilities allowed for in the existing ESR whereas the second table makes a simplifying assumption that both flexibilities are fully utilised.

Table 4-2 Estimates of allowance under ESR and ETS based on EU Increased Ambition (No Flexibilities)

Period	EU 55% Allocation	ESR	ETS
2021-2025	266	206	60
2026-2030	215	170	45
Periods 1+2	481	376	105

Table 4-3 Estimates of allowance for emissions based on EU Increased Ambition (both Flexibilities fully utilised)

Period	EU 55% Allocation
2021-2025	289
2026-2030	238
Periods 1+2	527

The resulting allocation for Ireland for the 10-year period 2021-2030 is 481 – 527 Mt CO_{2eq}. This compares with the first two carbon budgets proposed for Ireland, excluding LULUCF of 459 Mt CO_2eq split into 271 Mt CO_{2eq} for the first period and 188 Mt CO_2eq for the second period[54].

This implies that the carbon budgets are broadly equivalent over the ten-year period but that the EU targets may seem to spread reductions more evenly over time. The reasons for this difference are explained in the Section on Carbon Budgets, but essentially relate to the fact that policy interventions take time to deliver mitigation outcomes. Within the context of the ESR however there is a greater deal of flexibility in how emissions budgets are met which means that over performance in any given year can be used to meet under performance in any other year subject to some limited borrowing from future periods (up to 10% for years 2021-2025 and 5% for years 2026-2030); and intra-member state purchases (whereby Member States can under certain conditions sell up to 5% of its allocation for years 2021-2025 and 10% for years 2026-2030) are also allowed[55]. It will also be open to Member States to trade over-compliance with their obligations under the revised LULUCF Regulation (as proposed). The ETS related flexibility will also assist to smooth out some of the effects of this inter-temporal disparity at least within the context of demonstrating compliance with our EU obligations.

A final and critical point that should be noted is the rules (and proposed changes thereto) around access to the LULUCF credits. If Ireland fails to meet the stricter accounting rules in the period 2026-2030 or under-delivers in terms of the necessary mitigation action and thereby cannot access the credits, then effectively the EU budget becomes more stringent. However, within the EU context the ETS Flexibility and intra- Member State trading are still available and can be used to demonstrate

[54] These numbers are based on an assumption of a 51% reduction in LULUCF emissions by 2030. See section 3.1.3

[55] European Union (2018), Regulation (EU) 2018/842 of the European Parliament and of the Council of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013. [online] EUR-Lex - 32018R0842 - EN - EUR-Lex (europa.eu)

compliance whereas this will not be the case in relation to Ireland's compliance with national targets.

To summarise, the proposed budgets will enable full compliance with the State's current target of a 30% reduction by 2030. They are evaluated to be broadly consistent with future reporting obligations and proposed accounting rule and target changes under the EU Climate Law.

4.2 Paris Agreement & UNFCCC

Ireland is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and is committed to achieving the objective of that convention, as defined in Article 2; "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". Ireland is also a signatory to the Paris Agreement which defines an aim of "holding global temperature increase to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C, in the context of sustainable development and efforts to eradicate poverty" and "in a manner that does not threaten food production". The UNFCCC gives utmost importance to the stabilisation of greenhouse gas concentrations in the atmosphere. This requires that emissions of long-lived gases must reduce to net zero, and requires strong, rapid and sustained reductions in methane emissions. By setting temperature goals, the Paris Agreement gives additional direction and specificity on how quickly this needs to happen.

In its deliberations, the Committee considered the question of what Ireland's appropriate contribution would be to the global effort to reduce greenhouse gas emissions. Any such determination has implicit or explicit implications around climate justice, historical responsibility, equity and equality. It is not the job of the Council or the Carbon Budget Committee to make such value judgements. The Committee concluded that Ireland's carbon budgets for the periods 2021-2025, 2026-2030 and 2031-2035 must at least be consistent with the temperature goals of the Paris Agreement; the 'Paris Test', developed by the Secretariat under the guidance of the Carbon Budget Committee. This approach makes the lowest number possible of implicit assumptions.

4.2.1 'The Paris Test'

The Committee agreed that as a developed country, 1.5°C is the temperature target against which the proposed carbon budgets for Ireland should be tested. This section provides a high-level description of the approach and the results.

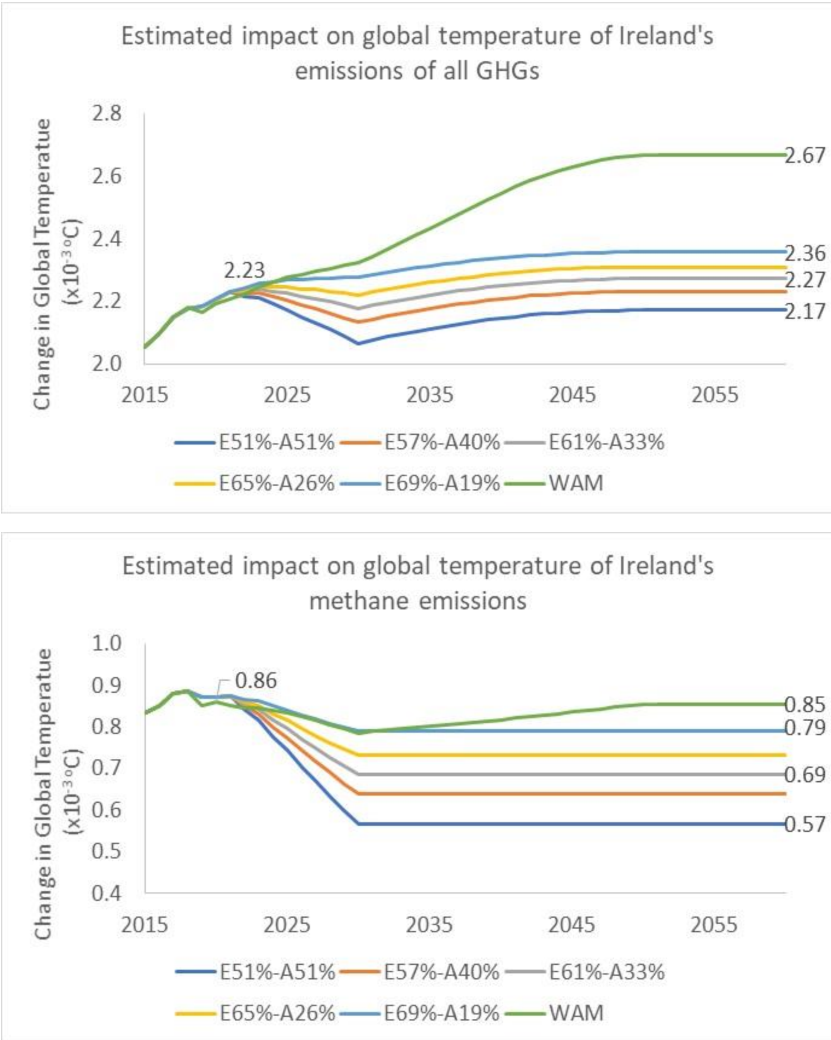
To assess the consistency of the proposed carbon budgets with the 1.5°C targets, a number of calculations are necessary;

1. Calculate the temperature impact of the carbon budget scenario
2. Calculate the gap between current global temperature levels and the 1.5°C target
3. Scale up the estimated temperature impact of the Irish carbon budget scenario and compare with the temperature target

If the scaled up Irish carbon budget scenarios exceed the temperature gap, deeper analysis would be required before they can be considered consistent with the 1.5°C target or the Paris Agreement.

4.2.1.1 Calculate the temperature impact of the carbon budgets

The analysis shows that the temperature impact of the carbon budgets depends on the assumed mix of gases. Therefore, the different scenarios that were modelled for the Committee in Section 3 each lead to different temperature outcomes. These are shown in Figure 4-3 and summarised Table 4-4.



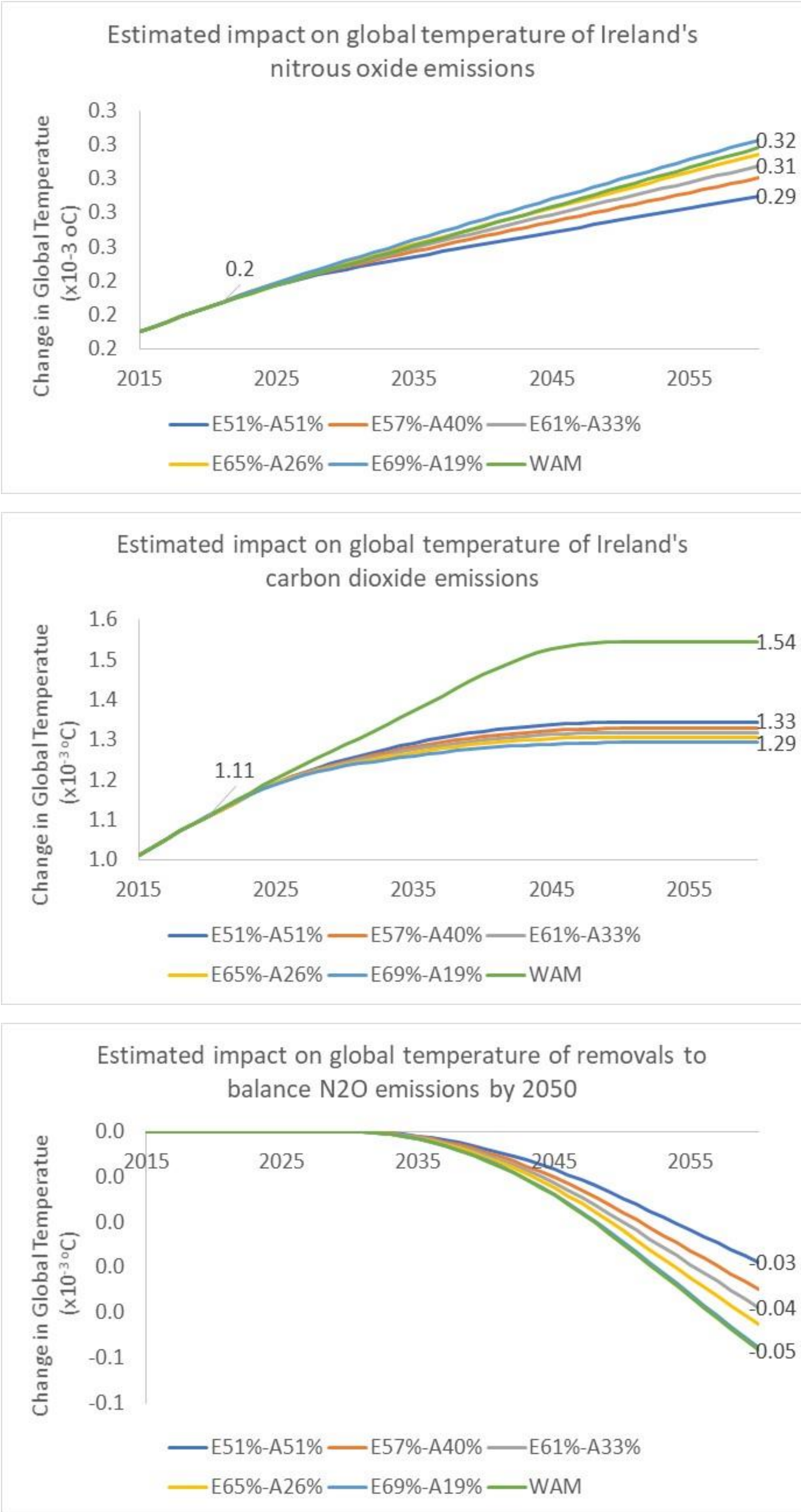


Figure 4-3 Estimated temperature response to emission of the main greenhouse gases based on the illustrative scenarios. The temperature impact of the proposed carbon budgets is at the scale of one-thousandths of a degree Celsius.

4.2.1.2 Calculate the global temperature gap

The recently published IPCC AR6 Working Group 1 report provides an up to date assessment of the current attributable human-caused global surface temperature; the extent to which current global temperatures already exceed pre-industrial levels. This is estimated at 1.07°C, within a likely range of 0.8°C and 1.3°C.[56]

In addition to the currently observed warming, based on the pathways by which global actions can achieve the 1.5°C goal, a further warming is expected due to interactions with other gases[57]. This is estimated as 0.2 °C based on the analysis of the IPCC AR6 WG1 report.

This leaves a remaining temperature gap of 0.23 °C expected to be taken up by global emissions of carbon dioxide.

4.2.1.3 Compare the temperature impact of the carbon budgets with the 1.5°C goal

Assessing entitlement or 'fair shares' are ethical and political judgements that can be fraught with difficulty. This 'Paris test' takes a different approach to consider what the temperature outcome would be if every country in the world, 1) had the same starting point as Ireland and 2) reduced emissions in the same speed and amount. In other words, on a per capita basis, we scale up Irish emissions to the global level. Different approaches could be taken (Price 2021, Smith 2021)[58]. This approach does not take into account previous actions nor does it take into account feasibility or cost. However, it is a useful approach to test a minimum level of consistency with the Paris temperature goals.

Table 4-4 summarises the results of the 'Paris test' for the five scenarios of carbon budget modelled for the Committee. All scenarios pass the test comfortably, with the exception of E69-A19 which marginally exceeds the estimate of the remaining temperature gap to Global 1.5°C goal. The Council concludes that the proposed carbon budgets are broadly consistent with the legislated criteria regarding the UNFCCC and the Paris Agreement.

[56] IPCC, 2021: Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.
[57] Efforts to reduce greenhouse gases will also lead to reduction in aerosol pollutants. These aerosol pollutants currently have a cooling impact in the atmosphere so their projected reduction will be experienced as a further warming impact.
[58] Price (2021) and Smith (2021). In press.

Table 4-4 Summary: Additional Impact of Ireland's emissions from 2020 on Global Temperature in 2050

Summary Table: Additional Impact of Ireland's emissions from 2020 on Global Temperature in 2050						
	Unit	E51%-A51%	E57%-A40%	E61%-A33%	E65%-A25%	E69%-A19%
Net Change in Global Temperature in 2050 relative to 2020	$x10^{-3}$ °C	-0.04	0.03	0.07	0.11	0.15
Upscaled to Global level Temperature change to 2050	°C	-0.05	0.04	0.11	0.16	0.24
Remaining gap to global 1.5 degree goal (with confidence range)	°C	0.23 (0.14- 0.32)	0.23 (0.14- 0.32)	0.23 (0.14- 0.32)	0.23 (0.14- 0.32)	0.23 (0.14- 0.32)

4.2.2 International Expert Input

Climate Science is continually evolving. The science-policy interface is notably informed by the IPCC which published the report of Working Group I of its Sixth Assessment Report in August of this year. In order to take on board the most recent and up to date understanding in climate science the secretariat of the Council arranged a meeting of science and policy experts on key topics including national mitigation efforts, relationship of different greenhouse gasses, the Paris Agreement and the 1.5°C temperature target. Four senior international science experts were invited to present and answer questions in an open discussion. These were IPCC co-chair Andy Reisinger; Joeri Rogelj Grantham Research Unit - Imperial College London; Myles Allen, Head of Climate Dynamics – University of Oxford; and Florian Vladu (Manager UNFCCC Secretariat).

Key messages from the expert meeting include:

- Legal agreements made under the Paris Agreement must be implemented.
- There is agreement on the physical science of what needs to be done to limit global warming at the global level, however debate remains around how this could and should be done at a regional/national level.
- There is urgency to reduce Carbon Dioxide (CO_2) and Methane (CH_4), as all additional emissions contribute to expected peak warming.
- A decrease in the rate of methane emissions is essential to limit future warming.
- Both fossil methane emissions and biogenic methane emissions need to be reduced from the global perspective.
- Global emission pathways of greenhouse gases should not be simply used as national emission pathways.

- Climate science can’t tell us how to distribute the effort among emitters, this depends entirely on value judgements about what is considered feasible and fair.

5 The Role of Different Gases

The legislation requires the Council to consider methane as part of the overall basket of greenhouse gases, on a GWP_{100} basis. Achieving the 51% emissions reduction target reduction will require a sharing of mitigation effort across all gases. The decision regarding what this share will be is for policy makers and should reflect the technical options and potential economic and social impact of mitigation across sectors, as clearly set out in the set of criteria to be considered by the Minister in setting sector emissions ceilings.

Two key characteristics determine the impact of different greenhouse gases on the climate: the length of time they remain in the atmosphere and their ability to absorb energy. An important distinction can be made between methane, as a short-lived greenhouse gas (with an atmospheric lifetime of approximately 12 years, and is often termed a flow gas), and long-lived greenhouse gases (e.g. CO_2 with an indeterminate lifetime and N_2O with an atmospheric lifetime 109 years).

Nitrous oxide is a much more potent greenhouse gases than CO_2, absorbing much more energy while it exists in the atmosphere. Because of its longer lifetime, concentrations of N_2O in the atmosphere is not in equilibrium as the growth in the rate of emissions in recent decades has exceeded the rate of removal, leading to on-going accumulation of N_2O in the atmosphere. Therefore, a comparison of the potential climate response to N_2O and CO_2 emissions is relatively straight forward, with the GWP_{100} being a reasonably accurate representation of relative impact of emissions on warming.

Methane is also a very potent greenhouse gases, however, its short lifetime means that atmospheric concentrations, and hence warming, are determined by the rate of emission rather than cumulative emissions.

The IPCC AR6 observes “biogenic methane” emissions arise from biological processes, such as microbial activity in soils or the gut of ruminants. The definition distinguishes biogenic emissions from those which arise from geological and fossil sources such as fugitive emissions from the extraction of natural gas. Methane from fossil fuel sources has slightly higher emission metric values than those from biogenic sources since it leads to additional fossil CO_2 in the atmosphere following oxidation. Globally, biogenic methane from agriculture and waste represents 60% of anthropogenic methane emissions. Biomass and biofuels represent approximately 9% of emissions while the remaining 31% of methane emissions arise largely from fossil fuel extraction, distribution and combustion. In Ireland, anthropogenic methane emissions are dominated by biogenic sources, from agriculture (93%) and waste (5%). Therefore, in an Irish context, mitigation of anthropogenic methane principally relates to “biogenic” methane the principle source of which is cattle.

Ireland's biogenic methane from cattle (and sheep) is very difficult to mitigate at present, as there are very few technologies available yet in Ireland or globally to reduce it. However, research internationally and in Ireland is gathering pace and some promising innovations (animal's diet, additives and genetics) are being researched. Nevertheless, the difficulty of mitigating enteric methane at present means that deep cuts in methane would require cuts in animal numbers, which could be very challenging for Ireland as discussed in section 3.2.2.

According to a recent UNEP report, The Global Methane Assessment[59], available targeted methane measures particularly for fossil fuel methane, together with additional measures that contribute to priority development goals, can simultaneously reduce human-caused methane emissions by as much as 45 per cent, or 180 million tonnes a year (Mt/yr) by 2030. This will avoid nearly 0.3°C of global warming by the 2040s and complement all long-term climate change mitigation efforts. The report also identifies very important global co-benefits for health, productivity and food production. There are readily available targeted measures that can reduce 2030 methane emissions by 30 per cent. Nearly half of these technologies are available to the

fossil fuel sector. There are also available targeted solutions in the waste and agricultural sectors.

Efforts to address methane are happening globally. Ireland is a member of the Climate and Clean Air Coalition which is driving initiatives in this area.

The EU Methane Strategy recently published as part of the 'Fit for 55' package envisages a 35% cut in methane relative to 2005, primarily focussed on reductions in fossil methane, which comprises 20% of EU methane. This will occur from a reduction in leaks during transmission and reducing emissions associated with the coal industry. The promotion of biogas is seen as a strategy to achieve reductions, primarily in the waste sector but also from manure management. In terms of agriculture, the EU proposals envisage an inventory of best practice techniques and that 'carbon farming' should be promoted via digital navigators and uptake of best mitigation techniques. They also highlight that the sector has '*inherent complexities, as increasing the use of confinement housing for livestock typically leads to reduced methane emissions and …… benefits from grazing ruminants especially in terms of carbon sequestration and biodiversity in grassland and pastures would be lost*.'

[59] United Nations Environment Programme and Climate and Clean Air Coalition (2021) Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions. Nairobi: United Nations Environment Programme. [online] https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions

In September of this year the EU and the United States signed an agreement, the Global Methane Pledge to pursue a reduction of at least 30% in global methane emissions by 2030 relative to 2020, and moving towards using best available inventory methodologies to quantify methane emissions, with a particular focus on high emission sources[60]. Six other countries including the United Kingdom and Argentina have also signed up to the Agreement.

A fundamental condition required for stabilisation of the climate system is the stabilisation of the concentration of greenhouse gases in the atmosphere. For long lived gases, such as CO_2 and N_2O, to stabilise their influence on climate, it is necessary that emissions reach net zero emissions, that is where emissions are balanced and. the amount of gas emitted equals the amount being removed. For methane, in order to prevent further impact on the climate, it is important first to stabilise the rate of emissions. However, the IPCC SR1.5 and AR6 WG1 indicate that merely stabilising global methane emissions at the current rate of emissions is not sufficient to achieve the objectives of the Paris Agreement. Whilst methane emissions do not need to be eliminated, a significant reduction in global methane emissions is necessary because this will give a "cooling" effect., as can be seen in the trajectories of methane emissions in the SSP1-1.9 and SSP1-2.6 scenarios in Figure 5-1. The 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 methane emissions associated with energy and waste sectors. Nevertheless, global agricultural emissions of methane would be required to reduce by between -11% and -30% by 2030, (24% to 47%) by 2050) and continuing to reduce at a slower pace for the rest of the century. [61]

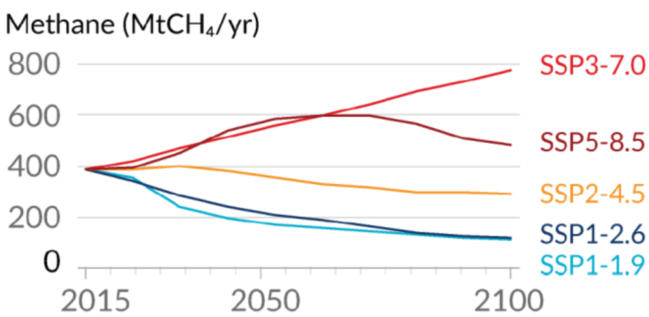


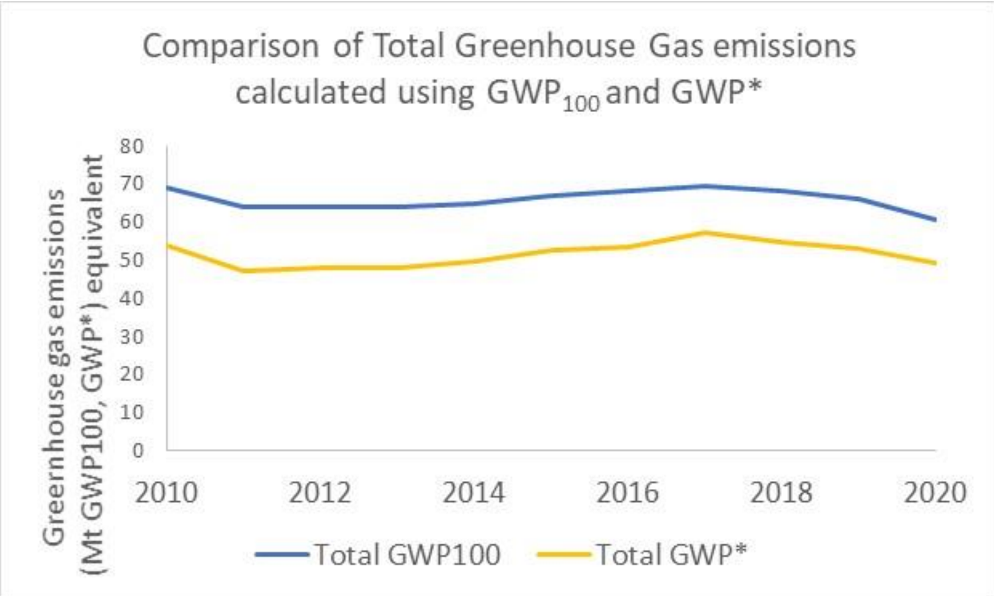
Figure 5-1 Global Methane emissions trajectories assumed in the Shared Socioeconomic Pathways, SSPS. Source IPCC AR6 WGI (2021)

[60] The White House (2021) Joint US-EU Press Release on the Global Methane Pledge, 18 September 2021. [online] https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/18/joint-us-eu-press-release-on-the-global-methane-pledge/

[61] IPCC (2018) Special Report Global Warming of 1.5°C. [online] https://www.ipcc.ch/sr15/

A reduction in the rate of emissions of short lived greenhouse gases leads to a reduction in their concentration in the atmosphere, and therefore has a cooling effect. This important difference between gases has led many to question the appropriateness of the GWP_{100} metric to express emissions targets linked with temperature goals. Nevertheless, national, EU and UN processes mandate the use of the GWP_{100} metric to aggregate total emissions based on reported value of absolute emissions of each gas. The IPCC SR1.5 demonstrates that GWP* is more accurate at aligning the rate of emission to temperature response and identifies the timing for stabilisation of global temperature. The IPCC-AR6 reports that net zero emissions for all greenhouse gases calculated with GWP* would result in no additional warming, in contrast, net zero emissions calculated with GWP_{100} would result in net cooling.   When the rate of methane emissions is decreasing faster than 3% per decade, GWP* for methane gives a negative value, analogous this “cooling” effect, and can be consider as having an equivalent impact on climate as negative emissions. This “cooling effect” is proportional to the level of reduction in the rate of emissions.

On the basis of GWP_{100}, methane emissions represent 26% of GHG emissions in Ireland. The alternative GWP* offers a different perspective on national emissions profile which can provide insight into the impact of recent growth in methane emissions (See Figure 5-2). In 2011, Ireland recorded the lowest rates of methane emissions, since 1990 which resulted in a negative value for methane in terms of GWP*, reflecting a short period where the trend in methane emissions in Ireland contributed to a reduction in global warming. However, in the period since 2014 there has been a rapid growth in methane emissions, leading to positive values for GWP* and a contribution to additional warming.



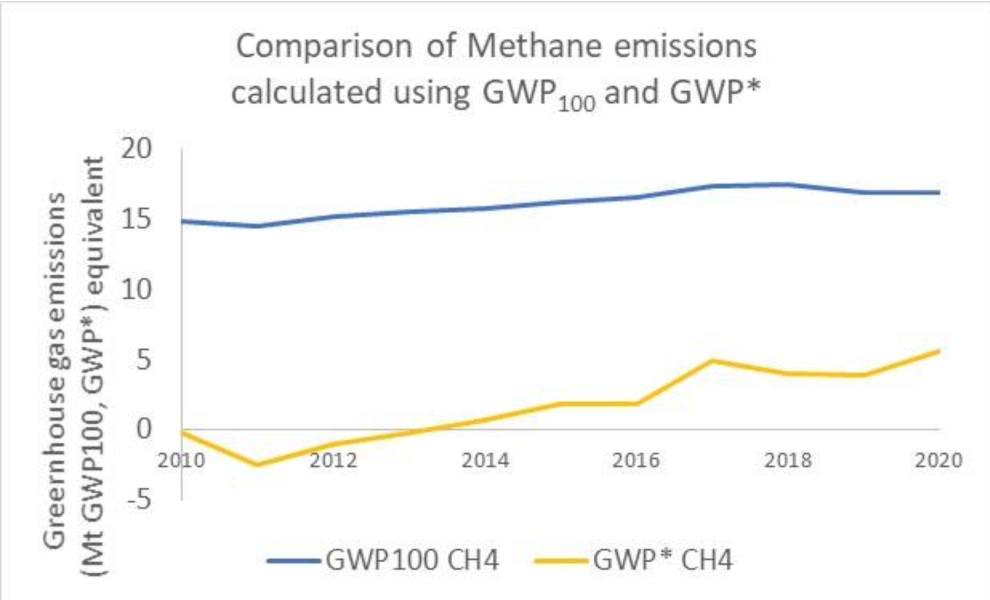


Figure 5-2 a) Comparison of the total national greenhouse emissions evaluated on the basis of Global Warming Potential evaluated over 100 year (GWP_{100}), and GWP. b) Comparison of the methane emissions evaluated on the basis of GWP_{100}, and GWP*.*

An illustrative scenario featured in Price (2021)[62] indicates that a 50% reduction in the rate of methane emissions in Ireland over the period to 2050 could contribute negative values of the order of -25 $MtCO_2$we per year for an extended period. This is significantly greater, than current total emissions of CO_2 and N_2O from the agriculture sector (~7.4 Mt CO_2e in 2019). However, as can be seen in Figure 5-3, negative values of GWP* gradually tend back to zero, as the climate responds to

[62] Price (2021) and Smith (2021). In press.

the lower concentrations of methane in the atmosphere. Smith (2021) reviews an alternative “split gas” approach to developing carbon budgets and finds a similar 50% reduction in the rate of methane emissions by 2050 would represent significant contribution to 2050 climate objective.

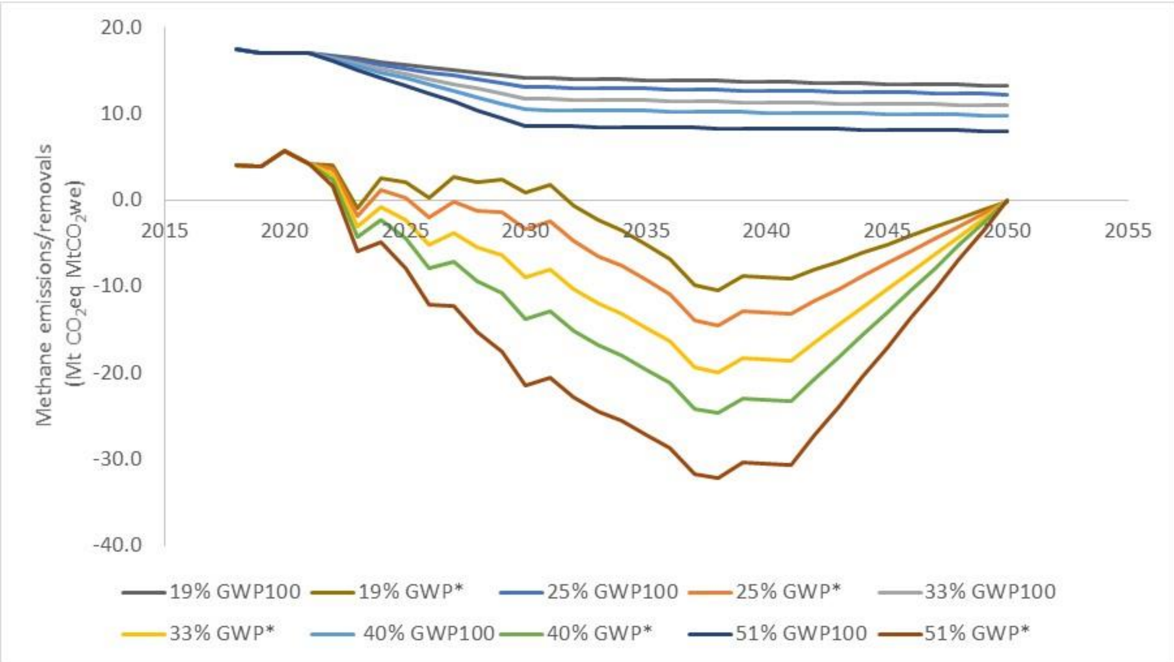


*Figure 5-3 Comparison between the assessment of methane emissions reduction on the basis of GWP100 and GWP**

A reduction in the rate of methane emissions can make a very significant contribution towards keeping Ireland within the carbon budget to 2050, as evident in Figure 5-3, where the GWP* metric gives a better representation of the climate impact. This is a similar finding to the analysis in Section 4.2 with respect to the contribution a reduction in the rate of methane emissions can make in limiting Ireland’s contribution to global warming. The extent of reduction requires value judgements with respect to Ireland’s ambition to contribute to global efforts to limit climate change, how rapidly other sectors can be decarbonised and a detailed assessment of the potential for negative emissions.

6 Carbon Dioxide Removals (CDR)

The IPCC AR6 WGI suggests that carbon dioxide removals are required to achieve the objective of keeping global temperatures to below the temperature goals set out in the Paris Agreement, as evident in Figure 6-1. [63] The report notes anthropogenic carbon dioxide removals (CDR) methods have the potential to sequester CO_2 from the atmosphere, also termed negative emissions. Negative emissions can be achieved through biological and technological methods. Biological negative emissions are achieved for example through afforestation, changes in forest management or changes to management of agricultural lands to enhance uptake of carbon by soils. Technologies for negative emissions include technologies such as Direct Air Capture (DAC) and storage. Carbon Capture and Storage with Biomass (BECCS) involves both biological and technological elements. Many CDR technologies have not been demonstrated at scale and therefore careful consideration is required before assuming deployment of these technologies will be feasible on a large scale.[64]

[63] *It is expected that the Working Group III report to be published in 2022 will consider negative emissions in more detail.*
[64] Bandilla, K. (2020) Carbon Capture and Storage. *Future Energy*, pp. 669-692. [online] https://www.sciencedirect.com/science/article/pii/B9780081028865000311

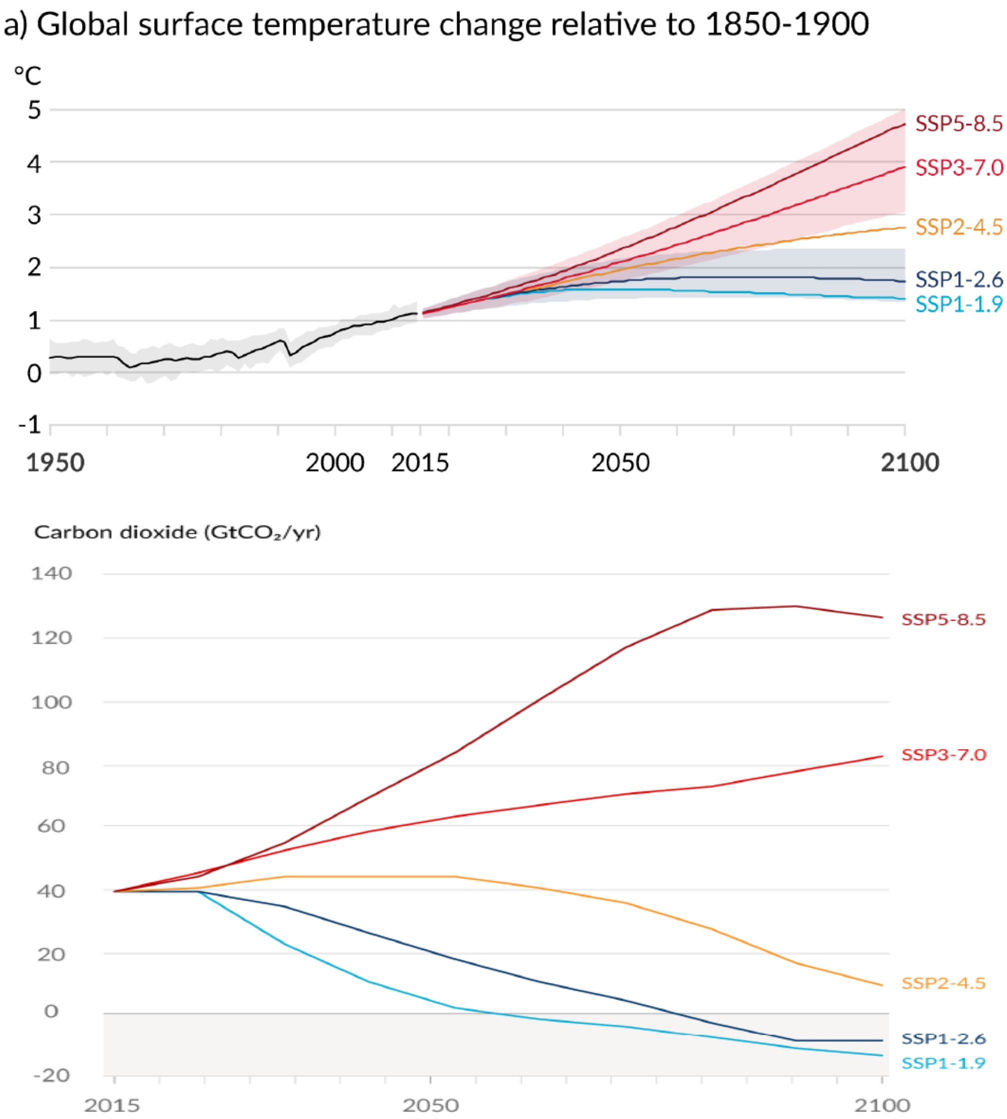


Figure 6-1 Upper panel: IPCC AR6 WGI SPM Figure 8(a) Projected global temperature change in response to emissions trajectories assumed in the Shared Socioeconomic Pathways, SSPS. Lower panel: IPCC AR6 WGI SPM Figure 6(a) Net global CO_2 emissions under each SSPS.

Negative emissions may be used to compensate for residual emissions to reach net zero CO_2 or net zero GHG emissions or, if implemented at a larger scale, to generate global net negative emissions. Reliance on and deployment of negative emissions is not without risk. Technological negative emissions have not been proven at scale, while biological negative emissions face competition for land use. Moreover, negative emissions methods can have potentially wide-ranging side effects on biogeochemical cycles and climate, which can either weaken or strengthen the potential of these methods to sequester CO_2 and reduce warming, as well as affect water availability and quality, food production and biodiversity. In considering an appropriate carbon budget envelope for Ireland out to 2050, it is prudent to adopt a cautious approach to the assessment of the magnitude of the potential for negative emissions in Ireland. Price (2021) suggests although there may be a large technical potential for negative emissions, an upper limit of 200 $MtCO_2$ would represent a challenging but feasible assessment for planning and budgeting purposes. Much of this potential would derived from the LULUCF sector in the medium term, saturating at approximately 100$MtCO_2eq$ cumulative removals, with negative emissions technologies becoming more prominent in the longer term.

The SeQUEsTER team in University of Limerick has explored the role of emissions and mitigation in land use in achieving climate neutrality targets for 2050, and how these align with carbon budgets, using the GOBLIN model.

Figure 3-3 shows the simple balance of emissions and removals (excluding CH_4) across agriculture, organic soils under grassland, wetlands and forestry associated with climate neutrality in AFOLU in 2050. Indicative scenarios are based on forestry removals needed to exactly balance residual emissions from AFOLU sources. Agriculture emissions are reduced by 25% (Ag-25) to 75% (Ag-75), whilst all exploited wetlands are rewetted and 25-75% (R-25 to R-75) of organic soils under grassland are rewetted to illustrate interactions and trade-offs across activities. Total removals required range from 3.8 to 11.4 Mt CO2 eq. annually, for Ag-75,R-75 to Ag-25, R-25 respectively.

The time series of net CO_2e flux from forests based on these scenarios is shown in *Figure 6-2*. Note that the "carbon cliff" in the baseline is a function of forest harvest cycles and arises later in GOBLIN than in EPA projections because GOBLIN is predicated on economically optimised (longer) rotations in line with historic trends. The timing of the "carbon cliff" will depend on future forest management but is not likely to substantially influence the 2050 balance calculations because the baseline forest trajectory post 2040 represents only a gradual improvement in balance. Meanwhile, it is clear that even at high planting rates of 32 kha/year for the Ag-25 R-25 scenario (*Figure 6-2* and Table 6-1), net removals are only ca. 1 Mt CO2e larger than for the baseline (5kha/year planting rate) by 2030. Nonetheless, this sustained rate of planting goes on to deliver an additional 11 Mt CO2e annually by 2050 – emphasising the important contribution of timely afforestation to climate neutrality targets (but not necessarily this programme of carbon budgets).

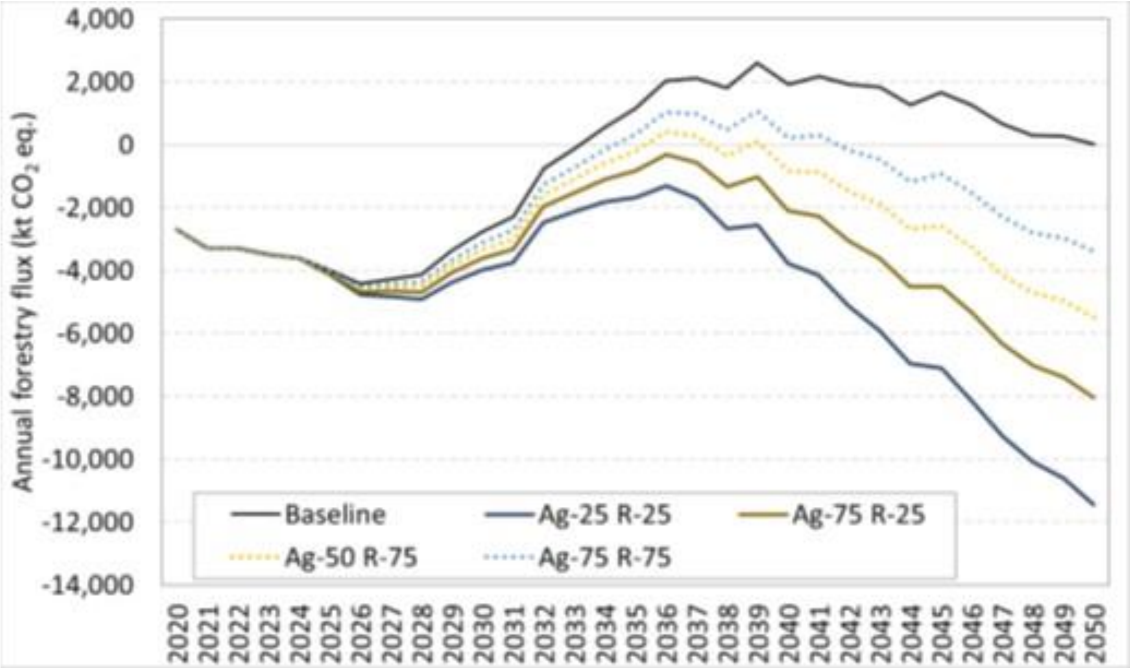


Figure 6-2 Trend in commercial-mix forestry net CO2e flux between 2020 and 2050 for planting rates (Table 1) needed to offset agricultural and organic soil emissions under the indicative scenarios. A baseline planting rate of 5 kha/yr from 2018 through to 2050 is also displayed for context.

Depending on the level of ambition in mitigation of AFOLU emission sources, AFOLU climate neutrality is likely to require sustained average rewetting rates for organic soils under grassland of over 8 kha per year, and sustained average afforestation rates somewhere between 13 and 33 kha per year, considerably higher than the Ag Climatise target of 8 kha/year. There is a considerable time-lag between forest planting and increased rates of CO_2 removal. Nevertheless, actions which achieve high levels of rewetting and afforestation in the next decade are largely assured to realise benefits in due course. Timely forest planting will be imperative to provide "headroom" for agricultural activities and residual organic soil emissions within the envelope of AFOLU climate neutrality by 2050. However it is nonetheless important that afforestation is carefully planned in order to avoid adverse impacts on biodiversity and water.

Concluding, it is clear that forest plantation rates need to significantly increase and that preparations need to be made for negative emissions technologies.

Table 6-1 Annual (bold), and aggregate to 2030 or 2050, levels of activity across organic soil rewetting and afforestation (70:30 or 30:70 conifer: broadleaf "commercial" or "conservation" mixes) needed to achieve climate neutrality in the AFOLU sector by 2050 in terms of GWP100 balance for CO2 & N2O. Afforestation rates rounded to the nearest 1000 ha.

	Organic soil rewetting			**Commercial-mix afforestation**				**Conservation-mix afforestation**			
Scenario	**Annual (ha/yr)**	**Aggregate 2030 (ha)**	**Aggregate 2050 (ha)**	**Annual (ha/yr)**	**Aggregate 2030 (ha)**	**Aggregate 2050 (ha)**	**Forest cover 2050**	**Annual (ha/yr)**	**Aggregate 2030 (ha)**	**Aggregate 2050 (ha)**	**Forest cover 2050**
Ag-25, R-25	**2,888**	23,103	83,750	**32,000**	160,000	800,000	22%	**40,000**	200,000	1,000,000	24%
Ag-75, R-25	**2,888**	23,103	83,750	**24,000**	120,000	600,000	19%	**30,000**	150,000	750,000	21%
Ag-25, R-50	**5,776**	46,207	167,500	**27,000**	135,000	675,000	20%	**33,000**	165,000	825,000	22%
Ag-75, R-50	**5,776**	46,207	167,500	**19,000**	95,000	475,000	17%	**24,000**	120,000	600,000	19%
Ag-25, R-75	**8,664**	69,310	251,250	**21,000**	105,000	525,000	18%	**26,000**	130,000	650,000	19%
Ag-50, R-75	**8,664**	69,310	251,250	**18,000**	90,000	450,000	17%	**22,000**	110,000	550,000	18%
Ag-75, R-75	**8,664**	69,310	251,250	**13,000**	65,000	325,000	15%	**16,000**	80,000	400,000	16%

7 Sectoral Engagement

The Carbon Budget Committee decided that it would conduct a process of sectoral engagement by way of bilateral meetings with various relevant Government Departments and Agencies such as Teagasc, SEAI and EPA. Meetings were held with the relevant bodies in respect of the Agriculture, Residential, Transport, Electricity and Industrial sectors over the course of June and July of this year. Members of the Carbon Budget Committee were invited to attend these meetings.

At each meeting the Secretariat gave a brief presentation explaining the process of designing and quantifying carbon budgets, clarified the precise role of the CCAC in carbon budget proposals more generally, outlined some possible sectoral implications and then took feedback in terms of issues that may need to be considered in further work.

After the meetings concluded the Secretariat reported back to the Carbon Budget Committee on its findings at the meeting of 5th July. They reflected that the engagement from all parties was very positive. The following common themes emerged from the sectoral meetings:

- The 51% target would seem to be at the limit of what is currently possible
- A need to understand clearly the inter-linkages between this process and the development of further actions under the National Climate Action Plan
- Concern around the sustainability of some employment opportunities that may arise if the implementation of the actions required was so compressed from a timing perspective
- Concerns around issues of supply chains in the context of multiple parties acting to address these issues concurrently
- The importance of the use of sectoral modelling and the need for expertise at sectoral level sense checking the outputs of such models

A range of sectoral issues of concern was also captured at each meeting. These were summarised and presented back to the Carbon Budget Committee by the Secretariat. The main points presented to the Committee for each sector are illustrated in Table 7.1.

Table 7-1 Main Points raised in Sectoral Engagement Process (June & July 2021)

Sector	Main Points
Agriculture	• DAFM recognises the need for mitigation in agriculture; reduction in N2O, action on LULUCF, energy substitution and reduction in CH4 • Due to limited technological options, at higher levels of ambition, mitigation is correlated with activity levels • Need a trajectory that is deliverable without disproportionate impact on output • LULUCF will need to be incentivised to deliver action • EU Common Agricultural Policy will be important but is not the whole solution • Impact on jobs will be greater than that estimated by McKinsey • Diversification is not straightforward – different land suits different types of farming. Big investments in machinery and human capital required to change from e.g. grass to tillage or horticulture • AFOLU has greater difficulty than other sectors in having mitigation actions reflected in the inventor
Electricity	• Security of supply concerns in electricity grid are acute • What part(s) of the economy do we need to slow down where no low carbon solutions exist yet? • Necessity to prepare for negative emissions • Importance of including estimation of grid costs – all scenarios require reinforcement of grid infrastructure • Onshore wind constraints due to new guidelines etc • Urgent need for offshore pilots to discover price • Important to ensure that low carbon solutions don't assume reliance on electricity imports as the interconnector capacity is very limited and market is unsure • Need to retain gas in the system for longer • Storage solutions needed; Hydrogen is the most likely contender • Impact on SMEs if electricity price rises
Enterprise & Industry	• What happens on the ground is different to what is technically feasible • Planning and licensing delays • Unit price of electricity in the model is different to price faced by companies – divergence of response • Limited opportunity for fuel switching vs. Price of gas might increase as less customers sharing the fixed costs; CHP has greater flexibility than the model shows vs Assumptions on biomass concerning • Ireland's electricity price higher than other EU MS and EU's are higher than world prices – implications for competitiveness with electrification • Food/drink compete in international market – cost increases from fuel switching etc could have implications • Also need to demonstrate internationally that Irish produce is clean green etc. • Questioned the economics of some required investments • CCS in cement/alumina is not feasible for 2030 • Question of where burden of cost lies

Residential	• Delivery of housing is one of the highest government priorities; overlap in skills needs • Overlap between low income and poorly insulated homes – affordability issues • Shallow retrofit – high risk of rebound effect • Would like to see more discussion of innovative solutions (with enterprise potential) such as mechanisation of retrofit solutions • Embedded life cycle emissions important too • The total number of households that have to be visited across shallow and deep retrofits and heat pump installations is a concern • Potential for shallow retrofit might be limited because of prevalence of hollow-block builds. • Assumed level of retrofit in CB1 is unachievable
Transport	• 1.5m EVs is very very big number (age of retirement of cars?) • TCO already there for high mileage drivers. Ireland ideal for EVs • Climate justice concerns for low income isolated households that can't afford EVs. How to deliver EVs in climate just way. • Concerns on high assumption on electric vans – limited options on market, and drivers constrained by weight limit on license (EVs are heavier) • Department modelling has less reliance on EVs and more modal shift to meet 51% target – due to affordability and willingness to pay concerns on EVs. • Livable cities is the 'easy' part; Need modal shift in the longer journeys to give emissions reduction results • Big changes required at provincial town level and therefore need to bring communities on board • Preference for backloading due to uncertainty on TCO shift happening in mid 2020s • Link between construction activity and transport levels

8 The Carbon Budget Committee

8.1 Mandate

The Climate Change Advisory Council agreed at its meeting on Friday 5th March to establish a Committee on Carbon Budgets. The Council agreed a Terms of Reference for the new Committee at its meeting on the 15th April 2021. The Committee was tasked with drawing up draft carbon budgets for the periods 2021-25, 2026-30 and 2031-35 (*CB1, CB2 and CB3 respectively*) to be considered by the Council. As part of this task, the Committee was mandated to include the criteria set out in the Climate Action and Low Carbon Development Act (2015) and the Climate Action and Low Carbon Development Amendment Bill (March 2021) in its consideration of carbon budgets. In drawing up the draft carbon budgets as above, the Committee was tasked by the Council to use the following methodological approach;

- Top-down: Estimate an appropriate carbon budget for Ireland for the period 2021 – 2050 based on consideration of the global carbon budget [addressing criteria: national climate objective, UN, Paris Agreement, science, climate justice]
    a. The global carbon budget
    b. The role of different gases
    c. The potential for negative emissions
- Bottom-up: Consider what legislative requirements at national and EU level mean for emissions up to 2030, covering the first two carbon budgets. [addressing criteria: national climate objective, 51%, EU, inventories and projections, science, reporting, economy, and climate justice]
    a. The implication of required compliance with EU and National Targets (e.g. 51%) incl. treatment/inclusion of LULUCF
    b. Feasibility, competitiveness impacts, implications for investment
    c. Distributional impacts, jobs

It was agreed that the starting point for addressing the bottom-up part of the mandate would be to undertake scenario modelling using the UCC TIMES Ireland Model, and other sectoral models such as the Teagasc FAPRI Ireland model.

8.2 Membership

The Council considered and agreed a list of individuals to be invited to join the Carbon Budgets Committee based on the anticipated requirements for expertise in this area. Subsequent to the establishment of the Carbon Budgets Committee a limited number of further members were invited. All Council members (and observers to the Council) were also invited to attend. All invited members are listed in Table 8-1. The meetings of the Carbon Budget Committee also benefited from the input of the Carbon Budget Research Fellows, Paul Price and Andrew Smith and a number of useful presentations from other organisations. All presentations to the Carbon Budgets Committee can be found on the Council's website.

Table 8-1 List of Invited Members to the Carbon Budgets Committee

Name	Organisation
Marie Donnelly (chair)	CCAC
Alan Matthews	TCD (Emeritus)
Lisa Ryan	UCD
Brian Ó Gallachóir	UCC
Aoife Ahern	UCD
Stephen Treacy	EPA
Jim Scheer	SEAI
Keith Lambkin	Met Éireann
George Hussey	DHLHG
Aoife Parker Hedderman	DECC
Trevor Donnellan	Teagasc
Bill Callanan	DAFM
Hannah Daly	UCC
Kevin Hanrahan	Teagasc
David Styles	UL
Frank O'Mara	Teagasc

8.3 List of work

- A report of work done by the Committee and Council against the methodology

Table 8-1 A report of work done against the methodology: Top Down

<table>
<tr><th colspan="2">Committee Mandate</th><th>Statement of work done</th><th>Conclusions</th></tr>
<tr><td rowspan="2">Top Down</td><td>The global carbon budget</td><td rowspan="2">A common approach was taken to the assessment of both the global carbon budget and the role of different gases as these have been substantially dealt with in the IPCC literature. The Committee received and considered a literature review addressing the global carbon budget and the role of different greenhouse gases from each of two CCAC Carbon Budget fellows (Price (2021) and Smith (2021). An expert meeting was held on 22nd June with international speakers including Dr. Andy Reisinger, NZ/IPCC, Dr Joeri Rogelj, ICL, Prof. Myles Allen, Oxford, and Mr. Florin Vladu, UNFCCC. A note of the meeting was provided by Met Eireann.</td><td>A global carbon budget consistent with the Paris temperature goal of making efforts to reach 1.5C can be considered as scenarios giving a 50% probability of staying within the 1.5C limit and 67% of staying within the 2C limit. The global carbon budget in such scenarios is estimated at approximately 440 Gt, the upcoming IPCC 6th Assessment Report may update this understanding.</td></tr>
<tr><td>The role of different gases</td><td>Every gas, every emission, every day matters. Each greenhouse gas must see a reduction in emissions. The long lived gases have to reduce to net zero. Methane is a potent greenhouse gas while it remains in the atmosphere but is a short lived gas. Therefore, a reduction in the rate of methane emissions can lead to a reduction in the historic warming impact. This will be a necessary tool nationally and globally to meet Paris objectives.</td></tr>
<tr><td></td><td>The potential for negative emissions</td><td>The potential for negative emissions were assessed within the literature review prepared by Research Fellow Paul Price, DCU. Additional consideration to the current state of play and the physical potential LULUCF have been discussed at a meeting of LULUCF experts convened by the Secretariat on 3rd June at the request of the Committee. Conclusions from this engagement was fed back to the Committee at its meeting on 14th June.</td><td>Both natural and technological negative emissions will be required. The literature suggests a prudent estimate of the potential available to Ireland up to 2050 is 200Mt</td></tr>
</table>

Table 8-2 A report of work done against the methodology: Bottom Up

Committee Mandate		Statement of work done	Conclusions
Bottom Up	**The implication of required compliance with EU and National Targets (e.g. 51%) incl. treatment /inclusion of LULUCF**	Prof. Brian Ó Gallachóir provided the Committee with an analysis of the existing and future EU targets, where national targets remain under negotiation. He also provided the Committee analysis of pathways to reach the 51% emission reduction target. Teagasc provided analysis of various scenarios of an agricultural sector contribution to meeting the 51% target while Dr. Hannah Daly provided analysis of complementary scenarios of varying energy sector contributions to meeting the 51% target. Further explanation of the scenarios analysed for the Committee and their results are discussed in section 4.	All scenarios modelled are mathematically compatible with achieving the 51% emissions reduction target by 2030. The proposed target for Ireland under a revision of the EU Effort Sharing regulation, at 42% is less ambitious than the national target. Sectoral allocation does not appear to have a major impact on total budget to 2030. The modelling suggests that the core scenario pathways, described in section 5, are the most feasible and cost-effective way to meet the 2030 51% emission reduction target. Setting greater ambition in CB1 would not allow sufficient time for investment in technologies to deliver the emissions reductions required. Less ambition in CB1 would leave an infeasible amount of mitigation to be achieved in CB2. The carbon budgets proposed for CB1 and CB2 are consistent with achieving the 51% emission reduction and compliance with anticipated increased ambition under the EU Climate Law according with current understanding of the same. All three proposed carbon budgets are consistent with the national climate objective to reach climate neutrality by 2050.
	Feasibility, competitiveness impacts, implications for investment	A common approach was taken to addressing the feasibility, competitiveness impacts, implications for investment, distributional impacts, and jobs due to the common inputs required. • The Committee requested modelling of carbon budget scenarios by 3 groups; UCC TIMES Ireland Model (TIM),	Ambitious action required of all covered sectors in all scenarios. However, there are a variety of technically feasible pathways to comply with the budgets recommended here. If appropriately implemented, the impacts on competitiveness and the attractiveness of Ireland for investment could be positive.

		Teagasc FAPRI-Ireland and UL Goblin model. These scenarios and runs were informed by data and insights from EPA inventory and projections	
	Distributional impacts, jobs	• The Committee requested ESRI to use scenario outputs from the TIM model to inform further economic analysis. • Teagasc provided input on mitigation potential, the economic and social profile of the agriculture and associated food/drink sector and the economic implications of different levels of mitigation. • A small scale study with UCD focussed on investment and jobs impacts of TIM energy modelling outputs • McKinsey provided analysis focussed on employment, the attractiveness of the State for investment and the long term competitiveness of the economy. • The Committee heard presentations from DFHERIS and SOLAS on skills on 28th June, training and higher education capacity and requirements to support the delivery of carbon budget ambition	The Committee requested an analysis of the distributional impacts both from McKinsey and the ESRI. There will be big changes in the job market, with loss of jobs in some sectors and gains in others. 1) Ireland has historically experienced full employment and therefore there may be competition between sectors to secure the labour necessary to deliver low carbon transition (e.g. in the construction sector) 2) It is not straightforward or easy for those losing jobs to change career. It will be important to identify the vulnerable sectors and prepare those workers for transition to alternative employment Detailed policy framework and significant educational and training infrastructure in place to response to workforce need from decarbonisation. As critical as identifying defined future needs is ensuring skills infrastructure sufficiently responsive, flexible and agile for rapidly evolving landscape