Irish Fiscal Advisory Council

What climate change means for Ireland's public finances

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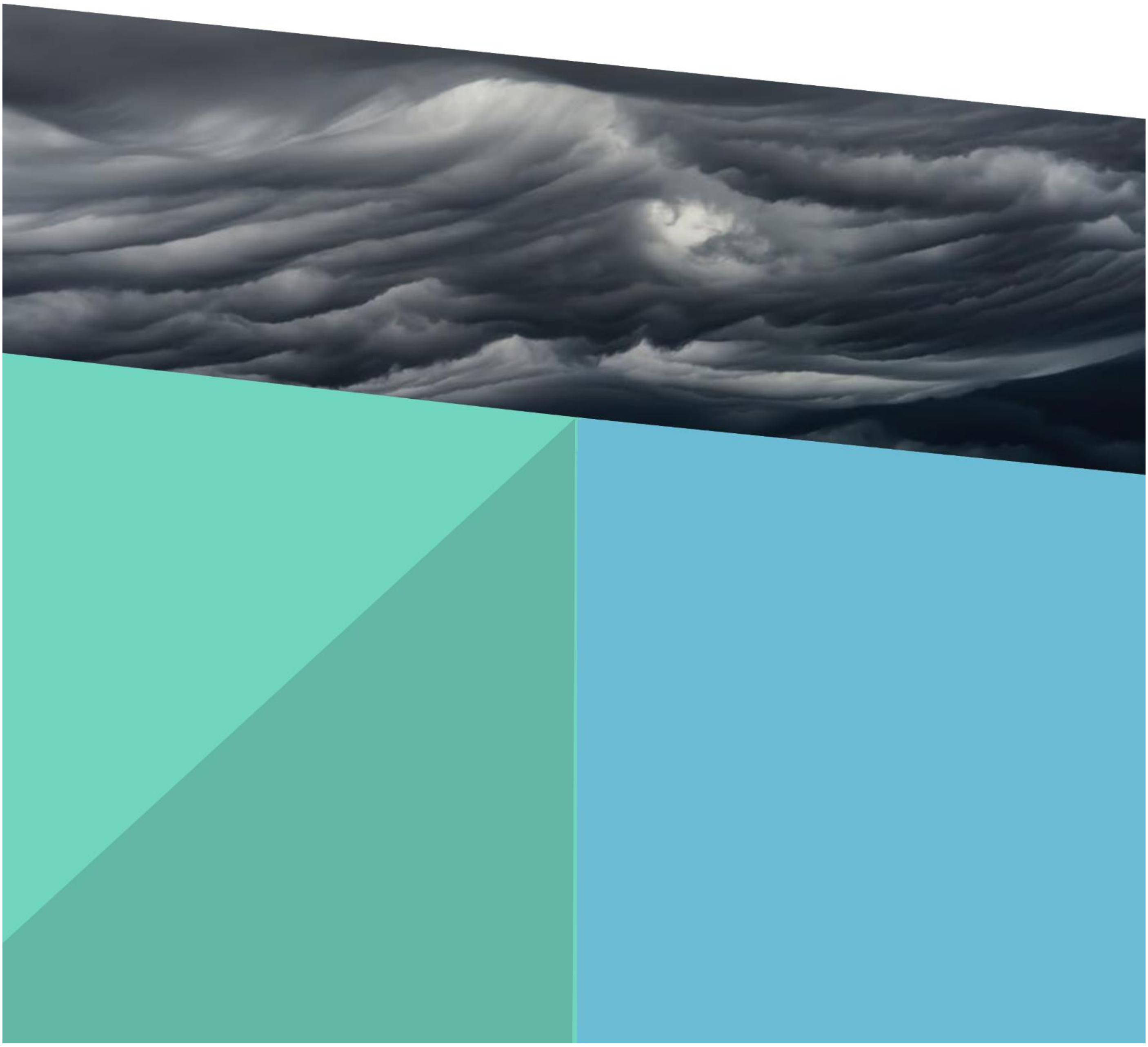

This paper is part of a new series of research outputs that supports the Council's assessments of the long-term sustainability of the public finances.

The series is specifically intended to provide analysis and research that feeds into the Council's Long-term Sustainability Reports.

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Executive summary

The climate is changing. Long-run data points to clear trends in Ireland of rising temperatures, increased rainfall, and more frequent extreme weather events.

A changing climate in Ireland and globally will impact the Irish economy and the public finances. There will be some costs associated with the transition to a less carbon-intensive economy, with the possibility of not hitting legal requirements, and from facing up to more regular extreme weather events. Of course, there will also be opportunities in moving towards a more sustainable growth model, including through lower imports of fossil fuels and less pollution.

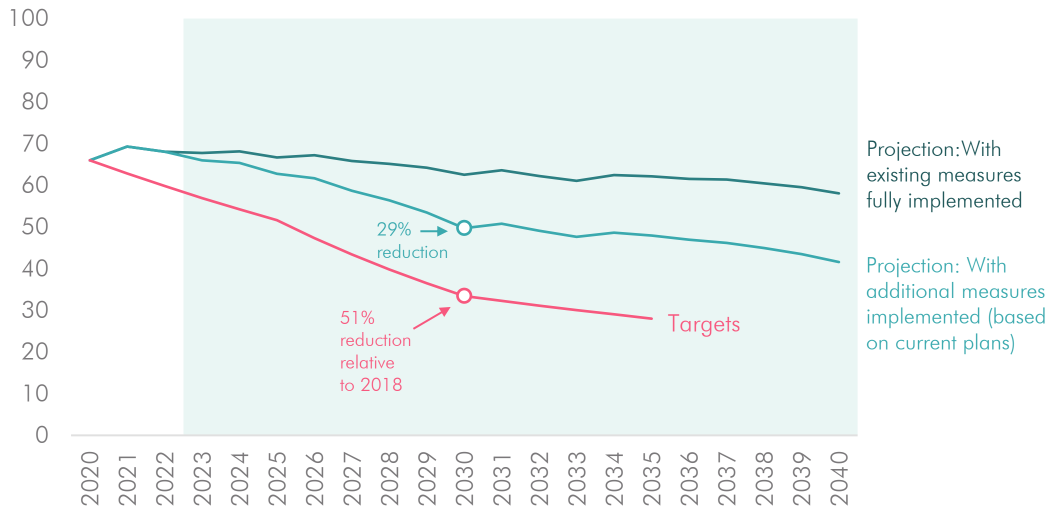
Assessing the likely impacts related to climate, we consider three avenues through which the public finances will be affected:

1) Compliance costs

Ireland is legally bound to achieve carbon neutrality by 2050 and to stay within three sequential carbon budgets between 2021 and 2035. These require greenhouse gas emissions to be reduced by 51% by 2030 compared to 2018 levels.

However, projections for Ireland based on existing plans show it missing its requirements. These indicate a reduction of just 29% by 2030. Failing to meet these targets would incur some compliance costs. Estimates by Walker *et al.* (2023) put the costs at an annual average of about €0.35 billion up to 2030, when costs rise to €0.7 billion (0.2% of GNI*).

Current policy is not sufficient to meet targets
Levels of greenhouse gas emissions (Mt CO_2eq)

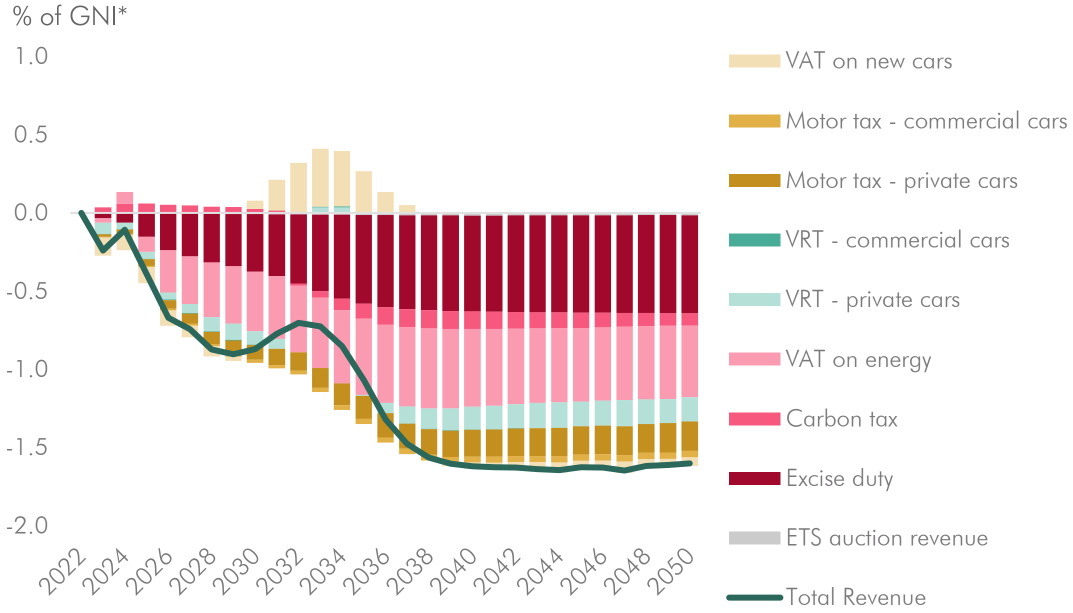


2) Transition costs

Even if Ireland's climate targets are met in full, there will be a range of substantial impacts on the public finances.

First, on the revenue side — and assuming unchanged tax rates — meeting Ireland's climate targets could see tax revenues reduced by 0.9% of GNI* (€2.5 billion in today's terms) per annum by 2030. This would rise to as much as 1.6% of GNI* (€4.4 billion) per annum in the long run.

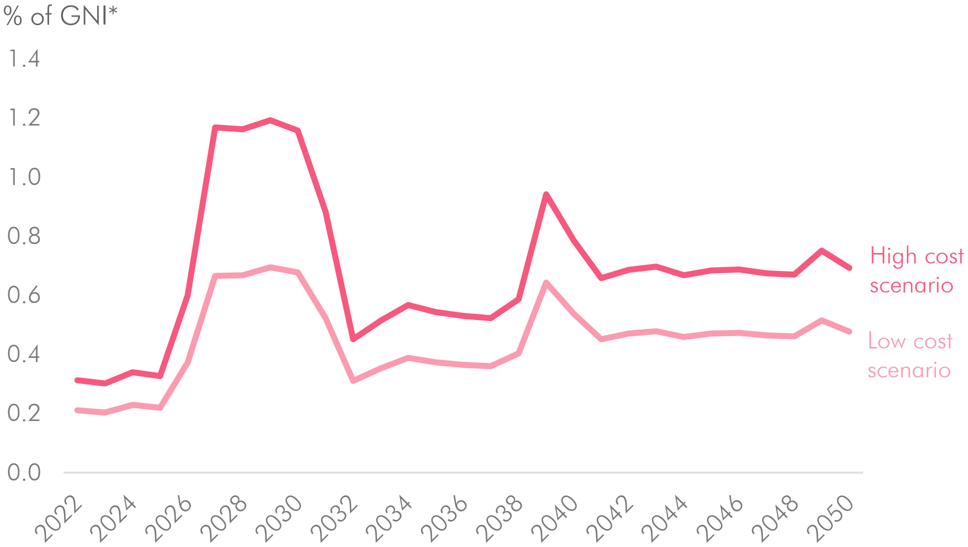
Climate transition sees a 1.6% of GNI* reduction in revenue



Most of this is due to a few factors: 1) a sharp decrease in tax on fuel and energy use, which stems from lower excise duties and reduced petrol and diesel consumption, 2) the lower VAT rates on electricity, and 3) the decrease in vehicle registration tax and motor tax, which are both tied to emissions under current policies.

Second, on the spending side, the Government will also likely need to provide substantial supports if Ireland's climate targets are to be met. Some of the adjustment will be carried out by the private sector. That is, many of the actions needed will sufficiently benefit private households and businesses as to be financially cost effective without Government intervention. However, a lot of the actions needed will have to be taken rather quickly, further tightening financial constraints on households and businesses. Depending on the extent of private sector involvement, we estimate that the Government may face costs of between 0.6 and 1.1% of GNI* (€1.6 to 3.0 billion in today's terms) per annum over the years 2026 to 2030. These costs could then average between 0.4 and 0.7% of GNI* (€1.1 to 1.9 billion in today's terms) over the longer term from 2031 to 2050.

Public expenditure related to the climate transition is likely to rise



3) Physical Risks (costs associated with extreme weather events)

There could also be additional costs arising from the State having to provide supports to respond to more frequent and more adverse extreme weather events.

Ireland has seen an increase in major weather events over time. Increased rainfall and rising temperatures carry risks of more regular flooding and wildfires. When these events occur, the costs associated with them could be in the region of 0.2% of GNI* (about €0.5 billion in today's money). Limiting these risks could require further adaptation costs beyond the €0.1 billion per annum allocated for flood defences in the National Development plan.

More work is needed

The estimates presented here are very much provisional attempts to estimate the fiscal impacts associated with climate change and the climate transition. This work is a first step. There is much to be done to better understand the impacts of climate change on the public finances. In this context, we are mindful that many of the costs look set to emerge towards the end of this decade — a period not too distant, but one generally not covered by official budgetary forecasts.

We hope to continue to develop this work and further refine our estimates in time — including by allowing for various indirect effects, such as the impact on economic activity from higher investment and lower taxes — and we welcome further feedback on our approach.

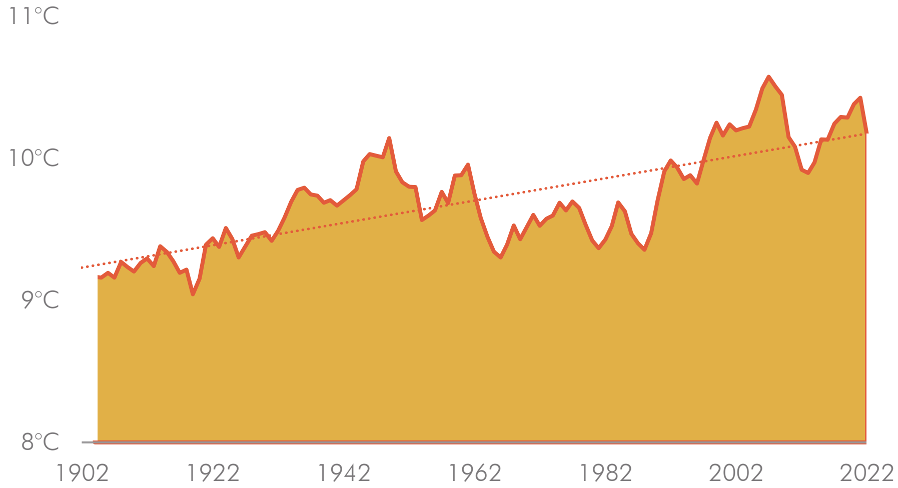
1. Ireland's climate is changing

Ireland's temperatures are increasing, rainfall levels rising, and extreme weather events appear more frequent.

Ireland is getting hotter. Temperatures for the past twenty years have averaged 10.2 degrees Celsius annually — 0.5 degrees higher than the previous 50-year average (Figure 1). Projections suggest annual average temperatures could rise closer to 11 degrees by 2050 (EPA, 2020).

Figure 1: Ireland's temperatures are rising

Annual Island of Ireland temperatures in degrees Celsius, five-year trailing average



Sources: Met Eireann; and own workings.
Notes: A linear trend line based on the five-year trailing average is shown here. The long-term average for 1961–1990 (9.5 degrees Celsius) is often used as a fixed reference period in climate change studies.

Ireland also appears to be getting wetter. Ireland recently experienced its wettest decade in 300 years and rainfall levels seem to be on an upward trend when viewed over a long period (Murphy *et al.*, 2018).[1] Assessing the trends further, Domonkos *et al.* (2020) find that Ireland is having significantly higher rainfall in winter and spring, but drier summers.[2]

The winter of 2015–16 saw some of the worst flooding in Ireland's history. Clarke and Murphy (2019) note that flooding continued in some regions into March 2016. Infrastructure damages amounted to approximately €106 million, with over 1,100 properties flooded. This outdid the previous worst flood on record, which took place in November 2009. More recently, Ireland experienced its wettest every July on record this year, with rainfall levels for the month more than double historical

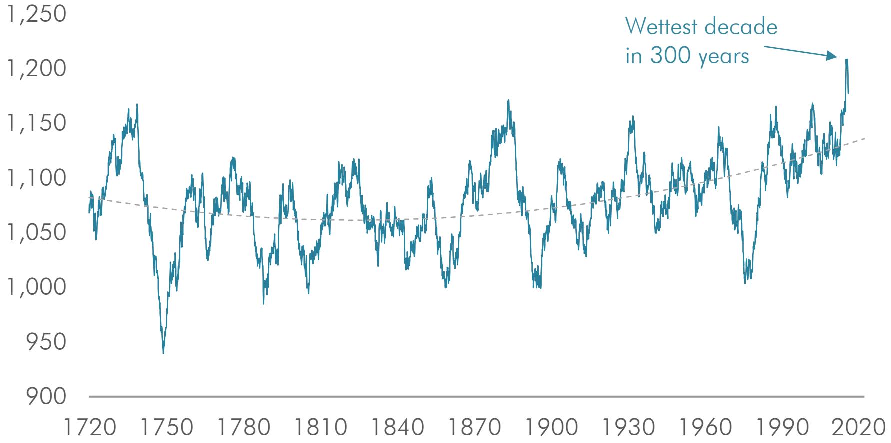
[1] The last period consistent long-run data were recorded for was 2016 and the wettest rolling ten-year period recorded was 2006 to 2015.

[2] One caution in the literature is that seasonal patterns may be influenced by temperature-related biases in early records that lead to an under-catch of snowfall.

norms. The same month also saw the highest temperature recorded in Ireland since 1887.[3]

Figure 2: Rainfall levels are increasing

Average annualised rainfall in millimetres (ten-year moving averages)

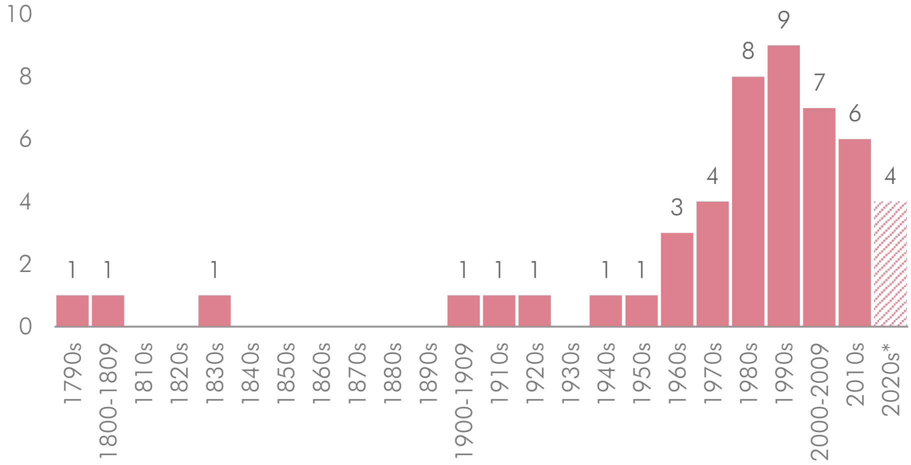


Sources: Murphy *et al.* (2018); own workings.
Note: The trend line is a second-order polynomial fitted to the decadal data of Murphy *et al.*, (2018).

There is also evidence that severe weather events are becoming more frequent. Met Eireann—Ireland's meteorological service—documents major weather events over time. Records begin with the exceptional summer of 1798 and show that "major" weather events have become more common (Figure 3). Since the 1970s, there has been an average of five to six major weather events recorded each decade. This could in part be affected by increased reporting, with better record-keeping, instrumentation, and more resources dedicated to meteorology.

Figure 3: Major weather events appear more common

Number of reported major weather events



Sources: Met Éireann; own workings.
Notes: Major weather events included here are those recorded under Met Eireann's online dataset, except for the D-Day landings and the Irish Famine. The data for the 2020s are incomplete, with the last event the July 2022 "Highest Temperature Recorded in Ireland since 1887".

[3] The rainfall records are based on data back to 1940 and the long-term average is based on the 1981 to 2010 reference period (Met Eireann, 2023a). The temperature reading was reported on separately (Met Eireann, 2023b).

The evidence for Ireland chimes with global developments.

There is broad consensus in the scientific community that global temperatures are rising, and that continued climate change could lead to catastrophic risks (IPCC, 2014; 2018).

Unless efforts are made to prevent further warming, global temperatures are expected to reach 3–4°C by 2100 (IPCC, 2014). It is likely that warming will exceed 1.5°C this century (IPCC, 2023). Some estimates point to a low probability — just a 5% likelihood — that a target of keeping temperatures below 2°C can be achieved (Raftery *et al.*, 2017).

There is considerable uncertainty. The increase in temperatures could be higher still, with the effects more devastating. There is some concern that catastrophic outcomes are not captured sufficiently in most studies (Stern, 2013). Tipping points — thresholds beyond which more catastrophic outcomes can occur — are believed to exist. These tipping points are already possible and may become more likely within the range of warming of 1.5 to 2.0°C (OECD, 2022). These could mean a pick-up in the speed that temperatures rise beyond some tipping point.

2. How climate change will affect the economy

A changing climate will impact the Irish economy and the public finances.

Dealing with a changing climate is likely to be very costly. However, there will also be opportunities in moving towards a more sustainable growth model, including through lower imports of fossil fuels and less pollution related to emissions.

It helps to use a framework to think about the risks of climate change. To map the potential effects of climate change on the Irish economy and the public finances, we draw on existing work developed by Hogan (2023); McInerny (2022); the European Commission (2019); the Office of Budgetary Responsibility (2021, 2019); Batten (2018); and Carney (2015).

How might climate change affect long-run growth?

As a start, it is useful to think of the impact of climate change on the economy in terms of its effects on long-run growth. That is, how the supply-side aspects of the economy are likely to be affected. In other words, how will things like workers, infrastructure and productivity be affected?

Long-run growth can be thought of as depending on four factors of production: land, labour, capital and productivity. These factors of production are the building blocks of the economy: what we draw on to produce goods and services. Figure 4 outlines how each of these building blocks could be affected by climate change.

Figure 4: How to think of long-run growth impacts of climate change

Land — or natural resources more generally—could dwindle if excessive dry weather, rainfall, or rising sea levels reduces the viability to access and produce basic inputs. For example, this could lead to food, water, and energy shortages. In addition, there could be a greater scarcity of land due to competing land use requirements for reforestation and renewable energy infrastructure. This could raise the relative price of goods and services that have intensive land use.

Labour — that is the amount of work hours exerted—could fall if worker health deteriorates or if deaths result from climate change. There could also be positive or negative impacts associated with changing migration trends. For instance, the number of workers in the Irish economy could increase for a time if younger workers move to Ireland due to relatively better climate outcomes here relative to elsewhere. This would be expected to boost growth. However, there are major uncertainties about the relative impacts of climate change across countries.

Capital — meaning human-made machinery, equipment, and buildings we use to produce goods and services. This could be subject to damage from more adverse weather conditions. It might also have to undergo radical changes to reduce emissions and adapt to a new climate.

Severe weather events such as storms, floods, or fires, for example, could lead to direct damages to infrastructure. If the climate becomes persistently worse, it is possible that infrastructure deteriorates faster than in the past. This would entail an acceleration in depreciation rates. These impacts could reduce the human-made resources that are available to produce goods and services across the economy.

In addition to these direct physical risks, there are risks associated with how we transition to a new climate. Simply responding to the changing climate might require more efforts being exerted in terms of adapting old capital. This emphasis on adapting old technologies could come at the expense of missing out on creating or adopting new technologies. For example, replacing coal and gas plants with clean energy technologies that produce the same output (energy) would mean foregoing capital that could be used to invest in producing other assets. An over-ambitious plan for switching to lower carbon technologies could lead to lower new investment in the short run with longer-term consequences for the capital stock (Lane, 2019).

Productivity — the long-run engine of growth — could be affected by climate change in many ways.

1) Poorer health could impair how productive people are. Air pollution has been linked to decreased productivity in both blue-collar and white-collar jobs (He *et al.*, 2019; Change *et al.*, 2019).

2) Higher temperatures are understood to benefit labour productivity up to a point before sharp falloffs are observed. Optimal temperatures are estimated to be between 12–15°C (Kumar and Khanna, 2019; Burke et al., 2015; Zhang et al., 2018; Letta and Tol, 2018).

3) Adapting to climate change can mean that people are diverted away from activities that boost productivity. For example, rather than pursuing Research and Development, people may have to shift towards mitigation efforts, repairing damages, and shifting to cleaner variants of existing technologies. That said, a faster uptake of new technologies could be beneficial in other ways. For example, it could improve Ireland's energy security.

4) International trade has tended to be associated with higher productivity growth. However, trade could be negatively impacted by moving away from traditional forms of carbon-intensive transport as well as by natural disasters (Gassebner *et al.*, 2010, Oh and Reuveny, 2010).

There are risks that changes to the climate itself could be more pronounced than is currently considered. In addition, the long-run impacts of climate change on the economy are highly uncertain and may turn out to be more severe than predicted even with the scenarios currently envisaged. There are risks that delayed action on climate change globally could severely impact the long-term growth of the economy.

How might climate change affect short-run growth?

In the short run, demand side aspects of the economy could also be affected by climate change. Some obvious channels are:

Wealth effects: Major weather events could mean that consumer spending falls, given negative wealth effects, for example, from damage to property. Negative wealth effects could also harm business investment due to damages to physical assets (buildings, machinery and equipment, inventories) and impacts on financial assets (rising insurance premia, reduced values of stocks, bonds, other financial instruments). While expenditure might increase to repair damaged assets, this would most likely be at the expense of other expenditure or investment.

One potential avenue through which wealth effects might take place is through stranded assets. Certain assets like petrol and diesel motor vehicles might lose value more rapidly than previously was the case. This may occur due to changes in taxation, outright bans, or through the reduction in availability of the petrol and diesel supply network.

These stranded assets could result in lower consumer spending and business investment as they would have to absorb the depreciation of the asset more quickly than would otherwise be the case.

Trade disruptions: Trade may be disrupted because of extreme weather events. Extreme weather events could alter the yields from various food crops globally causing disruptions to the supply of food (Adaptation Without Borders, 2023). Trade routes may also be altered by extreme weather events.

Uncertainty effects: A more volatile climate could result in higher levels of uncertainty. This, in turn, could depress consumer and investment spending. Uncertainty about tomorrow's demand and growth prospects could mean less incentives for businesses to invest today.

Preference effects: Consumers may reduce consumption of high carbon intensity goods and services or indeed switch away from these goods and services and towards greener products. This may reduce or alter the composition of consumption and affect domestic suppliers of these goods and services (positively or negatively).

Price effects: The volatility of prices may increase due to extreme weather events. This could be particularly the case for food and energy products. Price surges could also occur from an increased demand for products which are vital for the climate transition but are temporarily in short supply.

Transitioning to renewable energy sources that are domestically located may lead Ireland to be less susceptible to energy price shocks. The oil and gas price shocks that Ireland experience in the past will no longer be a source of vulnerability for the Irish economy. This may reduce the volatility of output and inflation.

3. Ireland's climate targets

Given the changing climate, and the potential wide-ranging impacts it could have, Ireland and other countries have agreed to targets for reducing greenhouse gas emissions. These targets are intended to limit the negative consequences of climate change.

Several high-level international targets to address the risks of climate change have been set out. These include the Kyoto Protocol, the Copenhagen Accord, and the Paris Agreement.

The 2015 Paris Agreement is the most recent of these international climate targets. It sets out a framework to limit the increase in global temperatures to well below 2°C and to pursue efforts to limit temperature increases to 1.5°C relative to pre-industrial levels.

Ireland's national climate targets

Under the *Climate Action and Low Carbon Development (Amendment) Act 2021* Ireland has a legally binding target of climate neutrality by 2050.

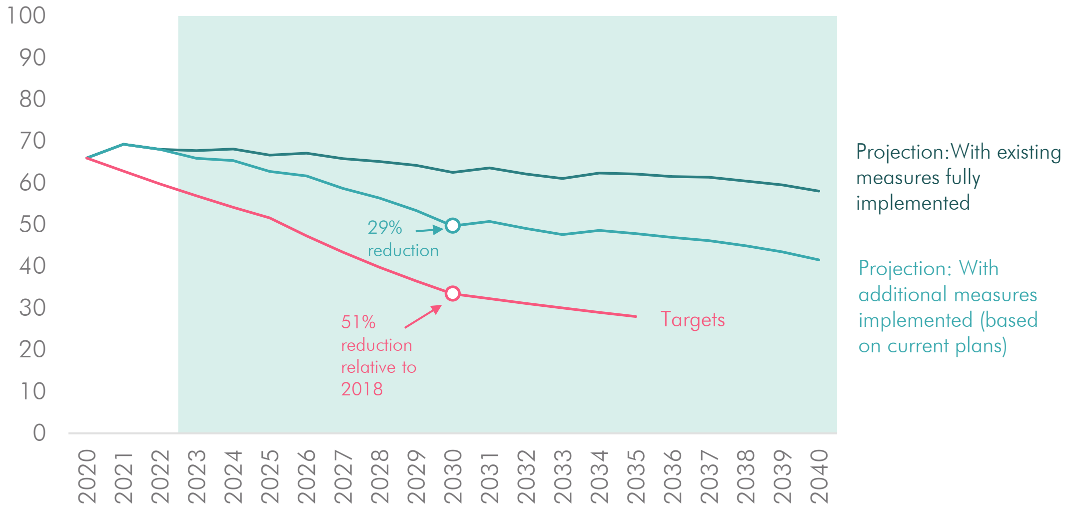
In addition, Ireland has set legally binding carbon budgets. These would see a 51% reduction of greenhouse gas emissions relative to 2018 by 2030. The carbon budgets limit the amount of greenhouse gas emissions Ireland can emit over a period of time. Any emissions over the carbon budget limits, will have to be made up through lower-than-budgeted emissions in later periods.

These targets are consistent with Ireland's requirements under the EU's "Fit for 55" legislative package to reduce EU greenhouse gas emissions by 55% by 2030, relative to 1990 levels.

However, the reduction in greenhouse gas emissions required under these targets will not be reached based on plans set out to date. The latest projections by the Environmental Protection Agency (EPA, 2023) suggest that — based on plans to date — Ireland will only reduce greenhouse gas emissions by 29% by 2030, well short of the 51% target (Figure 5).

Figure 5: Current policy is not sufficient to meet targets

Levels of greenhouse gas emissions (Mt CO_2eq)



Sources: Environmental protection agency (2023); Climate Action Plan 2023 (DECC, 2022); and own workings.
Note: Targets incorporates the necessary annual reduction in emissions to comply with the three sequential carbon budgets. Any emissions over the carbon budget limits, will have to be made up at later periods. With existing measures or "WEM" projection scenario produced by the EPA projects emissions based on measures implemented by the end of 2021 (the last inventory year). With additional measures or "WAM" scenario produced by the EPA which incorporates measures included in Government plans that are not yet implemented.

The Government agreed three five-year carbon budgets in February 2022, which were consistent with Ireland's climate targets. These budgets were then approved by the Oireachtas in April 2022, and took effect from 6th April 2022.

In July 2022 the Government agreed sectoral emissions ceilings consistent with the carbon budgets for the periods 2021–2025 and 2026–2030. However, an additional 5.25 Mt CO2eq in annual savings remains unallocated for the period 2026–2030 pending additional abatement measures being identified before this period starts. The Climate Change Advisory Council noted this was a cause for concern and that these unallocated savings needed to be assigned urgently (CCAC, 2023).[4]

These current ceilings require a reduction of approximately 75% of greenhouse gas emissions for the electricity sector by 2030, and a reduction of approximately 25% for the agricultural sector. The Climate Change Advisory Council (2021, p.29) noted that a scenario where agriculture reduced its emissions by 19%, close to but below the current requirement, and the energy sector by 69% would be estimated to result in marginal abatement costs that were extremely high for the energy sector. Indeed, the costs led the modelling groups to express serious reservations as to the practical feasibility of such a scenario.

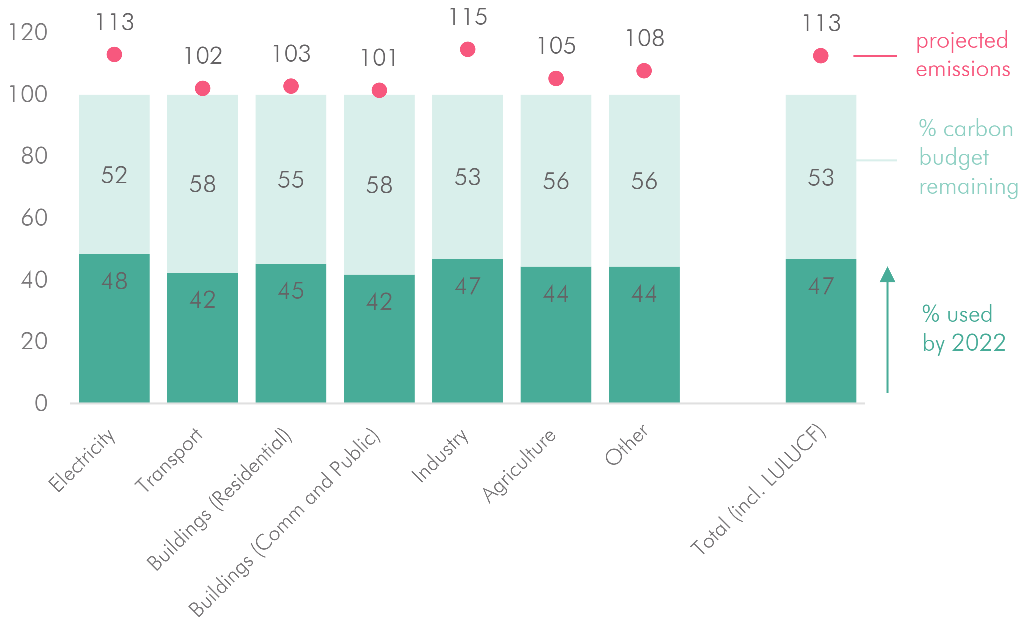
However, all sectors are set to exceed their emissions ceilings based on plans set out to date (Figure 6). The first five-year carbon budget, covering the period 2021–2025, is set to be exceeded by 13% based on these

[4] The Climate Action Plan 2023 commits to assigning these unallocated savings by the end of 2023.

plans. After just two years of the first five-year carbon budget period, 47% of the available carbon budget has been used up. The latest projections based on current policies would also see Ireland exceeding the second carbon budget (2026–2030) by 40%.

Figure 6: All sectors look set to exceed 2021-2025 carbon budgets

% of sectoral emissions ceilings for 2021–2025



Sources: Environmental Protection Agency (2023); Climate Action Plan 2023 (DECC, 2022); and own workings.
Note: Other includes Waste, F-gases, and petroleum refining. Projections are based on the with additional measures (WAM) scenario produced by the EPA. LULUCF is Land Use, Land-use Change and Forestry.

4. Budgetary Impacts of Climate Change

Climate change can have a wide variety of budgetary impacts. A useful way to think about these potential impacts is through the frameworks developed by the Bank of England (Carney, 2015; Batten, 2018) and used by the UK's Office for Budget Responsibility (OBR, 2021, 2019) to assess risks related to climate change.

The framework differentiates between two types of risks:

Transitional risks result from the costs/benefits of adjustment towards a lower emissions economy.

Physical risks relate to the impact of climate and extreme weather-related events that damage property, infrastructure and disrupt regular economic activity including trade. These risks could result in discrete or one-off periodic shocks to a given baseline, as well as ongoing costs to mitigate these risks.

Along with these two risks we consider a third:

Compliance Risks which cover the potential costs of not achieving required reductions in emissions.

4.1 The fiscal impacts of the climate change transition

While Section 3 discusses some potential fiscal costs from not meeting Ireland's climate targets, this section assumes Ireland meets its climate targets and assesses the fiscal impacts of such a scenario. However, not meeting the current climate targets may incur greater fiscal costs down the line to catch up with the trajectory for emissions required under international agreements.

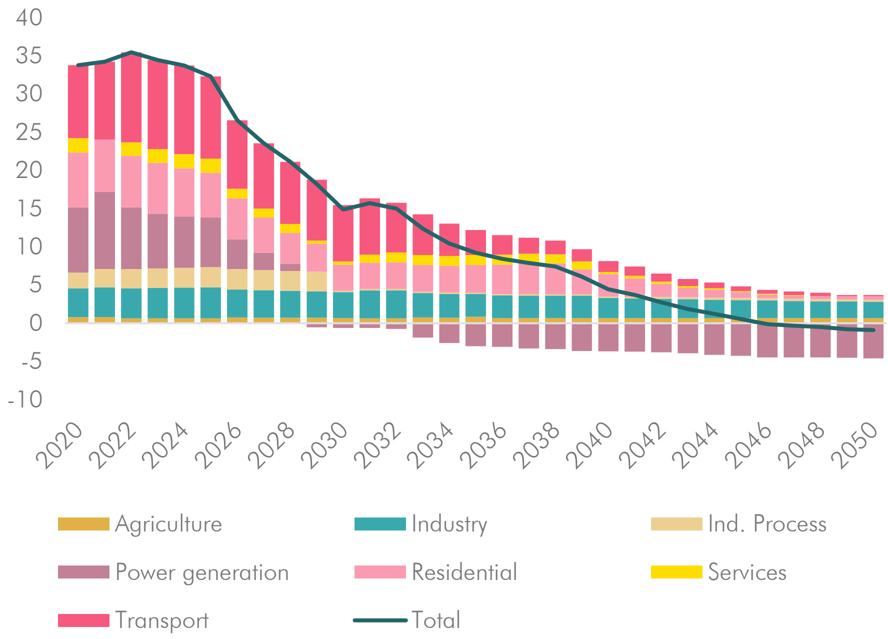
To model the transitional risks to the public finances, we use projections from the TIMES-Ireland Model. This model has been developed by the MaREI Energy Policy and Modelling Group at University College Cork (UCC) since 2010 and were also used to inform Ireland's 2022 carbon budgets (Balyk, *et al.* 2022).

The projections assume that Ireland's climate change mitigation targets are met in a "least-cost" approach. That is, the projections model the optimal way to achieve the required adjustment under different scenarios that keep costs to a minimum. The different scenarios considered include varying assumptions such as a more optimistic outlook for improvements in technology and a lower burden of adjustment falling on certain sectors, for example on the farming sector. Each of the different scenarios considered has different implications for the public finances. For instance, some scenarios may incorporate a large shift from the use of private cars to public transport. This could have different implications for the trajectory of government revenue.

The scenarios modelled provide projections for key variables, such as energy usage by fuel source, the stock of vehicles, and investment costs. These variables are especially useful as inputs to modelling the implications for government revenue and expenditure.

Figure 7 shows the projected CO2 emissions by sector from the "whole system carbon budget – tech optimism" scenario. This scenario is used as the baseline scenario for the fiscal impacts in this paper based on consultations with UCC MaREI and our view that this represented a more realistic scenario for technological developments. See Appendix A, for the results under different climate transition scenarios.

Figure 7: Domestic CO_2 emissions from energy use projected to decline
ktCO_2e (kilotonnes of carbon dioxide equivalent)



Sources: MaREI EMPG.
Notes: Data is from the "Whole System Carbon Budgets – Tech Optimism" scenario.

Some work on modelling the revenue impacts of the climate transition has been caried out by the Department of Finance (Department of Finance, 2023b). The Department estimated the potential loss of revenue out to 2030 from implementing the *Climate Action Plan 2023* using projections prepared by the EPA and the SEAI. However, as highlighted above, the estimates from the EPA indicate that measures in the Climate action plan 2023 would not be sufficient to meet Ireland's climate targets for 2030, with only a 29% reduction in greenhouse gas emissions occurring based on Climate Action Plan 2023 policies.[5]

As a result, the Department's estimates of potential revenue losses can be thought of as towards the lower end of estimates of the impact on revenue by 2030 from meeting Ireland's climate targets. This reflects the expectation that that further mitigation measures will be required to achieve the 51% reduction in emissions by 2030.

In contrast, the scenario we present below assumes that climate targets are met. This therefore gives a better indication of the likely revenue impacts from achieving Ireland's climate targets and transitioning to net zero by 2050. Moreover, we extend our analysis out to 2050 to better gauge the long-run fiscal impacts associated with the climate transition.

[5] The measures included in the Climate Action Plan 2023 would see emissions cut by only slightly over half of the requirements underpinning the 2030 targets.

4.2 Government revenue

The shift away from fossil fuels will lead to a significant erosion in tax receipts over the next ten years, assuming no policy changes. The reduction in revenues would be mainly due to the electrification of Ireland's stock of vehicles. A temporary rise in tax receipts as people ramp up purchases of new cars will soften the transition a little initially. But the additional revenues here would be limited in scale and would not last. Unless policies adapt, we project that government revenues will reduce substantially over time.

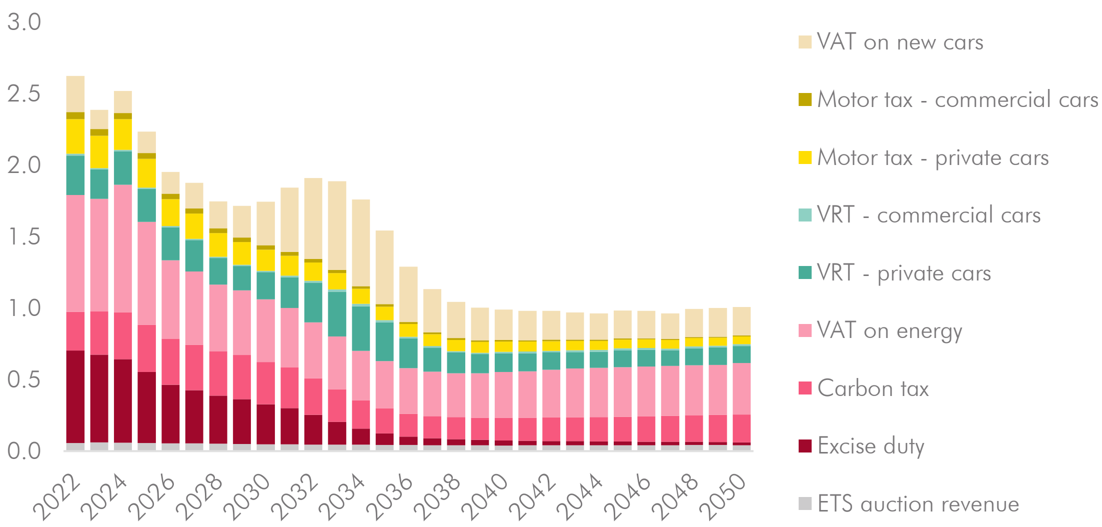
Our estimates show a marked decline in climate-related revenue as a share of GNI* out to 2050 (Figure 8).

The projected fall in overall revenues occurs relatively quickly. Some 0.9 percentage points of the eventual 1.6 percentage points of GNI* fall in revenues is projected to occur by 2030 (Figure 9).

There is a moderate increase in revenues for a short period in the early- to mid-2030s as significant numbers of new electric vehicles are purchased. This leads to an associated intake of VAT receipts. However, this surge in VAT receipts eventually subsides as more normal levels of vehicle purchases resumes.

Key taxes related to emissions fall substantially. For example, VAT on energy halves from 0.8% of GNI* to 0.4% of GNI* over the long run. Excise duty, excluding carbon tax, starts at 0.6% of GNI* but virtually disappears by the 2040s.

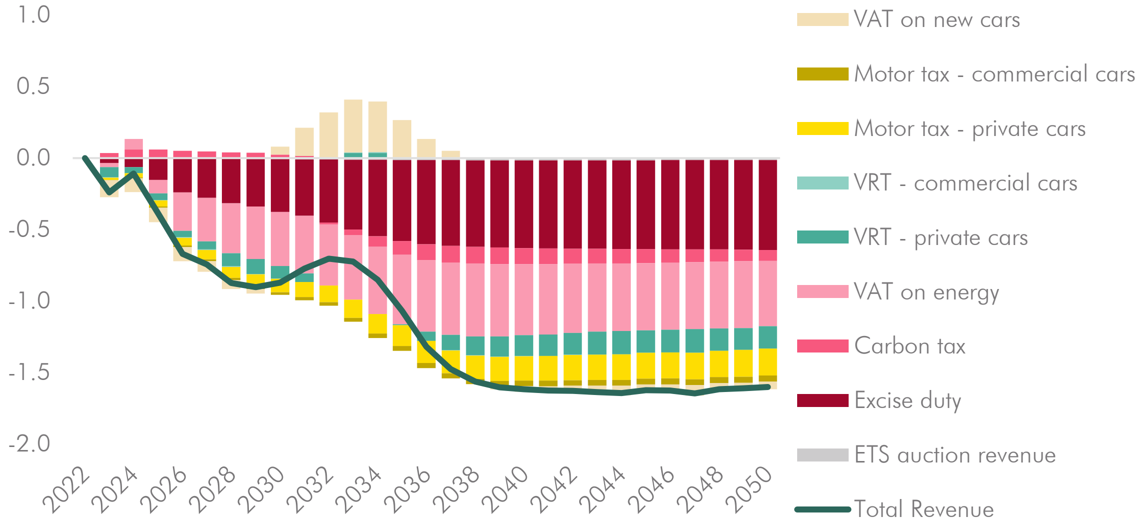
Figure 8: Climate-related revenue is likely to fall over time



Sources: Authors' workings.
Notes: Data for 2022 is based on model output and may differ slightly from actual 2022 revenue.

Figure 9: Climate transition sees a 1.6% of GNI* reduction in revenue

% of GNI*

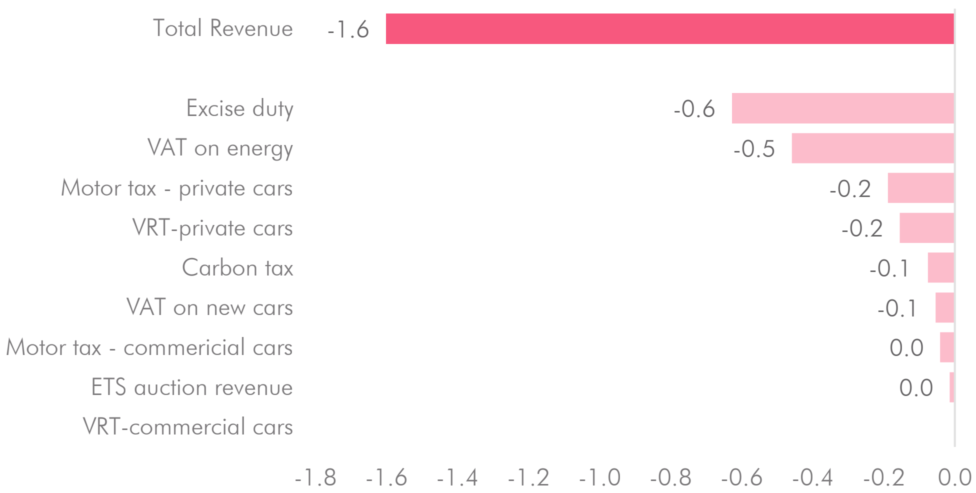


Sources: Authors' workings.

Revenues will end up structurally lower by the 2040s. Most of this is due to a few factors: the drastic reduction in fuel and energy taxes due to lower excise duties associated with lower petrol and diesel use and the lower VAT rates on electricity; plus, the decrease in vehicle registration tax and motor tax, both tied to emissions (Figure 10).

Figure 10: Reductions mainly reflect lower excise and VAT on fuel/energy

% of GNI* change 2050 vs 2022



Sources: Authors' workings.

When modelling the revenue implications of the climate transition, we assume that there are no further policy changes. That is, the tax rates that are in place today, are the same tax rates assumed as in place for the entire projection horizon. The one exception is the carbon tax rate, which is currently legislated to rise out to 2030. We also assume that the carbon tax rate will continue to rise out to 2050 (discussed below).

Excise duty (excluding carbon tax)

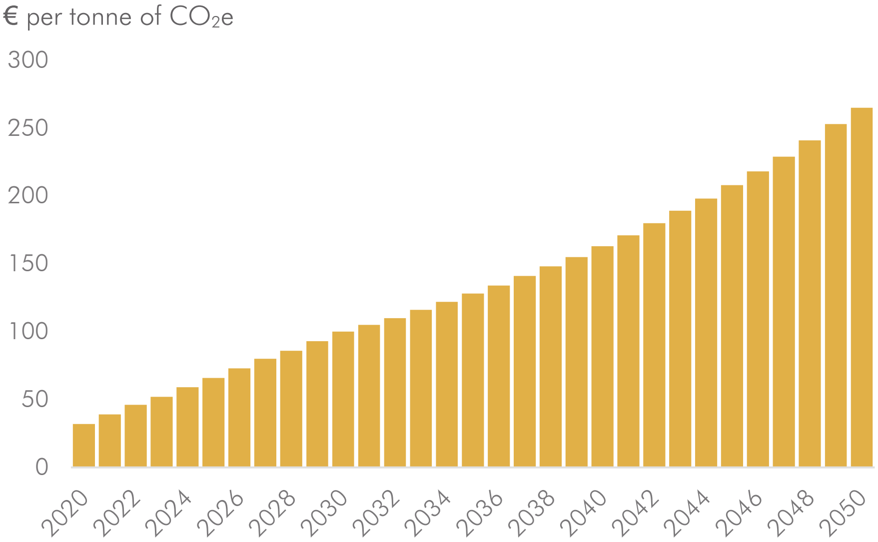
Mineral oil tax is levied on several fuels, notably diesel, petrol, and marked gas oil (Agricultural diesel). For the purposes of our projections, we assume that the rates of tax applied to these fuels remains constant from 2023 to 2050.[6]

Carbon tax

The carbon tax rate in Ireland is set to rise to €100 per tonne of CO_2 by 2030, in line with legislation set out in the *Finance Act 2020*.

After 2030, we assume that the carbon tax rate will continue to rise. We base this on the assumed carbon price for non-ETS sectors for the period 2030 to 2050 as set out in the Public Spending Code (DPER, 2019). This sees the carbon tax rise to €265 per tonne of CO_2 by 2050 (Figure 11).

Figure 11: Carbon tax rate assumed



Sources: *Finance Act 2020*; and Public Spending Code, (DPER, 2019)
Notes: The carbon tax rate is as laid out in legislation up to 2030. From there, the assumed carbon tax rate is based on the Public Spending Code's assumptions on the carbon price for non-ETS sectors out to 2050.

[6] The rates of excise duty on fuels were reduced temporarily in response to the cost-of-living crisis. These temporary reductions are set to be fully reversed by 31st October 2023. It is these post-31st October rates that are used in the analysis.

VAT on energy

Different energy products have different VAT rates. The current VAT rate on petrol and diesel is 23%, while the rate on electricity, gas, kerosene, and marked gas oil is 13.5%.[7] Given this disparity in tax rates, the changing composition of energy use will have an impact on revenue.

The non-tax element of oil and gas prices are assumed to follow the futures prices out to 2030. Thereafter they are assumed to increase in line with a general inflation rate assumed to be 2%. This is then combined with the carbon and excise rates to arrive at a price per unit which the differing VAT rates can be applied to.

Vehicle Registration Tax (VRT) on private cars

VRT applies at the time a vehicle is registered in the State. This applies to new vehicles and to newly imported used cars.

To estimate the amount of VRT received, we need to make assumptions as to how car prices will evolve. Over time, it is expected that the price of new battery electric vehicles will fall relative to petrol and diesel cars. Here, we use the assumptions in the TIMES Ireland model that the real price of battery electric vehicles falls out to 2050. By contrast, the model assumes that the real price of petrol and diesel cars is expected to remain constant over time. Outside of this real price reduction in battery electric vehicles, all car prices are assumed to rise in line with general inflation.[8] For simplicity, we do not assume different growth rates in the prices for new cars as compared to imported used cars.

One key output from the TIMES Ireland model we rely on is a set of estimates for the number of additional cars added to Ireland's overall car stock. A proportion of this additional car stock will not be new vehicles, but instead imported second-hand vehicles from, for example, the British car market.

We assume that new purchases make up 57% of total new registrations of diesel and petrol cars in Ireland going forward, with used imports making up the rest. This share is in line with rates in recent times and we assume it remains constant for the forecast horizon. Initially, the proportion of battery electric vehicles that are imported second-hand from the British car market is likely to be low, given that the stock of second-hand electric vehicles itself is still relatively low. Currently, new battery electric vehicles account for 93% of the battery electric vehicles being licenced in Ireland for the first time. We assume that this share falls linearly and converges towards the same 57% proportion for petrol and diesel cars by 2040.

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[7] Reduced to 9% temporarily.

[8] General inflation is assumed to follow the Department of Finance's SPU 2023 forecasts out to 2030 and remain at 2% thereafter.

Finally, we assume that the VRT relief on electric cars does not remain in place over the full projection horizon.[9] Were this VRT relief to remain in place, the loss of VRT revenue would be larger than we currently estimate.

VAT on new cars

The same car price assumptions and assumptions on the proportion of used imported cars that are used to calculate VRT receipts are also used here.

In general, VAT on new cars is levied at 23% on the VRT-exclusive price. While there is VAT liable on imported second hand cars, motor dealers who import them as stock-in-trade are entitled to claim back this VAT. As a result, we assume no change to the net VAT revenue from imported second-hand cars.

For Irish-registered second-hand cars, VAT is due on the difference between the sale price and the purchase price of the car. We assume that these types of resales would be similar to those in a no climate change transition scenario. As a result, no loss (or increase) in VAT revenue arises from this.

VRT on commercial vehicles

Commercial vehicles liable for VRT fall into two categories. Category B is generally for vehicles that carry goods less than 3.5 tonnes, and Category C is for larger commercial vehicles. The majority of commercial vehicles fall into category C, which has a flat rate of €200.[10] On the other hand, those that are in category B generally have a VRT rate of 13.3% on the open market selling price.

To arrive at projections for VRT revenue for commercial cars, we assume that the proportion of new vehicles in category B and C are constant throughout the projection horizon, while we assume that the open market selling price rises in line with general inflation.

Motor tax on private cars

We assume that government policy on motor tax rates is unchanged. However, as vehicles on average become more efficient — as the least efficient and generally older cars are removed from the car stock — the average tax rate should fall over time, even with an unchanged tax policy.

The average tax rate for private cars in 2021 was €309. This was made up of two distinct elements. First, an average tax rate of €247 for cars on the newer post-2008 tax regime based on emissions, of which there were

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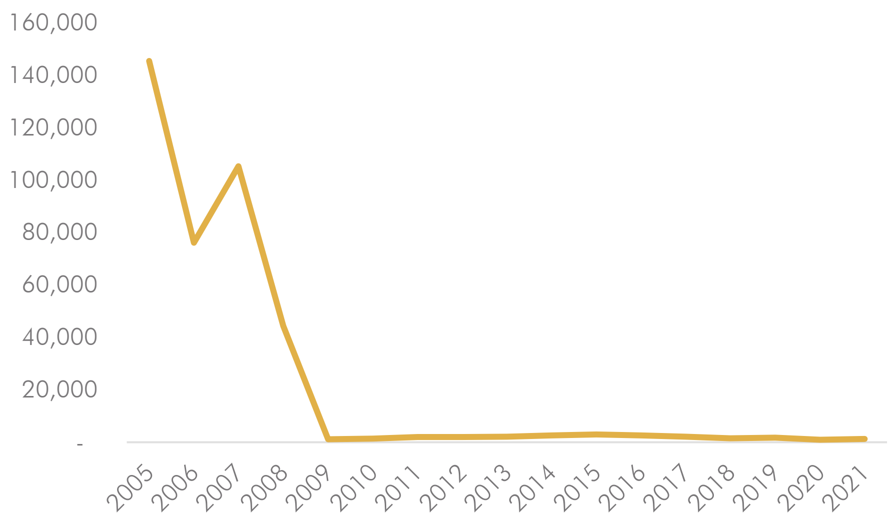
[9] The VRT relief on electric vehicles is currently legislated to expire on 31st December 2023.

[10] In 2021, 16% of commercial vehicles liable for VRT were in category B.

1.8 million. Second, an average rate of €589 for cars on the old pre-July 2008 regime taxed based on engine size, of which there were 0.4 million. The registration year for cars on the old regime is shown in Figure 12.

Figure 12: Year registered for cars on the old tax regime

No. of Cars

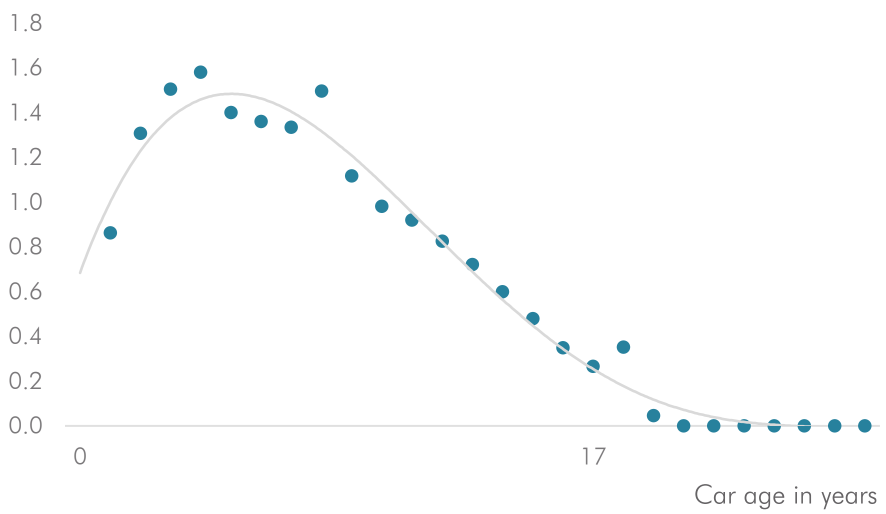


Sources: Department of Transport.
Notes: The figure for 2005, also includes cars registered prior to 2005.

There are relatively few cars on the road which are over 20 years old (Figure 13). In our modelling of the average tax rate, we assume that by 2028, the majority of those on the old regime are gone, such that the average tax rate for non-electric vehicles converges to €250 by 2028.

Figure 13: Lifespan of passenger vehicles seldom more than 18 years

Survival probabilities



Sources: Held, M., Rosat, N., Georges, G. *et al.* (2021).
Notes: Ireland's survival probabilities in the short run exceed 1.0 due to the high number of imported used cars.

To allow for technological advancements, we assume that, by 2042, the average motor tax rate on petrol and diesel cars converges to the average motor tax rate for the frontier of new petrol and diesel cars in 2021. This average tax rate is close to €200. The rate of convergence is assumed to be linear between 2028 to 2042. Thereafter, the average tax rate is assumed to be constant at €200.

We assume that the motor tax rate for all electric vehicles is €120 per annum, in line with current policies.

Motor tax on commercial vehicles

The TIMES Ireland model projects the stock of commercial vehicles out to 2050. The stock is divided into three categories: light (including light battery electric vehicles), medium, and heavy goods vehicles.[11] These are used together with the five categories of motor tax rates for commercial vehicles based on weight. The average of the tax rate for vehicles that weigh between 3,001and 4,000 kg (€420) and between 4,001 and 12,000 kg (€500) is applied to all vehicles in the medium category.

EU ETS auction revenue

The EU operates a "cap and trade" system for greenhouse gas emissions from certain sectors called the Emissions Trading System (ETS). This scheme mainly covers emissions from power generation, energy-intensive industries and aviation.

Figure 14: ETS auction revenue has increased as prices continue to rise

A. ETS revenue has increased
€ million

B. ETS allowance prices set to rise
Futures, €/EUA MtCO^2

Sources: Eurostat: National Tax Lists; and the European Energy Exchange.

As part of this system, Ireland auctions off ETS emission allowances.[12] The revenue from this has been rising over time (Figure 14A) and is expected to continue to rise as auction prices increase (Figure 14B).

[11] The TIMES model classifies light vehicles at those below 5,000 kg, medium vehicles as those between 5,001-10,000kg and heavy vehicles as those above 10,000kg.

[12] Some allowances are provided for free, although the number of allowances provided for free is declining over time.

As part of phase 4 (2021–2030) of the Emissions Trading System, and in order to reduce emissions, the total EU-wide number of emissions allowances is set to decline at an annual rate of 2.2% from 2021 to 2030. As a result, in our modelling work we assume that the total number of allowances auctioned by Ireland decreases by 2.2% per annum from 2023 to 2030. We further assume that the number of allowances auctioned by Ireland continues to decline at this rate out to 2040. From there we assume the number of auctioned allowances is unchanged out to 2050.

On the price side, we assume that ETS allowances prices follow prices implied by the ETS futures market out to 2031 (Figure 14B). From 2032 to 2050, we assume that the price of these allowances continues to increase at a rate of 3.5% per annum, the average annual rate of increase in the price of the futures over the period 2026 to 2031. However, given the likely increasing scarcity of these allowances, the actual price may rise more rapidly.

In December 2022, the European Parliament and the Council of the EU agreed to establish a new ETS — called "ETS II" — to cover the emissions from fuels used for buildings and road transport. This new system is due to launch in 2027. As Ireland has a carbon tax that covers fuel emissions from these sectors, it is likely that it will have a derogation from these requirements out to 2030. However, as yet, it is unclear what will happen after this point. For this reason, revenue from ETS II is not modelled here.

4.3 Public expenditure

Modelling the public expenditure implications of climate change differs significantly from modelling the revenue side. While we can examine the impact of unchanged policies on the revenue side, the expenditure side will more than likely necessitate various policy changes to meet Ireland's climate targets while ensuring a "just transition" — an approach that is both sustainable and inclusive.[13]

For this reason, our projections for the expenditure side are highly uncertain. The expenditure involved will ultimately depend on the type of policies that policymakers pursue. We make a number of judgement calls on the likely proportion of the climate change transition costs that will be borne by the State. To that end, we are guided by the work of FitzGerald (2021) and the OBR (2021, 2019) as well as by past precedent, and international examples.

Given the uncertainties involved, we assess a low and high-cost scenario when modelling the expenditure side. The "low cost" scenario can be seen as a lower bound on potential State involvement whereas the "high cost" scenario can be seen as a reasonable upper estimate, recognising that costs could still end up higher. Ultimately, it will be down to policymakers to decide how much intervention is required to achieve climate objectives.

Figure 15: Public spending to support climate transition is likely to rise

% of GNI*

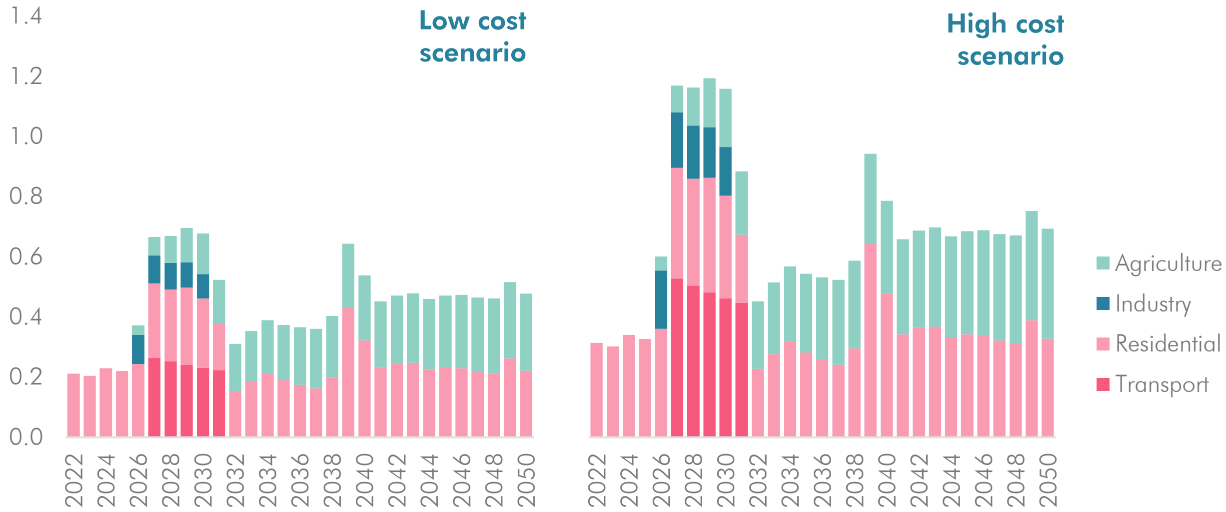
Our results suggest that annual investment outlays by the State could peak at between 0.7 and 1.2% of GNI* per annum in the latter part of this decade (2027–2030). The level of annual outlays is then expected to fall

[13] The Climate Action and Low Carbon Development (Amendment) Act 2021 provides for a just transition, within the wider statutory framework of climate action, that will (i) maximise employment opportunities, and (ii) support persons and communities that may be negatively affected by the transition.

back slightly after 2030 but still remains high, settling at rates closer to between 0.4 and 0.7% per annum in the 2030s and 2040s (Figure 15).

Most of the expenditure involved is related to retrofitting and farming supports. These amounts are substantial and are assumed to continue over the full forecast period (Figure 16). Cumulatively, these two areas make up 80 to 90% of the expenditure costs projected out to 2050 in the two scenarios. Retrofitting represents just over half of the cumulative costs, with farming supports making up at least a third. By contrast, costs related to transport, accelerating the switch to electric vehicles, are more upfront in nature, as are costs associated with industry.

Figure 16: Most expenditure would likely relate to retrofitting and farming supports
% GNI*, estimated public expenditure



Transport

The main cost related to climate transition in terms of transport is the shift to electric vehicles. This primarily relates to passenger vehicles.

In the UCC MaREI scenario we use as our baseline, an average of 65,000 new battery electric vehicles are purchased each year between 2027 and 2030. This then rises sharply to an average of 260,000 per annum between 2031 and 2040, before slowing to 175,000 from 2041 to 2050.

This entails a substantial transformation in Ireland's car stock. We assume that Government supports to enable and accelerate this transition would most likely target older vehicles. This is given that they are more likely to be held by lower-income individuals and they are likely to be less efficient and produce more emissions.

We draw on historical and international precedents to assess how the transformation of Ireland's car stock might be enabled. Based on the evidence for scrappage schemes (Box A), we assume that grants of

€5,000 are provided in our "low cost" scenario and up to €10,000 in our "high cost" scenario for cars 10 years or older over the period 2027 to 2031. This is a period when the baseline scenario projections assume a big uptick in the switch from internal combustion engine vehicles to battery electric vehicles.

Box A: Vehicle incentive and scrappage schemes

A variety of incentive and scrappage schemes are in place internationally to help encourage the uptake of lower emissions vehicles and the removal of high emissions vehicles from the car stock.

France
The "primes à la conversion" scheme in France involves grants of €6,000 to €9,000 for the purchase of new or used electric or hydrogen vehicles and grants of up to €4,000 for e-bikes in exchange for scrapping an old vehicle.[14] The generosity of the grants depends on incomes and location. Those on lower incomes can avail of larger grants as can those living or working in certain zones that are singled out as having an objective to achieve larger reductions in overall emissions.

UK
London's "Ultra Low Emission Zone" scheme involves scrappage grants of up to £2,000 for those with non-compliant cars or motorcycles. Additional financial incentives are provided for those that take part of the payment in the form of a bus and tram season ticket. For example, taking part-cash and two annual bus and tram season tickets would increase the overall value of the grant by more than 50%. Charities, sole traders, and micro-businesses scrapping can avail of grants of up to £10,000 for retrofitting vans or minibuses or scrapping and replacing them with fully electric vehicles.[15]

Italy
Italy has a range of subsidies linked to scrapping combustion-engine cars. These are worth up to €6,000 for the purchase of new electric vehicles costing no more than €35,000. Hybrid electric vehicles up to €45,000 are subsidised up to €2,500, while incentives of €1,250 are available for state-of-the art combustion-engine cars when older vehicles are scrapped. Funds are also available for incentives to buy new motorcycles and for small- and medium-sized business to buy fully electric vans.

Ireland (historical)
Ireland's last experience with a car scrappage scheme was in January 2010, when a scheme was introduced with VRT relief of up to €1,500 for cars at least 10 years old scrapped and where new cars under emissions bands A or B were purchased.

Other
Other schemes in Europe have varying levels of grants provided. Useful summary information on tax benefits and purchase incentives is available from the European Automobile Manufacturers' Association, which shows new electric vehicle purchase incentives of up to €20,000 in Cyprus including scrappage.[16]

Using Department of Transport data for 2022, we can see that some 38% of cars were 10 years or older. Assuming a similar age distribution in 2027 when the UCC MaREI scenario assumes a car stock of 2.4 million, we estimate that about 900,000 vehicles would be eligible for a scrappage scheme.[17] At €10,000 per car, what would otherwise be a loss to households would amount to a €9 billion cost or about €1.8 billion per

[14] See details from ecologie.gouv.fr.

[15] See details from tfl.gov.uk.

[16] See for example: https://www.acea.auto/files/Electric_cars-Tax_benefits__purchase_incentives_2023.pdf

[17] To avoid excess costs and perverse incentives, we assume the scrappage scheme is limited to vehicles newly registered prior to the scheme's announcement.

annum over 2027 to 2031.[18] These costs are also in line with those outlined in FitzGerald (2021). Note that the Government already has grants set at €3,500 for electric vehicles purchased privately. These were reduced to this level from a previous maximum of €5,000 as of July 2023. It is unclear whether the grants will be gradually phased out or kept in place and so we cannot judge to what extent this will be incorporated in any baseline in the absence of new measures.

Other costs related to the uptake of lower emissions vehicles might require State involvement. Internationally, there are examples of cases where countries have introduced government-funded incentives to promote the move to lower-emission vehicles by commercial enterprises. There would also be direct costs to the public sector as it moves to electrifying trains, buses, and introducing other active transport infrastructure.

We do not assume additional costs in relation to commercial vehicles and the electrifying of the public sector bus and rail fleet and in relation to facilitating active transport. This is for two reasons: first, we assume that the phase-in of new electrified vehicles occurs gradually and in line with historical patterns such that the increase in investment is not beyond normal rates and, second, the UCC MaREI scenario we treat as our baseline does not show a significant increase in the use of these forms of transport. In fact, the stock of passenger vehicles increases from 2.1 million in 2022 to 2.6 million in 2030 and to 3.2 million in 2050.

Residential

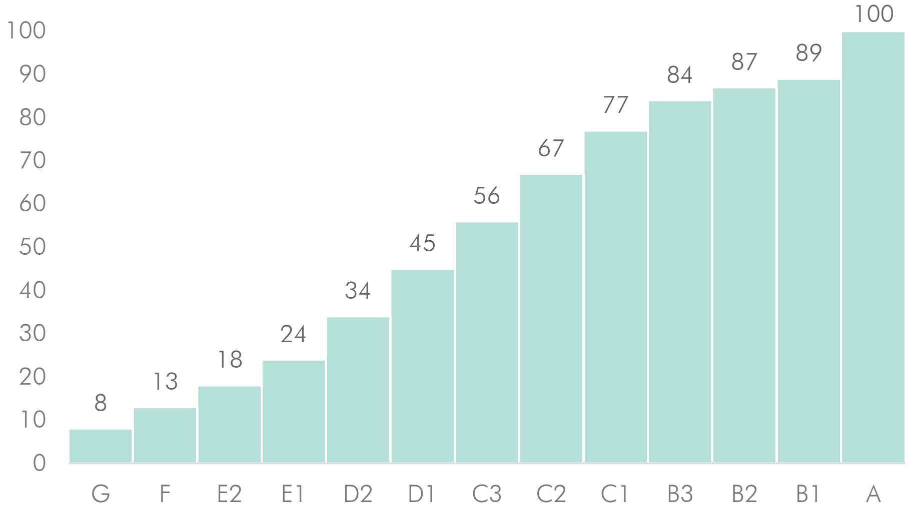
The bulk of residential costs associated with the climate transition relates to retrofitting homes. As argued by FitzGerald (2021), energy cost savings from retrofits would likely take many decades to fully recoup the upfront capital cost involved. As a result, many households will not have a financial incentive to retrofit their homes. Given the lack of financial incentives involved, ongoing government intervention will likely be necessary to meet climate targets related to home retrofits. This would also include the necessary supply-side interventions to ensure there is capacity to meet retrofitting targets at a time of ongoing housing shortages.

[18] As FitzGerald (2021) notes, this early scrappage of petrol and diesel cars would represent a real loss to affected households that would not be offset by potentially lower running costs unless there was some form of scrappage scheme. Note that the Government currently has a grant scheme of up to €3,500 in place, which was reduced from €5,000 previously. This is separate and distinct from a scrappage scheme, which would be specifically to compensate vehicle owners for a loss from stranded assets.

Data from the CSO on domestic Building Energy Ratings weighted to national level from Q2 2023 suggest that 45% of households have a D-rated or lower energy rating (Figure 17).[19]

Figure 17: Building Energy Ratings

Cumulative % of national dwellings using Census of Population 2016 figures



Source: CSO; and own workings.

Notes: These figures are estimates based on the housing stock audited for Building Energy Ratings and are weighted to a total of just 1.6 million homes rather than the full housing stock (2.1 million as of April 2022). The CSO note that around 8% of households were excluded because there were no Building Energy Rating households in that stratum, with an example being detached houses in Dublin 1 constructed between 1919 and 1945. It is therefore likely that the 45% estimate of dwellings that are rated D or lower is likely to be a lower bound.

Government commitments in the *Housing for All* plan are to retrofit some 500,000 homes by 2030 to a B2 Building Energy Rating or Cost Optimal equivalent (Department of Housing, Local Government and Heritage, p.120). This includes the direct retrofit of 36,500 Local Authority-owned homes by 2030.

Given the weak financial incentives for households to retrofit dwellings, FitzGerald (2021) assumes that two thirds of the cost of retrofitting homes will ultimately fall on the State. We use this assumption in our "High Cost" scenario and consider a 45% assumption in the "Low Cost" scenario reflecting the share of low-rated energy homes (rated D or worse). These assumptions are applied to the UCC MaREI scenario we consider as our baseline.

Agriculture

In estimating the likely fiscal costs arising from the agricultural sector reducing greenhouse gas emissions, we make use of modelling work commissioned by the Climate Change Advisory Council and carried out by Teagasc (CCAC, 2021). This work has indicated that a large reduction

[19] This D-rating equates to more than 5 tonnes of CO^2 emissions for a 100sqm, 3-bed semi-detached house as compared to less than 1.7 tonnes for an A-rated build and an indicative 2.2 tonnes for a B2 Building Energy Rating.

in agricultural greenhouse gas emissions would require a reduction in livestock numbers.

The Teagasc work assumes that livestock reductions result in a loss of farm income. This serves as the basis for our assumptions on government expenditure supports. However, it should be noted that beef and lamb farms operate at a net loss on average (Conefrey, 2018).[20] Maintaining CAP payments, while reducing livestock numbers could therefore lead to higher net farm incomes. Similarly, foregone land could be used for other income generation such as forestry.

Similar to FitzGerald (2021), we assume in our "High Cost" scenario that any loss in farm income from a reduction in livestock numbers will be compensated by a direct government transfer. FitzGerald (2021) notes that while these direct transfers will have to continue for several years, as farmers eventually retire, the costs of these schemes should ultimately fall.

Teagasc modelled a range of scenarios including a 20% reduction in greenhouse gas emissions in the agricultural sector by 2030 and a scenario in which greenhouse gas emissions had to reduce by 33% by 2030. The Government has decided that the carbon budget for the agriculture sector is to be set at a 25% reduction in greenhouse gas emissions by 2030. As this scenario was not modelled by Teagasc, we take the mid-point of the impacts from the 20% and 33% scenarios as an approximate basis for our projections out to 2030.

From there, we assume that the agricultural sector will be required to reach a 40% reduction in emissions by 2040. Teagasc also modelled a scenario for a 40% reduction in greenhouse gas emissions by 2030. We use this scenario to estimate the farm income lost between 2030 and 2040.

From there, we assume that any additional costs to the State arising from compensating farmers for lost income due to any further reduction in agricultural greenhouse gas emissions will be offset by farmers retiring leading to lower costs of the scheme. That is, from 2040 to 2050 the costs to the State are assumed to rise only in line with price inflation.

In the "Low Cost" scenario, we assume that farmers are compensated for only 70% of their estimated income losses.

Outside of the direct costs to the agricultural sector from the climate transition, there may be further costs to the food processing sector. We do

[20] Conefrey (2018) notes that, based on 2017 data, cattle and sheep farms CAP payments accounted for 114% and 115% of farm incomes, respectively. Where the dependency on direct payments exceeds 100%, this indicates that the market income on these farms was negative with the only income which farm families received from their enterprises coming from direct payments.

not consider any government supports to that sector for the purposes of this analysis.

Industry

In terms of industry, some sectors will face substantial costs to reduce their emissions. In the absence of State supports, some sectors would likely have to relocate or undergo rapid contractions due to competition from countries with less stringent carbon abatement policies.

The data available on sector-specific impacts for Ireland are limited and so a detailed sector-level analysis is not possible at present. By contrast, the UK's Office for Budget Responsibility (OBR, 2021) would have drawn on detailed sector-level output assumptions. This allowed the OBR to assume that the State meets the full costs for all the industries where growth is reduced. Its assessment focused on those industries where output fell, initially, by more than 2.5% relative to its baseline due to measures to reduce emissions. It then assumed that costs to the State declined to cover only those industries facing more than 5% in output losses by 2050.

In line with the approach adopted by FitzGerald (2021) we focus solely on Ireland's cement sector when assessing the potential cost of State supports related to industry.

The cement sector is a high emitter of greenhouse gases. Manufacturing cement involves firing clay and limestone to high temperatures in furnaces, which results in substantial CO_2 emissions. Reducing emissions tends to rely heavily on carbon capture and storage.

Closing cement production in Ireland would reduce emissions. However, with Ireland still likely to consume cement, emissions would just be shifted elsewhere with no wider reduction in emissions. Closing production would also entail large costs in terms of importing cement, job losses, and lost output. As such, it is likely that public support would be provided, and this could potentially be significant.

The UCC MaREI scenario we consider as our baseline assumes a cost of €3.2 billion in nominal terms related to this.[21] While their scenario assumes this is incurred in 2030, we assume that it is phased in more gradually over the period 2026 to 2030 at an annual average cost of €0.6 billion per annum. Our "high cost" scenario assumes that the full cost of installing carbon capture and storage would be carried by the State, whereas our "low cost" scenario assumes half of the costs are.

[21] Note that this is in line with the €2.4 billion assumed in FitzGerald (2021) though we convert to nominal prices as the UCC MaREI scenarios are set in constant prices or real terms.

Power (energy and grid infrastructure)

We assume that the Government increases the share of electricity generated from renewables through competitive auctions as noted in its Climate Action Plan. This means that the delivery of renewable energy generation is assumed to be largely led by the private sector.

Several actions and projects are also likely to be required to facilitate the increased use of renewables, such as wind and solar, which are more variable. This will mean the power system will have to be upgraded to ensure stable supply. That means building new substations, improving old ones, adding more generators, interconnectors, and ways to manage electricity demand flexibly, while accommodating onshore renewables and offshore wind energy. In addition to the upgrade of grid infrastructure within Ireland, there are plans for additional interconnectors to ensure secure energy supply.

For the purposes of these projections and assessing fiscal impacts, we assume that these costs are borne by EirGrid PLC and therefore do not have an impact on general government expenditure. It is likely that the associated costs will be funded by a mixture of charges on customers and the use of EU grants.

Services

While there will be additional costs to the services sector from transitioning to a net zero economy, we assume that this cost is all borne by the private sector. In any case, these costs are estimated to be relatively small compared to other areas.

4.4 Fiscal costs of Physical Risks

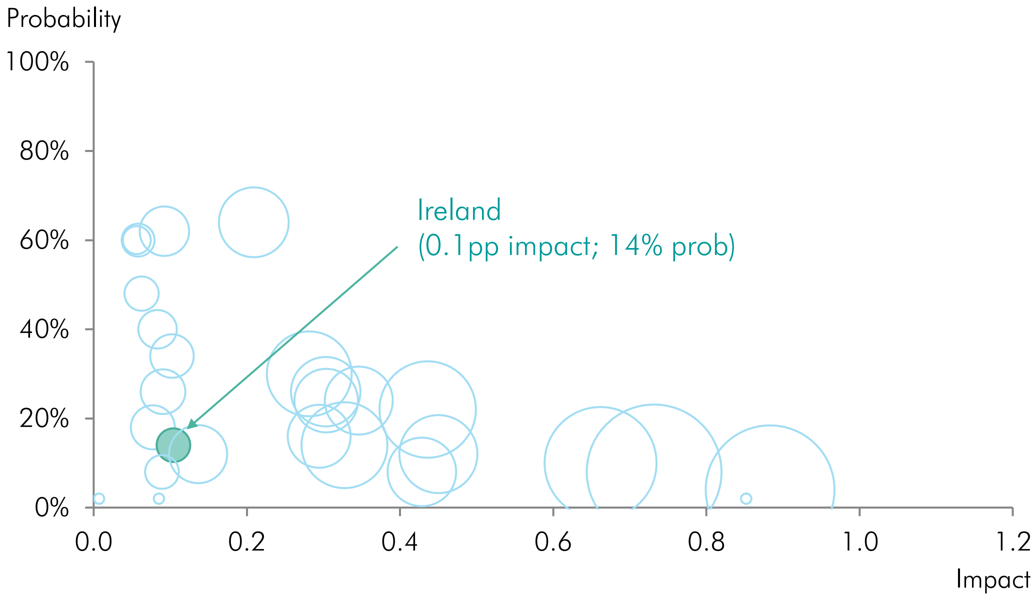
Physical risks from climate change can impact revenue in several ways. For instance, days of work may be lost due to extreme weather conditions. Similarly, extreme weather events may negatively affect agricultural output leading to a loss in tax revenue from this sector.

Given the unpredictable nature of extreme weather events, quantifying the risks to revenue from physical risks is extremely uncertain.

In terms of public expenditure related to physical risks from climate changes, the repairing/rebuilding of public property, including critical infrastructure, will see an increase in expenditure as weather events become more extreme. Were some of the costs of repairing/rebuilding private property to be subsidised, this could also see additional public expenditure.

Figure 18: Experiences with natural disasters in Europe

Damages (% GDP or GNI* for Ireland) and probability (%) of 1 or more occurrences in a given year (1970-2019)



Sources: EM-DAT; own workings.
Note: Each bubble represents data for individual European countries on average annual event damage costs as % GDP (x-axis), unconditional probability of occurrence in a given year (y-axis), and (depending on size of bubble) the standard deviation of estimates (smaller bubbles represent lower standard deviations). The natural disasters covered include floods, storms, landslides, wildfires, drought, and extreme temperatures.

Ireland's historical experience with extreme weather events has been relatively limited but could rise in future. Historically, Ireland has had a 14% probability of one or more extreme weather events occurring (equating to once-in-every-seven years). Costs associated with these events have averaged about 0.1% of GNI* (Figure 18).

However, major weather events appear to have become more frequent in Ireland in recent decades. For instance, current 1-in-100 year extreme sea level events are projected to occur at least annually in half of all tidal gauge locations by 2100 (IPCC, 2023). As such, these events may become more frequent and more costly. Experiences in other European countries show that events closer to once every three years and with costs potentially closer to 0.2% of GNI* are not unprecedented (Figure 20).

Government expenditure is also likely to be needed to help adapt to a changing climate. One such example would be building and reinforcing flood defences. The Department of Communications, Climate Action and the Environment provided an indicative estimate of flood damages of €1.15 billion per year by 2050 (DCCAE, 2018). Under the National Development Plan 2021–2030, a total of €1.3 billion was allocated to flood defences (averaging €130 million per annum).

In the absence of mitigation measures like this, the estimated costs associated with future flood risks could potentially be quite high. For example, Table 1 shows the damages associated with future flood risk scenarios for Dublin city. In a mid-range scenario, a one-in-10-year event would be estimated to see damages rise to €333 million from €25 million today. A high-end risk scenario could see such costs rise to €2.9 billion.

Table 1: Example of flood risks: high probability risks for Dublin City
(impacts of 10% probability or "1-in-10-year" events)

	Present day	Mid-Range Future Scenario	High-End Future Scenario
Event Damage (€m)	25	333	2,937
No. Residential Properties at Risk	343	2,789	14,514
No. Business Properties at Risk	23	384	2,947
No. Utilities at Risk [1]	1	3	16
No. Major Transport Assets at Risk [2]	10	50	392
No. Highly Vulnerable Properties at Risk [3]	2	12	102
No. of Social Infrastructure Assets at Risk [4]	72	169	410
No. Environmental Assets at Risk [5]	16	17	17
No. Potential Pollution Sources at Risk [6]	0	0	2

Source: Office of Public Works Flood Risk Management Plan for the Liffey & Dublin Bay River Basin (2018, UOM09, Appendix E, pp.9-10).
Notes: The "Mid-Range" future scenario assumes an increase in rainfall of 20% and a sea level rise of 0.5 meters, whereas the "High-End" scenario assumes a 30% rainfall increase and a sea level rise of 1 meter. Examples of risk types include: 1) Power Stations, Water Treatment Plans, Waste Water Treatment Plans, Gas Assets and Telecommunication Exchanges; 2) Motorway, National, Regional and Local Roads, Ports, Airports; 3) Hospitals, Schools, Nursing / Residential Homes, Prisons, Camping / Caravan / Halting Sites; 4) Schools, Libraries, Community Centers, Local and Central Government Offices (incl. Post Offices), Emergency Services (Fire, Garda, Civil Defence, RNLI and Coast guard Stations), Health Centers, Churches, Parks and Public Gardens, Sports Facilities, Playgrounds, Local Cultural Heritage Sites; 5) Natural habitat sites, Natural Heritage Areas, Nature Reserves, National Parks; 6) Septic tanks, slurry storage facilities.

Given the likely magnitude of flood risks, action would likely be needed on flood defences sooner rather than later. What's more this could potentially involve a large continuing investment over decades.

The Climate Change Advisory Council (2023) emphasises the need for better planning by Government in relation to potential adaptation costs. They note that "detailed information on the budget for, costs of and investment requirements for adaptation is lacking across central and local government". They recommend that an adaptation budget be set for 2030 and that the Government formally assess what is required to make Ireland resilient by 2050 and beyond.

Further work in this area could make use of the approach adopted in studies for the UK. For instance, Watkiss (2022) looks at available information and makes several recommendations on how estimates of adaptation costs can be developed. Similarly, the UK's Climate Change Committee (2023) looks at the investment required to build resilience to climate change as well as looking at the barriers to delivering it and how key investment streams can be scaled up. In the EU context, the costs and benefits of adaptation measures are considered by the European Environment Agency (2023).

There is also a risk that the increase in extreme weather events may have knock-on effects for the financial stability of the insurance industry, and this may have further implications for fiscal sustainability.

In addition to the areas of direct expenditure we consider here, there is potentially a very large contingent liability for the State arising from the insurance industry, with the probability of the realisation of this liability increasing the more severe climate change becomes. The potential for a very extreme weather event (or multiple over a short period) could threaten the financial stability of insurance firms.[22] Exceptionally large claims from damage to property arising from an extreme weather event may cause insurance firms to sell assets in order to meet these claims. Given that these claims would be correlated across insurance firms and that these insurance firms are investing in the same asset classes (Central Bank of Ireland, 2019a; 2019b), the simultaneous selling of these assets could lead to unfavourable price dynamics that may threaten the financial stability of these firms. In such an event, the State may have to step in to ensure the stability of the financial system.

[22] For instance, the costs to the insurance industry of claims relating to extreme weather events in 2010 amounted to more than €0.54 billion (Joint Committee on Environment, Culture and the Gaeltacht, 2016). This related to two separate "freeze" events.

4.5 Fiscal impacts from non-compliance

In addition to both transitional and physical risks, there are also risks of fiscal impacts from not meeting Ireland's climate targets (Section 3).

Over the medium-term, Ireland needs to reduce its non-Emissions Trading System (ETS) greenhouse gas emissions by 42% from 2005 levels by 2030 to comply with legally binding EU targets.[23] Failing to comply with these targets would come with a fiscal cost, as credits or statistical transfers would need to be purchased from other Member States.

Current projections show that these targets will be missed. Work by Walker *et al*. (2023) estimated that based on current plans, the cumulative cost of non-compliance by 2030 could be up to €3.5 billion, and approximately €0.7 billion per annum by 2030.[24]

[23]The ETS is a "cap and trade" system. Companies receive/buy emission allowances, with the number of allowances, set by the European Commission, falling each year. The ETS sector consists mostly of companies in power and heat generation and other energy intensive sectors (such as aviation). In 2017, emissions from the non-ETS sector amounted to 72 per cent of total emissions in Ireland (EPA, 2019). Companies covered under the ETS must receive/buy emissions allowances equivalent to their total emissions to comply with the legislation.

[24] The cost of non-compliance will be a function of the price of future carbon credits and statistical transfers that would need to be purchased from Member States who overperform on their carbon emission reduction targets. The future price of these credits is unknown, but the authors use the price of ETS futures contracts as a proxy to estimate the cost of non-compliance based on the With Additional Measures (WAM) greenhouse gas projections scenario by the EPA.

5. Conclusions

Ireland's climate is changing. This is being caused by human activity. Ireland's climate will continue to change until the world reaches Net Zero.

To limit the extent of this climate change, Ireland and other nations have agreed to lower their greenhouse gas emissions. To this end, Ireland has committed to reducing greenhouse gas emissions by 51% by 2030, compared to 2018 levels, and to net zero by 2050.

Climate change will have notable impacts on the public finances. These will be visible across three key avenues: the costs of not complying with required reductions in emissions, the impact of transitioning to lower emissions on tax receipts and government expenditure, and physical costs associated with extreme weather events.

The largest impacts will be in terms of transition costs. But there are also risks related to non-compliance penalties and responding to extreme weather conditions through mitigation measures and repairing and rebuilding damaged property.

First, there is likely to be a significant erosion in tax receipts if people successfully shift away from fossil fuels over the next ten years. These losses are mainly due to the expected electrification of vehicles. Assuming unchanged tax rates, meeting Ireland’s climate targets could see tax revenues reduced by 0.9% of GNI* (€2.5 billion in today’s terms) per annum by 2030, and by as much as 1.6% of GNI* (€4.4 billion) per annum in the long run. A temporary rise in tax receipts as people shift to new car purchases will soften the transition a little initially, but this is limited and not expected to last.

Second, on the spending side, the Government will also likely need to provide substantial supports if Ireland’s climate targets are to be met. Some of this will be carried out by the private sector, but many actions required will not be financially cost effective without Government intervention. Depending on the extent of private sector involvement, we estimate that the Government may face costs of between 0.6 and 1.1% of GNI* (€1.6 to 3 billion in today’s terms) per annum over the years 2026 to 2030. These costs would then average between 0.4 and 0.7% of GNI* over the longer term (2031 to 2050).

Third, there are risks that the Government could face heavy penalties for not complying with targeted reductions and more extreme weather could lead to sporadic costs to the State. The costs associated with not hitting Ireland’s climate targets are estimated at an average of €0.35 billion annually until 2030, rising to around €0.7 billion (0.2% of GNI*) in 2030. In terms of risks related to extreme weather events, historical costs have averaged about 0.1% of GNI* and have occurred once every seven years or so. These events appear to be becoming more frequent and the European experience shows that damages closer to 0.2% of GNI* once every three years are not unprecedented.

Our analysis suggests that reforms will be required to address the challenges related to climate. These will take time to plan for and enact. For example, governments may yet counteract losses in vehicle-related revenues through the introduction of other taxes on vehicle use, reductions in fossil fuel subsidies and changes to the electricity tax. Charging drivers for road use, by distance, congestion charges, and for vehicle weight are options discussed briefly in a 2023 Tax Strategy Group Paper (Department of Finance, 2023a).

It is important that the Government sets out its plans now so that the disruptions necessary will be less pronounced. That means introducing adjustments in a gradual and phased way rather than overnight.

While these aspects of Ireland's climate transition will be costly, the changes will be necessary to achieve Ireland's requirements. More broadly, the costs of inaction, particularly if mirrored by other countries, could be far greater if it means a greater likelihood of more catastrophic outcomes related to climate change.

Beyond this, more work is needed to improve the modelling and precision of the impacts we estimate in this paper. We intend to further reinforce the analysis produced. We also intend to explore the indirect effects and costs of impacts set out in this paper in future research.

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Appendix A
Alternative paths to net zero

This appendix lays out the fiscal implications of alternative paths towards meeting Irelands climate objectives. The scenarios involve differing assumptions for the extent of technological improvement, the extent of energy demand, and lower than currently legislated agricultural emissions reductions.

Five scenarios are used based on the projections by the TIMES-Ireland model.[25] These five scenarios include:

Baseline: This is our baseline scenario presented in the paper, which is from MaREI's "whole system carbon budget – tech optimism" scenario.

Whole system carbon budget: This scenario does not have the technological optimism that our baseline scenario has.

Whole system carbon budget HL: This scenario has a lower energy service demand relative to the Whole system carbon budget scenario.

Reduced carbon budget: This scenario has a higher energy sector emission reduction, and a lower reduction in agricultural emissions (only 22%), relative to the whole system carbon budget.[26]

Reduced carbon budget technological optimism: This scenario has a higher energy sector emission reduction, and a lower reduction in agricultural emissions (only 22%), relative to our baseline scenario.

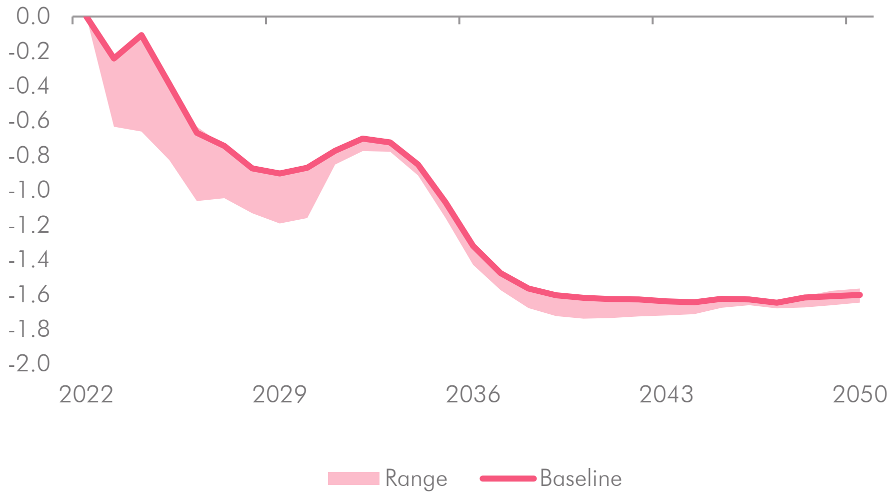
Figure A1 shows the range of revenue losses as a percentage of GNI* using these scenarios. In the short term, the revenue losses could be larger, averaging 0.3 percentage points larger per year over 2026–2030. However, over the longer run, the revenue losses are relatively similar and all fall within a range of 1.5 to 1.6% of GNI*.

[25] An interactive version of the scenario projections from the TIMES-Ireland model are available here: https://epmg.netlify.app/tim-carbon-budgets-2022/results/overview/emissions-and-cost.

[26] In the reduced scenarios, the corresponding income loss in the agricultural sector is adjusted to reflect the reduced emissions reduction targets in the agricultural sector. As a result, the fiscal cost from compensating the loss of agricultural income is also lowered.

Figure A1: Range of scenarios for revenue reductions

Revenue reductions, % of GNI*

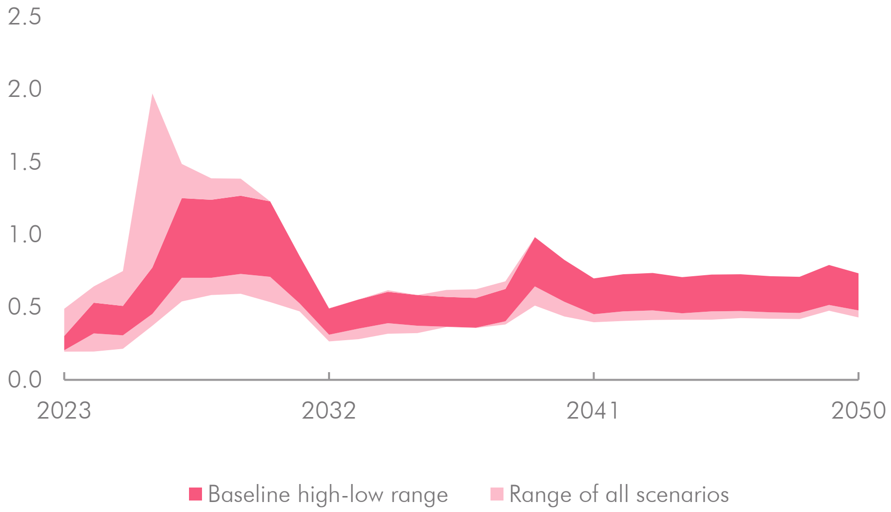


Sources: Authors' workings.

Figure A2 shows the range of high-low estimates for each scenario from the TIMES-Ireland model. In this case, the baseline expenditure estimates lie roughly in the middle of the full range of expenditure estimates in the other scenarios.

Figure A2: Range of scenarios for expenditure

Expenditure, % of GNI*



Sources: Authors' workings.

Appendix B
Macroeconomic Assumptions

Summary table of macroeconomic assumptions

	2025	2030	2040	2050
Oil (per barrel)	€78.73	€77.74	€94.77	€115.52
Gas (per mwh)	€51.84	€29.23	€35.63	€43.43
Inflation rate (%)	1.8	2.0	2.0	2.0
Nominal GNI* (€ billion)	316.9	398.5	546.8	710.6

Sources: Authors' workings.