# Carbon Budgets Modelling Review

## 2024 Report of SEAI Analysis for Carbon Budgets Working Group

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October 2024



**Sustainable Energy Authority of Ireland**
SEAI is Ireland's national energy authority investing in, and delivering, appropriate, effective and sustainable solutions to help Ireland's transition to a clean energy future. We work with the public, businesses, communities and the Government to achieve this, through expertise, funding, educational programmes, policy advice, research and the development of new technologies.

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# Executive Summary

The 2021 Amendment to the Climate Action and Low Carbon Development Act established a framework for setting legally binding 5-year carbon budgets limiting total cumulative greenhouse gas emissions in Ireland. The first two carbon budgets between 2021 and 2030 have been adopted and subsequently apportioned across greenhouse gas emitting sectors into sectoral emissions ceilings. Though some progress has been made toward reducing emissions to comply with this first programme of carbon budgets, there is still significant scaling of efforts needed to reach longer-term stricter decarbonisation goals. The SEAI was engaged by the Climate Change Advisory Council (CCAC) to support the development of a proposed second programme of carbon budgets out to 2040. SEAI's Energy Modelling Team provided views based on its own analysis through membership in the Carbon Budgets Working Group (CBWG) and performed additional testing of energy carbon budget scenarios produced by University College Cork (UCC)'s Energy Policy and Modelling Group (EPMG). This analysis has been presented for consideration by the CCAC in their recommendation of a third and fourth carbon budget.

This report summarises the work completed to contribute to an evidence base for assessment of potential carbon budgets. It presents key findings from SEAI analysis of the carbon budget scenario outputs from UCC's TIMES-Ireland Model (TIM), and addresses risks and critical actions regarding the feasibility of adhering to existing budgets and potential new budgets to 2040. This analysis consisted of a qualitative review of assumptions and outputs of the TIM scenarios, comparison to the latest SEAI National Energy Projections (NEP) With Existing Measures (WEM), With Additional Measures (WAM), and risk scenarios, and additional detailed testing of electricity system modelled scenarios using the National Energy Modelling Framework (NEMF).
Key messages derived from this analysis are summarised below:

### *Required action and implications of carbon budget pathways*

- The carbon budget scenarios explored for energy imply a necessary achievement of net-zero in advance of 2050 to contribute to efforts to limit global warming to 1.5°C. They imply a need for deeper cuts in emissions than currently planned, beyond compliance with the second carbon budget, to aim for a near net-zero energy system in the 2030s. There is no room for carbon budget overshoot and in fact all scenarios require higher levels of immediately implemented emissions reduction measures than are currently planned.

- The carbon budget pathway (CB) scenarios produced by EPMG set out necessary levels of mitigation in energy-related emissions across all sectors which exceed those currently expected to be delivered through policy targets included in planning documents such as the Climate Action Plan (CAP). Though TIM modelling suggests technology deployment scale and pace and indicates where demand reduction may be needed, it is agnostic to the policies needed to achieve the emissions reductions indicated. When compared to the NEP outputs, however, the implication of these scenarios is that a significant and immediate step change in policy would be needed to make the proposed pathways achievable. Given the number of technology and policy targets already included in CAP, increasing pre-2030 technology targets no longer seems plausible, leaving widespread reduction in energy use as the only alternative.

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

### *Pace of progress to date*

- To date, climate policy in the energy sector has been focused on 2030 targets, but all scenarios examined would require both ongoing acceleration of existing policy and the addition of new policy out to 2040 and beyond to deliver the necessary level and pace of mitigation. Current policy is more technology-focused than demand-focused and current policy development and implementation lead times put the achievement of a pace of action consistent with these carbon budget pathways at significant risk.

- To achieve Ireland's share of global climate goals, it is necessary to implement emissions reduction measures at an unprecedented scale and pace. The cumulative nature of the carbon budget targets necessitates an acknowledgement of where the rate of implementation has fallen behind ambition thus far, and a reflection on feasible trajectories for delivery of measures that can make up for any shortfall.

- The pace of decarbonisation in transport, the built environment and industry required by the carbon budget scenarios presented is significantly beyond those in the NEP scenarios, assuming both current implemented emissions reduction measures (WEM) and the currently most ambitious set of planned policy measures (WAM). The rate of assumed uptake of renewable heating technologies, retrofit measures and electric vehicles from now to 2030 in these NEP scenarios presents a risk to compliance with the existing carbon budgets, and this risk propagates into the carbon budget scenarios explored for the energy system from 2030 to 2040.

- The energy carbon budget scenarios in which trajectories follow the WEM and WAM emissions projections to 2030 and accelerate to catch up in the period post-2030 (e.g. 350Mt-WAM) illustrate an extreme pace of implementation, pushing the limits of feasibility, particularly in the period from 2030 to 2035. However, alternative scenarios that assume greater progress than the WEM and WAM trajectories until 2030 require an immediate step change beyond the level of ambition currently included in CAP, arguably also straining feasibility of timely policy implementation to match. The reality is that Ireland is off-track under current planned policy. If emissions cuts fall behind the core carbon budget trajectories before the end of the current decade, there is a significant risk that the post-2030 rates in the adjusted core scenarios which assume WEM or WAM to 2030 become the only carbon budget compliant path.

### *Risk of further delay*

- There is now a severe risk of delayed achievement of many Climate Action Plan targets, including for renewable electricity, biomethane, electric vehicles, district heating, heat pumps and building energy efficiency upgrades. If even some of these risks materialise, it could result in certain target failure, higher greenhouse gas emissions, lower renewable energy share, and higher energy demand.

- The risk scenarios produced by SEAI to supplement the WEM and WAM scenarios (as presented to the CBWG, publication pending) show that there are credible risks to planned CAP target achievement by 2030 across all sectors, and that these significantly impact the potential overshoot of the first and second carbon budgets. This should be taken into consideration when selecting appropriate third and fourth carbon budgets.

- Risk scenarios for variable electricity generation deployment were developed using a pooled forecast from surveys of a range of expert stakeholders. The scenarios represent alternative deployment rates for each variable renewable technology, as judged by a pool of expert stakeholders in Q1 2024. The provisional results of this expert elicitation were presented to the CBWG and a report documenting the methodology and results of the surveys will be published by SEAI in late 2024.

### *Implication of scenario assumptions for electricity generation*

- Simplified methodologies of modelling the electricity system limit the ability to capture the full picture of future emissions, as well as future investment and operational requirements and costs. In 2030 alone, SEAI's hourly-resolution modelling approach[1] resulted in as much as ~3Mt additional emissions attributed to gas generation relative to the annual-resolution modelling approach employed in the TIM scenarios. In the final iteration, most carbon budget scenarios show no run-hours of gas generation for the majority of the third carbon budget period (2031-2035) prior to any BECCs or hydrogen coming on stream. There are also potential additional sources of emissions that are not captured in either modelling approach, e.g. emissions arising from re-dispatch in the balancing market, which should be considered as a possible margin around selected carbon budget trajectories.

- Immediate action on renewable electricity generation is critical to enabling electrification strategies across other sectors. This means that the risk of overestimating the date of reaching 80% renewable share in electricity (RES-E) has a knock-on impact to emissions reduction achievement elsewhere. Current best estimates indicate a likely under-delivery of renewable generation in comparison to the CAP targets, particularly offshore wind and onshore wind.

- Lower carbon budget scenarios such as the 250Mt scenario necessitate the acceleration of technology deployment in electricity generation by a decade before the 350Mt scenario. The deployment of new installed capacity, increased interconnection, large-scale storage and transmission and distribution system reinforcement all come with lead times that must be factored in and reduced where possible to make even the carbon budget scenarios with a more conservative level of ambition (e.g. 400Mt) feasible to 2040. Some critical conditions constraining infrastructure deployment, such as the planning system, labour market and international supply chains, could not be factored into these scenarios.

- All scenarios produced with TIM and reviewed by SEAI rely on emissions removals through Carbon Dioxide Removal (CDR) technologies, for which the option available in TIM is Bioenergy with Carbon Capture and Storage (BECCS). The NEMF modelled scenarios do not include any CDR technologies out to 2040 at present. This is due to a lack of clarity in current planned policy on expected capacity and supports for these technologies at scale and, particularly for BECCS, the availability of a sustainable biomass supply. The results of the expert elicitation on CCS capacity demonstrate a significant level of uncertainty on the timing of the availability of this technology.

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

The pooled best guess from experts is that no CCS will be deployed in the power sector before 2040, and this remains a significant risk to the feasibility of the carbon budget scenario options.

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

More information and analysis from SEAI's Energy Modelling Team can be found in SEAI's forthcoming 2024 National Energy Projections Report, shortly to be published on the SEAI website.

# Contents

# 1. Introduction

## 1.1. Scope of analysis and report

The focus of this report is on energy use and emissions that result from burning of fossil fuels for energy, corresponding to the scope of the energy system expertise and analysis contributed by SEAI. It should be noted that the carbon budgets relate to total greenhouse gas emissions (energy and non-energy related); however, testing carbon budget scenarios combining energy with agriculture, LULUCF and other emissions, was outside of the scope of SEAI's analysis. The analysis completed covers the areas of energy supply and use in electricity generation, transport, buildings, and industry.

This report describes the approach taken to the modelling analysis and review of three iterations of carbon budget scenarios produced by University College Cork's (UCC's) Energy Policy and Modelling Group (EPMG), including additional testing of their TIMES-Ireland Model (TIM) outputs for the power sector. The main tool used for this analysis was the National Energy Modelling Framework (NEMF), developed and applied by SEAI's Energy Modelling Team. Also discussed is additional relevant work from other teams in SEAI included to enrich the evidence base for the consideration of the scenarios for the Climate Change Advisory Council (CCAC) to provide a recommendation on third and fourth carbon budgets.

Throughout the process of developing and refining the set of energy carbon budget scenarios during the work of the Carbon Budgets Working Group (CBWG), SEAI provided feedback to the UCC EPMG team on iterations of the TIM modelled outputs, which contributed to some of the updates made in later modelling iterations. This peer review included a qualitative review of key model assumptions in TIM, as well as quantitative comparison with modelling outputs from the NEMF.

This report contains an appendix providing additional detail on the NEMF model and its outputs.

## 1.2. Approach to review and testing of carbon budget modelled scenarios

### *Carbon budget scenario review approach*

To provide feedback and analysis, SEAI reviewed outputs from TIM scenarios on EPMG's web portal[2], which included data by scenario, sector, and fuel. This data was compared to NEMF assumptions and outputs from several scenarios.

The main two scenarios used for comparison were the With Existing Measures (WEM) and With Additional Measures (WAM) scenarios produced as part of the National Energy Projections, which informed the energy component of the EPA Greenhouse Gas Emissions (GHG) Projections published in May 2024[3]. The WEM scenario is a projection of future energy use based on the estimated impact of policies and measures currently implemented and actions committed to by Government. The stated ambition must be commensurate with the resources or legislation already in place or committed to by Government Departments or Agencies and does not assume the implementation of

[2] UCC 'Carbon Budget Analysis with the Times-Ireland Model'. 2024. [Online]. Accessed from: https://epmg.netlify.app/TIM-Carbon-Budget-August_2024/

[3] EPA 'Ireland's Greenhouse Gas Emissions Projections 2023-2050'. 2024. [Online]. Accessed from: https://www.epa.ie/publications/monitoring--assessment/climate-change/air-emissions/irelands-greenhouse-gas-emissions-projections-2023-2050.php

any new policies or measures post-2022[4]. The WAM scenario is more ambitious. It is a projection of future energy use based on the estimated impact of measures outlined in the latest Government plans at the time the National Energy Projections are compiled. This includes all policies and measures included in the WEM scenario, plus those included in the latest Government plans but not yet fully implemented, considering CAP24[5]. In nearly all cases this scenario assumes that the CAP targets will be fully achieved. Where current levels of support are unlikely to be sufficient to deliver the target, it is assumed that unspecified additional policies and measures will be implemented in time to ensure target achievement. These projected outputs of annual and cumulative emissions out to 2040 were assessed against potential reduction trajectory from the EPMG scenarios to illustrate the gap between the current policy landscape and the emissions reductions measures implied by the potential carbon budget pathways.

In addition to the WEM and WAM projections, SEAI have modelled several risk scenarios to examine the potential impact of delays in achieving some of the most significant targets set in CAP24. These point to areas where immediate acceleration and strengthening of existing policies and measures is essential to mitigate the risk of shortfall to 2030 targets. SEAI also reviewed the TIM outputs against a combined risk scenario to understand the impact of potential delays in current policy commitments and their implication for carbon budget overshoot. The risk scenario for variable generation capacity was developed using forecasts from surveys of expert stakeholders, the outputs of which were presented to the CBWG by the SEAI Research & Technology team.

The SEAI Energy Modelling Team also performed more detailed quantitative testing of the electricity system outputs, as this area is critical for early decarbonisation to facilitate electrification strategies of emissions reduction across other sectors. The methodology used here was to align NEMF trajectories of installed capacities for variable renewable sources of electricity generation – offshore wind, onshore wind, and solar photovoltaics (PV) – to those included in the carbon budget scenarios. These modelled outputs were then compared to see how the energy and emissions outputs from the annual-resolution TIM power sector outputs compare with the NEMF's hourly-resolution electricity (Power) module, which employs PLEXOS[6].

Review documents were prepared for the first two iterations of the TIM modelled outputs for engagement with UCC before the final iteration. These included observations and questions across all energy sectors, as well as suggestions for areas of calibration or alignment, which the EPMG team took into consideration when refining subsequent iterations. Additionally, the key findings from these iterative reviews and additional analysis were presented to the CBWG.

### *Model Description*

The National Energy Modelling Framework, developed and maintained by SEAI, is a full national energy-economy model that is used to assess the impacts of packages of energy policies and measures on future energy supply and demand. It combines several SEAI sectoral models to produce policy-rich outlooks for the whole energy system.

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[4] 2022 was the cut-off year for the 2024 Projections, as it was the last historical reporting year at the time that the projections were carried out. The cut off is carried forward annually.

[5] Full input assumptions available for EPA 'Ireland's Greenhouse Gas Emissions Projections 2023-2050'. 2024. [Online]. Accessed from: https://www.epa.ie/publications/monitoring--assessment/climate-change/air-emissions/irelands-greenhouse-gas-emissions-projections-2023-2050.php

[6] Energy Exemplar 'PLEXOS'. 2024. [Online]. Accessed from: https://www.energyexemplar.com/plexos

The NEMF has a policy focus, and scenarios are primarily defined to reflect policies that are being implemented or planned, and their impact is assessed against targets. The NEMF is not typically used to solve for a carbon budget constraint, but it can be used to test outputs of an optimisation approach like that used in TIM by aligning documented input assumptions and sense-checking the outcomes. This was the approach used in the additional testing of electricity results from TIM. More detail on the NEMF structure, inputs, outputs, and uses is included in the Appendix.

# 2. Progress to date and risk of delayed achievement

## 2.1 Key findings from National Energy Projections

The National Energy Projections examine future energy use in Ireland under different scenarios and account for factors such as economic growth and the anticipated impact of Government energy policies. The results provide an assessment of how we are likely to perform against targets such as the existing and potential future carbon budgets.

### *Shortfall projected for all targets*

This year's emissions projections WEM and WAM scenarios published by the EPA illustrated that there are significant projected gaps to all legally binding national and EU targets. This includes the first programme of national carbon budgets. Even with full delivery of all key targets in the CAP, it is likely that the energy sector will not keep within its share of Ireland's first two national legally binding carbon budgets to 2030. The greenhouse gas emissions from energy and industrial processes accounted for 55% of the 2018 baseline total, and by 2030 they are projected to make up 46% and 47% of total emissions in the WEM and WAM scenarios, respectively.

The carbon budgets for total greenhouse gas emissions are shown in Table 1. If the indicative trajectory for the carbon budgets had been followed every year from 2020, then emissions in 2030 would have needed to be 51% lower than in 2018. However, this indicative trajectory has already been exceeded in the first two years of CB1. Where any exceedance occurs, steeper reductions are required thereafter to compensate, leading to a larger reduction required by 2030.

**Table 1: Overall national carbon budget obligation 2021 – 2030 and related indicators**

| Overall carbon budget | |
|---|---|
| 2018 baseline emissions (single year) ($MtCO_2eq$) | 68 |
| CB1 ceiling 2021-2025 (five-year cumulative) ($MtCO_2eq$) | 295 |
| CB2 ceiling 2026-2030 (five-year cumulative) ($MtCO_2eq$) | 495 |
| Indicative average annual % reduction required in CB1* | -4.6% |
| Indicative average annual % reduction required in CB2* | -9.6% |
| Initial indicative reduction required by 2030 (relative to 2018) * | -51% |
| **Assuming indicative target trajectory met in all years* | |

Data on emissions for the NEMF results in this report are taken from the latest EPA GHG Projections as published in May 2024 and submitted to the EU, including modelled data for 2023. The EPA have since published provisional historical data for 2023[7], including an early version of the SEAI energy balance produced in June 2024. The provisional 2023 figures include a reduction in emissions,

[7] EPA 'Latest Emissions Data'. July 2024. [Online]. Accessed from: https://www.epa.ie/our-services/monitoring--assessment/climate-change/ghg/latest-emissions-data/

including in electricity, which will slightly reduce the 2023 values in the next set of NEP and GHG Projections.

Figure 1 below shows the WEM and WAM projections for total energy-related annual emissions (including industrial processes) to 2040 under current implemented and planned policy, respectively. The indicative carbon budget trajectory from 2020 to 2030 to meet the energy component of the first programme of carbon budgets is shown to illustrate the path that should have been followed to avoid steeper reductions in later years. As emissions have overshot this trajectory, there is also a correction trajectory shown below, illustrating the rate of annual reduction required for compliance with the budgets if the WAM trajectory is followed to the end of 2025.

The divergence between the WEM and WAM beyond 2025 shows how the implementation of additional measures consistent with the higher level of ambition in CAP is projected to occur gradually and ramp up in the last few years of this decade.

**Figure 1: Energy-related CO2 emissions – NEP and indicative trajectories for first two carbon budgets**

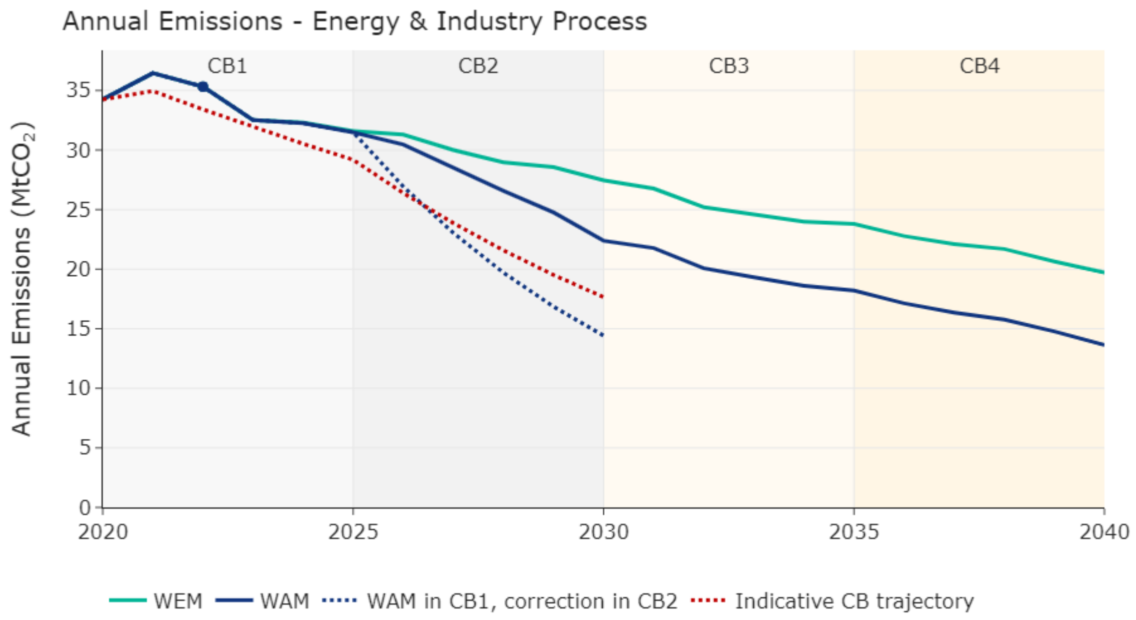
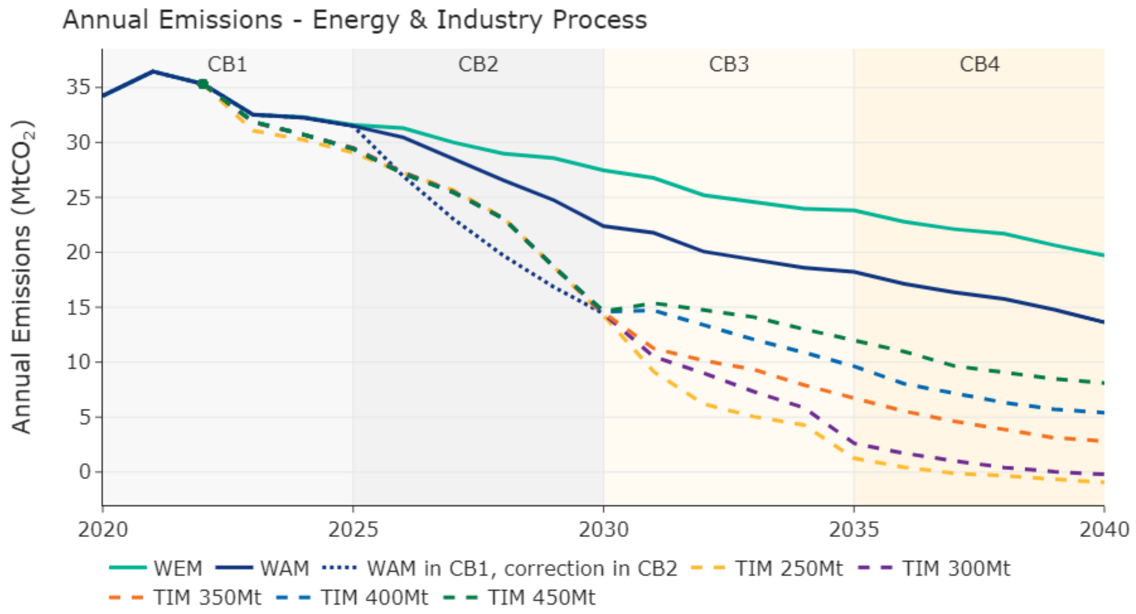



Figure 2 compares the core carbon budget scenarios produced for the preparation of the second programme of carbon budgets to the NEP scenarios. All core carbon budget pathways require an immediate departure from the WEM and WAM trajectories and follow the same path to 2030 with significantly steeper annual emissions reductions than in the WAM projections. After 2030, these pathways then diverge based on the total budget, with the 300Mt and 250Mt especially implying a further acceleration in the 2030s of the annual pace of reduction.

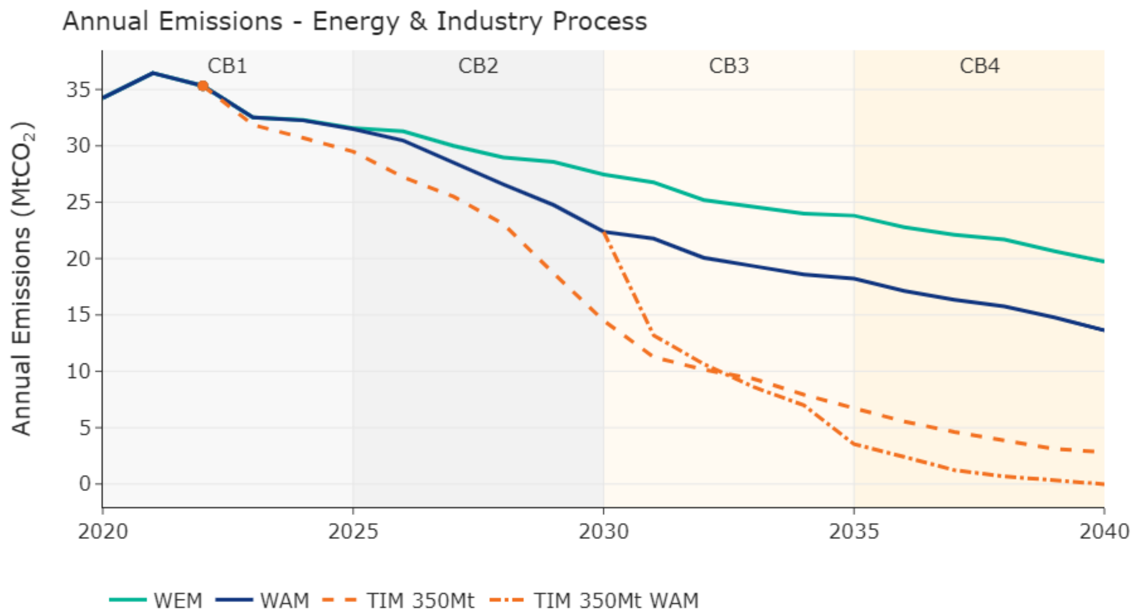
**Figure 2: Energy-related CO2 emissions – NEP comparison to TIM core carbon budget scenarios**




Given the significant difference between the WAM and the trajectory of core carbon budget pathway scenarios from now to 2030, it is important to review the pace of emissions reduction required post-2030 under the potential carbon budgets if Ireland's emissions reductions follow the WAM to 2030. In the CB scenarios, there is a rapid drop post-2030 if a WAM trajectory is followed to 2030.

The comparison, taking the middle EPMG scenario 350Mt as an example, is illustrated in Figure 3.

**Figure 3: Energy-related CO2 emissions – NEP comparison to TIM 350Mt and 350Mt WAM scenarios**




The extreme rate of acceleration in the early 2030s indicated by the WAM-adjusted carbon budget scenarios stretches the limits of feasibility in the absence of an unprecedented tripling of the pace of measure implementation. The core scenarios show significantly steeper reduction in energy-related emissions than currently shown in even the WAM projections, the latter broadly representing the achievement of all planned policy targets. The latest NEP outputs point to the risk of delay in achieving CAP targets and its impact on the likelihood of keeping on the WAM trajectory if the current pace of implementation continues.

## 2.2 Delayed achievement risk scenarios

### *Risk of falling further behind*

To explore the consequences of delayed achievement of core targets, SEAI have developed several "risk" scenarios in addition to the WEM and WAM scenarios. These risk scenarios aim to address the gap between current (existing and implemented) policy trajectories and the most ambitious planned policies scenario. The impact of delayed target achievement is modelled for several core measures, including the deployment of wind and solar capacity, district heating networks, bioenergy, retrofitting and renewable heating technology in buildings, and electric vehicle adoption.

If even some of these risks materialise, it would result in target failure and increased carbon budget overshoot beyond that indicated in the WAM scenario. The risks considered here have been selected for the purpose of impact analysis and are not exhaustive. For example, there are ambitious targets to decarbonise industry energy use, but while there are low carbon alternative technologies available today for many industry applications, uptake to date has been slow. Reduction in transport energy demand is critical, but the continuing trend for larger vehicles is undoing much of the progress that is being made in active and public transport, as is the continuously increasing demand for goods that increases the activity of hard-to-decarbonise goods vehicles.

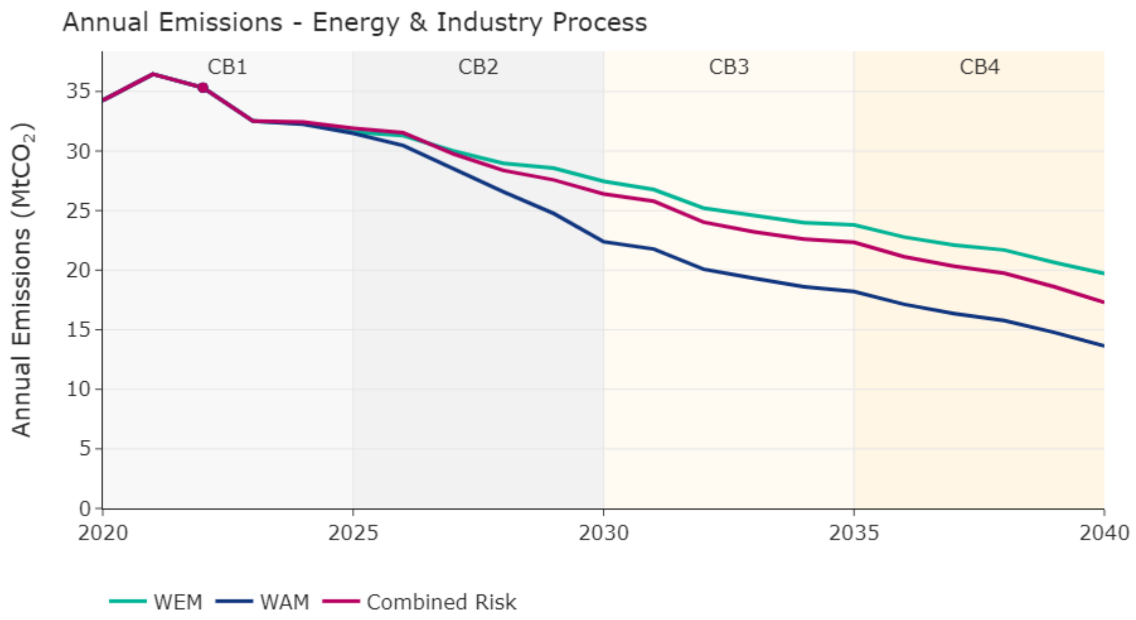
Risk scenarios were evaluated both individually relative to WAM and combined to show potential trajectory with delays across multiple areas relative to WEM and WAM, the emissions results of which are illustrated in Figure 4. The key assumptions for credible risks to the implementation pathway for 2030 target achievement presented in this report as the "combined risk" scenario are as follows:

- Biomethane: 1.9 TWh by 2030 (vs 5.7 TWh in WAM/CAP – the target is assumed to be achieved by 2040 in the risk scenario).
- District heating: 360 GWh by 2030 (vs 2.7 TWh in WAM/CAP – the target is assumed to be achieved by 2040 in the risk scenario).
- Transport demand reduction: CAP21 levels of activity reduction (10% reduction in private car vehicle-kilometres vs 2019 is assumed to be achieved by 2030).
- EVs: ~743k EVs by 2030 (vs 944k in WAM/CAP).
- Offshore wind: 0 GW new installed capacity by 2030 (vs 4 GW in WAM).
- Onshore wind: 6.2 GW by 2030 (vs 7.2 GW in WAM).
- Solar PV: 5 GW by 2030 (vs 6.5 GW in WAM).
- Residential retrofits and heat pumps: uptake modelled based on current grants/supports (vs WAM assumption of increased levels of support to meet 500k B2s and 400k heat pumps in existing dwellings by 2030).

Note that the risk scenarios for variable generation capacity were developed using forecasts from surveys of expert stakeholders. The scenario represents a plausible worst case deployment scenario for each variable renewable technology, as judged by a pool of expert stakeholders in Q1 2024. A report documenting the methodology and results of the surveys is expected to be published by SEAI in late 2024.

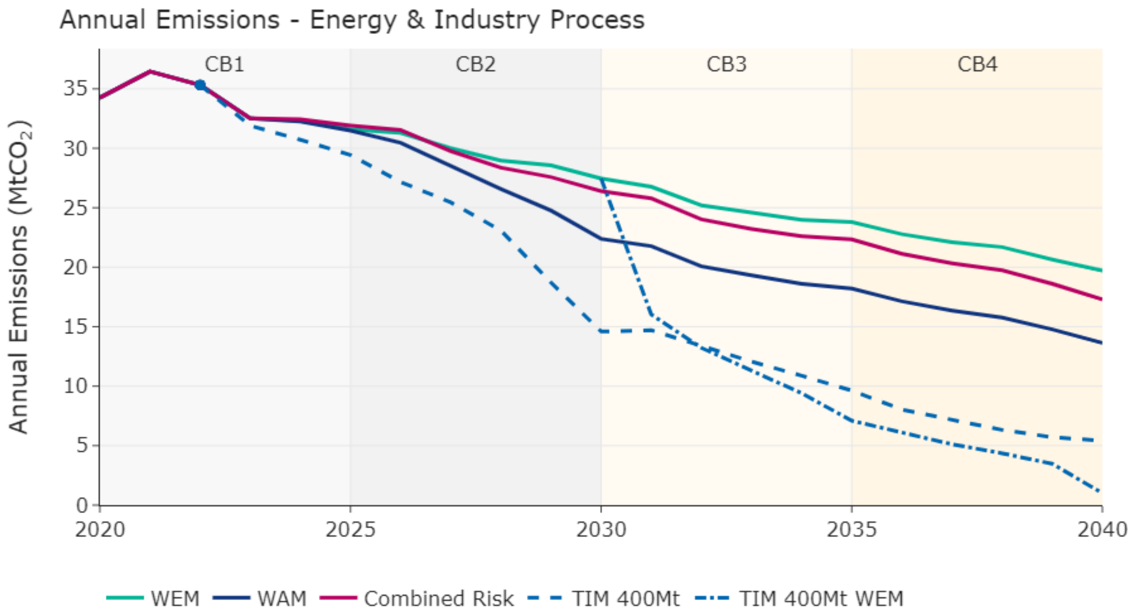
Figure 4 shows the NEP projections of annual emissions compared to those of the combined risk scenario described above.

**Figure 4: Energy-related CO2 emissions – NEP and combined risk scenario representing widespread delays**




The combined risk of delays in the achievement of CAP targets across sectors results in a projected annual emissions reduction trajectory much closer to WEM than WAM. It is therefore important to consider these risks and the implication for the carbon budget pathways explored if a trajectory closer to the WEM was seen up to 2030. This comparison is shown in Figure 5 below, illustrated with the TIM outputs for the 400Mt and 400Mt WEM scenarios as an example.

**Figure 5: Emissions from NEP and combined risk scenario compared to TIM 400Mt and 400Mt WEM**




If the risk trajectory is followed to 2030, this would necessitate extreme rates of emissions cuts in the 2030s and bringing the net-zero timeline forward by a decade to comply with a 400Mt carbon budget. Failure to make these levels of cuts in the 2030s would also increase the potential for reliance on negative emissions technologies, increase the cost of mitigation, and increase the likelihood of unabated emissions to be added to the current unallocated emissions savings of 16Mt from the first two carbon budgets sectoral ceiling allocation.

# 3. Reviewing carbon budget scenarios by sector

## 3.1 Electricity

Following review of the emissions reduction pathway scenario outputs from TIM for electricity, feedback was provided on the areas below:

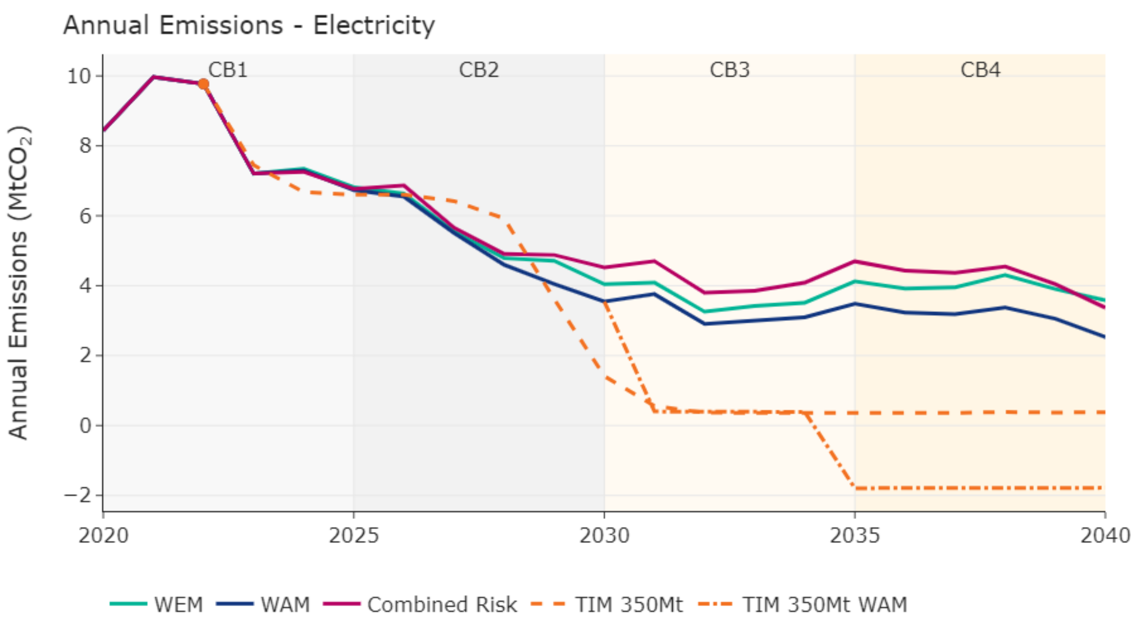
- **Latest energy supply data**: monthly indigenous electricity figures published on SEAI's website[8] are supplemental to the EPA inventory, which is the definitive source, but provide useful provisional information on the latest trends in supply.
- **Trends in total generation**: electricity demand in the NEMF projections scenarios continues to grow throughout the model horizon beyond the 2040s, with increasing electrification across heat, transport, and industry, as well as the addition of new demand from large energy users such as data centres. The latter is a risk to carbon budget overshoot as these sources are not displacing demand for fossil fuels elsewhere.
- **Phase-out of conventional generation**: to meet increased demand across the day and seasons, some residual use of non-renewable fuels, particularly natural gas, in electricity generation is still expected well into the 2030s.
- **Renewables maximum capacity**: The availability of suitable lands for onshore wind farm development beyond ~10 GW may be very constrained.

[8] SEAI 'Monthly Electricity Data'. 2024. [Online]. Available from: https://www.seai.ie/data-and-insights/seai-statistics/monthly-energy-data/electricity-monthly/

- **Pace of renewables deployment:** Current best estimates (derived via expert elicitation) are that there is likely to be an under-delivery of renewable generation in comparison to the CAP targets, particularly for offshore wind and onshore wind.
- **Timing of CDR technologies and hydrogen storage:** Given the risks and uncertainties associated with both carbon capture and storage, and bioenergy for power generation, it is essential to consider the alternatives if CDR options like BECCS were not present in the 2030s, as it would necessitate a decrease in demand or an even faster rate of decarbonisation to stay within carbon budgets.

In the most ambitious NEP scenario with current planned policy (WAM), there is still over 2Mt of electricity generation emissions projected in 2040, primarily from gas generation required to meet net load (electricity demand minus the output from variable renewable energy (VRE) generators, e.g. wind, wave, and solar PV). In contrast, most carbon budget scenarios from the early 2030s show no run-hours from gas generation and therefore contain emissions only from the waste-to-energy plants, leading to near-zero sectoral carbon dioxide ($CO_2$) emissions, as seen in the TIM 350Mt scenario in Figure 6. This result in the CB scenarios is possibly due to the selected temporal resolution for the electricity aspect of the CB scenarios not capturing the variability in renewable generation over a 24-hour period and across seasons, and the consequent requirements on the planning and operation of the power system.

**Figure 6: Electricity sector annual $CO_2$ emissions – NEP vs TIM 350Mt and 350Mt WAM scenarios**




The 350Mt WAM scenario in Figure 6 shows that if the WAM trajectory were followed to 2030, compliance with a 350Mt budget for energy would depend on extremely steep reductions in the first couple years of 2030, as well as on the use of negative emissions technologies (NETs), in the form of a risky 0.5 GW BECCS capacity by 2034 here, to remove 2Mt$CO_2$ emissions. More detail on the testing of the electricity system modelling is provided in Section 4. Testing delivery assumptions in electricity

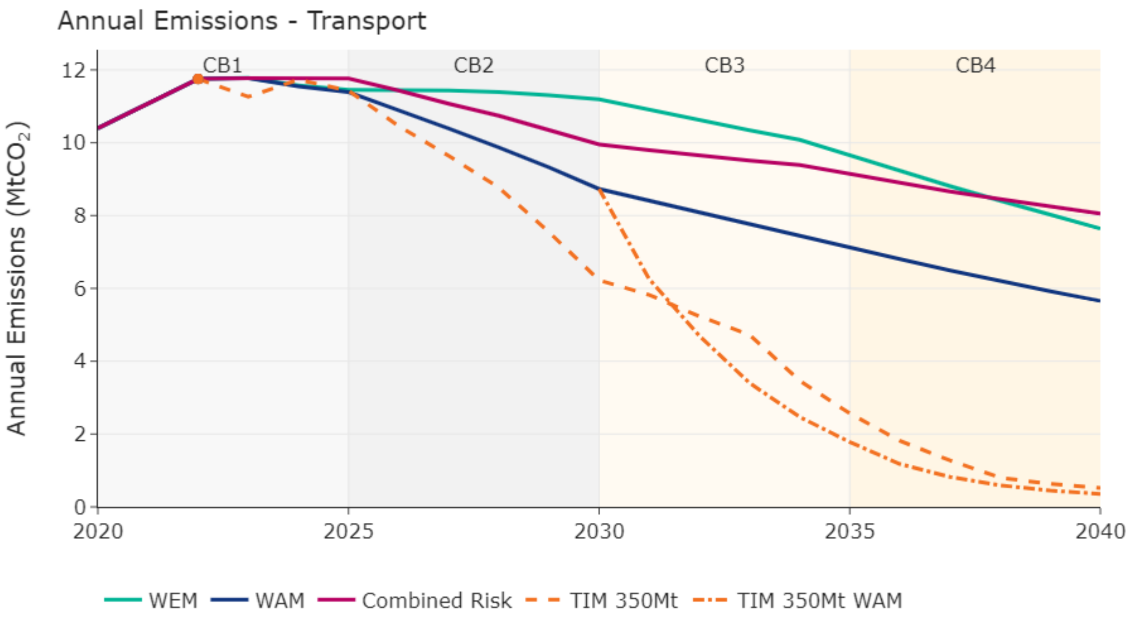
## 3.2 Transport

Following review of the emissions reduction pathway scenario outputs from TIM for transport, feedback was provided on the areas below:

- **Date of cessation of ICE vehicle sales**: In all core carbon budget scenarios, new internal combustion engine (ICE) vehicle sales are almost entirely phased out from 2025 (private car and LGV from the start of 2025 and HGV from the start of 2027). This outcome is necessary to meet the specified carbon budget. In policy application however, adopting this outcome as an action would mean exploring the legality of effectively banning ICE vehicles immediately in advance of EU regulation, to ensure compliance with EU internal market rules.
- **Rate of EV uptake**: In the core CB scenarios, there are ~867k private car battery electric vehicles (BEVs) by 2030 and this more than doubles from 2031 to 2035. This is higher than the total private car EV target in CAP of 845k by 2030, which in the WAM is assumed to be made up of just 574k BEVs with the rest hybrid rather than fully electric. The WEM and combined risk scenarios assume just 430k private car BEVs by 2030.
- **Annual EV sales**: In CB scenarios there are also very high volumes of annual EV sales (~300k for private cars in each year of CB3, 2031-2035). A benchmark of the CSO statistics[9] on previous peaks of new car sales (~185k in Celtic Tiger peak, 225k in 2000s) is a useful guide for high volumes of sales to form a realistic picture of maximum annual EV uptake rates.

In NEP WAM there is projected to still be over 5Mt of transport emissions in 2040, with a significant risk of increase if there is a delay in planned measures. Whereas in most of the CB scenarios, transport is near zero-carbon by 2040, as shown in Figure 7**Error! Reference source not found.**.

**Figure 7: Transport sector annual CO2 emissions – NEP vs TIM 350Mt and 350Mt WAM scenarios**




9 CSO ‘Vehicles Licensed for the First Time’. 2024. [Online]. Accessed from: https://data.cso.ie/table/TEA01

As in other sectors, if the WAM trajectory were followed to 2030, dramatic cuts would be required to maintain compliance with the select carbon budget for energy. For transport in particular, the pace of decarbonisation to 2040 is even more challenging given the scale of emissions in this sector.

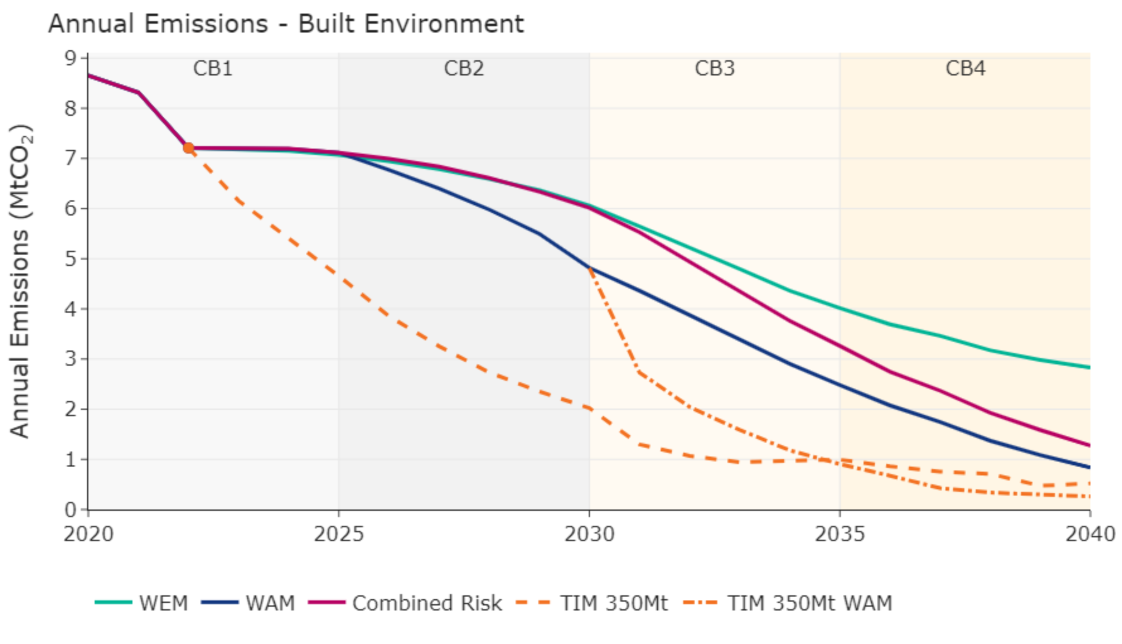
## 3.3 Built Environment

Following review of the emissions reduction pathway scenario outputs from TIM for the built environment, feedback was provided on the areas below:

- **Early spikes in residential emissions reductions**: Many scenarios showed large numbers of residential retrofits between now and 2030, dropping significantly thereafter. SEAI suggested considering limits on the annual number or percentage increase of home upgrades possible in a single year. Ideally limits would be based on available labour and materials.
- **Rate of retrofit and renewable heating technology uptake**: It is important that the acceleration of retrofit assumed remains within likely delivery bounds. Current WEM projections indicate current levels of supports for these measures are unlikely to incentivise the level of uptake needed to reach rates of reduction implied by the TIM scenario outputs.
- **Latest data on number of retrofits and heat pumps**: Quarterly retrofit data[10] published by SEAI can give some indication of how the rate of uptake has evolved in the residential sector under existing levels of support.

In the NEP WAM scenario, there is projected to be an emissions reduction of ~2Mt$CO_2$ between 2022 and 2030 in the built environment, whereas in the CB scenarios, the reduction is approximately 2.5 times greater over the same period, as shown in Figure 8**Error! Reference source not found.**. This is mostly due to the electrification of over 50% of residential heat by 2030.

**Figure 8: Built environment sector annual CO2 emissions – NEP vs TIM 350Mt and 350Mt WAM scenarios**




[10] SEAI 'Statistics for National Home Retrofit Programmes'. 2024. [Online]. Accessed from: https://www.seai.ie/grants/home-energy-grants/home-upgrades

The NEP scenarios point to the challenge of substantially increasing the rate of emissions reduction under the current suite of implemented and planned policy in the built environment. Though uptake of heat pumps and retrofit measures has increased, it will be challenging to continue to increase the pace to that required to meet CAP targets without increased supports for homes and businesses, and even then, the 2030 timeline is at risk. Additionally, for the CAP24 2030 district heating target to be achieved, a further 88 schemes the size of the Tallaght District Heating Network would need to be identified, planned, and delivered by 2030.

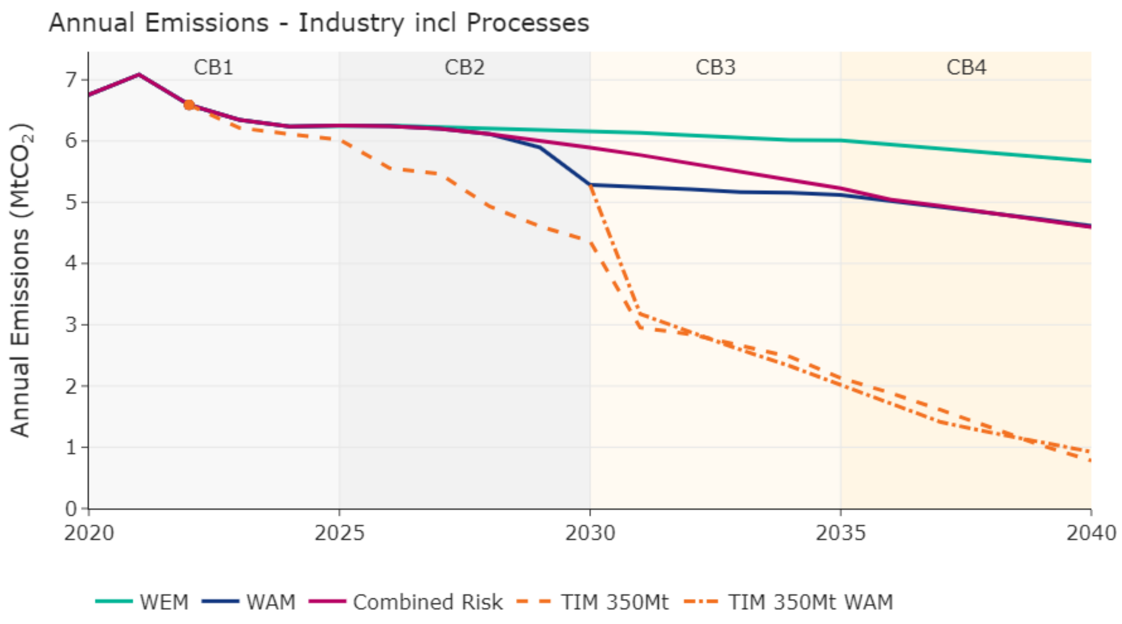
## 3.4 Industry

Following review of the emissions reduction pathway scenario outputs from TIM for industry, feedback was provided on the areas below:

- **Timing of availability of CCS technology in cement production**: There is a critical assumption in the stricter CB scenarios (including the 350Mt) that CCS technology is available in 2031 (<10 years away) for all Irish cement plants. This requires further consideration of feasibility of delivery this soon, as it is by far the biggest influence on GHG emissions in the sector. CCS is not assumed to be adopted in the NEMF, based on current planned policy. In the 400Mt CB scenario CCS is delayed until the mid-2040s.

In the NEP WAM, current planned policy assumptions leave ~4.5Mt emissions by 2040, as seen in Figure 9**Error! Reference source not found.**. In the CB scenarios, there is an accelerated adoption of CCS and a doubling of electricity consumption in the sector by 2040 leading to ~1Mt emissions by 2040. In the NEP WAM, the share of low carbon energy in industry (electricity and renewables, incl. biomethane) is 67%.

**Figure 9: Industry sector annual CO2 emissions – NEP vs TIM 350Mt and 350Mt WAM scenarios**




The risk scenario above indicates the impact of a delay in biomethane capacity on the WAM scenario. The timing of this capacity, along with the challenge of electrifying industry put steeper emissions reductions before 2030 at risk.

# 4. Testing delivery assumptions in electricity

## 4.1 Recent developments in electricity imports

The NEMF projections presented here were modelled in early 2024. Since April 2023, there has been a significant increase in electricity imports across the interconnector with Great Britain. 2023 saw a record level of electricity net-imports. This trend has increased further in 2024, where the level of net import in the first half of 2024 has already exceeded all of 2023 and is higher than projected in the WEM or WAM scenarios presented below. Consequently, the sectoral emissions ceiling for electricity for the first carbon budget period will be much closer to being achieved than previously projected. There is uncertainty on whether this trend will continue to such an extent in CB2 as the EU Carbon Border Adjustment Mechanism (CBAM) comes into full effect in 2026. Electricity imports from Great Britain will then be subject to the EU CBAM until such a point in time when the EU ETS and the UK ETS become fully linked[11].

The exact behaviour of the interconnectors in the future remains uncertain, given the multiple factors (both internal and external to Ireland) that influence the direction and scale of cross-border electricity trade. While this uncertainty is likely to persist, its drivers and the range of possible outcomes need to be characterised to understand its effect on national emissions. A delay in the roll-out of all types of variable renewables, e.g. onshore wind, solar PV, and particularly offshore wind, poses large risks. While imports may somewhat aid in mitigating this delay from a national emissions perspective, there is little to no mitigation for our European renewable energy targets.

## 4.2 Electricity demand in the National Energy Projections scenarios

The decarbonisation of electricity generation, combined with the electrification of energy demand for heating and transport, is one of the main strategies for decarbonising energy use in Ireland. In the WEM and WAM scenarios, variable renewables are projected to be the largest input to electricity generation by 2028, with a sharp increase later in the decade due to connection of large offshore wind projects. Natural gas use increases in all scenarios to 2026 to meet increased demand and to compensate for the phase out of coal but declines in the second half of the decade as the delivery of variable renewable energy capacity begins to outpace the growth in electricity demand. This increase in demand necessitates additional dispatchable generation capacity to ensure electricity supply reliability standards are maintained. It is anticipated that new conventional generation will be open-cycle gas turbines. The faster rollout of renewable generation assumed in the WAM scenario leads to faster reduction in gas use in this scenario.

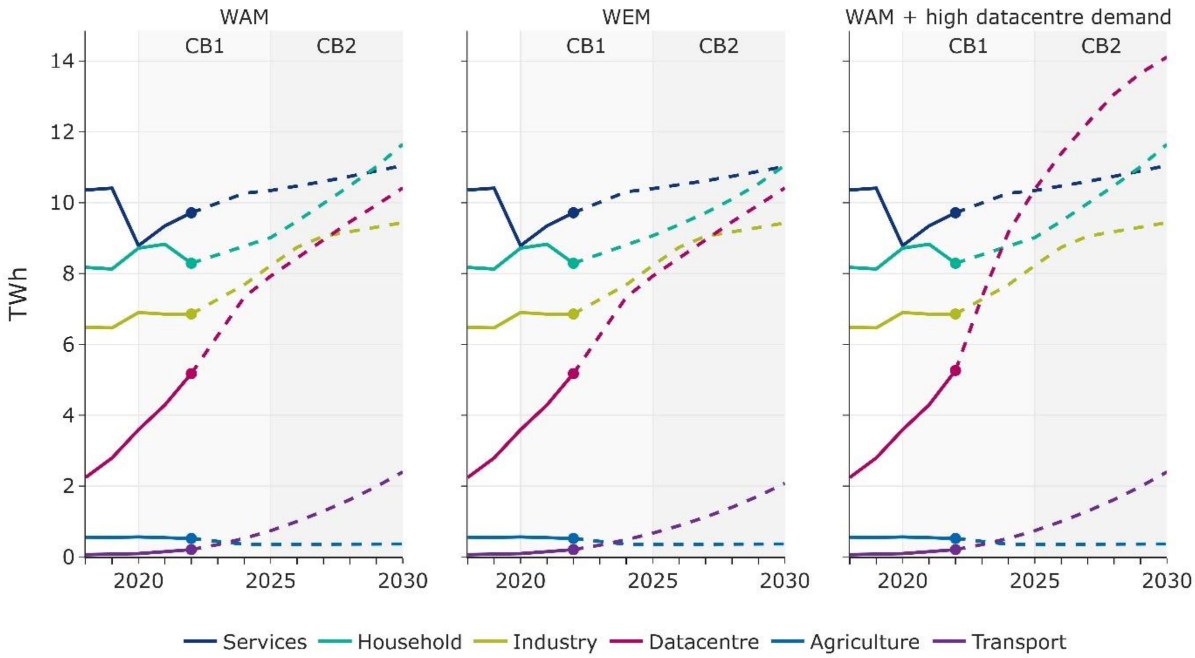
The rate at which we can decarbonise electricity generation is determined by four factors:

- The rate at which electricity demand grows.
- The rate at which we can deploy renewable energy generation capacity and integrate its energy.
- The rate at which we can reduce the carbon intensity of our remaining non-renewable dispatchable generation, e.g. switching from coal and oil to gas in the short-term, and to a lower-carbon fuel in the long-term.
- The scale and direction of cross-border interconnector trades.

[11] Afry, ‘EU CBAM impact study focused on electricity imports from Great Britain’. Mar 2024. [Online]. Accessed from: https://afry.com/sites/default/files/2024-03/afry_eu_cbam_impact_study_summary_report_mar_2024_v200.pdf

Figure 10 shows projected final electricity consumption, which in the WAM scenario is 45.3 TWh in 2030, an increase of 47% or 14.5 TWh from 2022. Of this increase, 7.9 TWh is anticipated to come from the electrification of heat and transport and 6.6 TWh is anticipated to come from datacentres and other large energy users.

**Figure 10: Final electricity consumption in NEP scenarios**




For the WEM and WAM scenarios, the projected growth in datacentre electricity demand is taken from EirGrid's best estimate Median scenario[12]. EirGrid also produce Low and High growth scenarios. The High scenario assumes that a higher share of the currently contracted datacentre capacity is used (~4 TWh of energy consumption in addition to the growth already assumed in the Median scenario by 2030), though it still assumes that some attrition of contracted datacentre demand will occur. Figure 10 also shows the WAM scenario with the High datacentre growth assumptions included. It is evident that the scale of energy consumption growth from datacentres is likely to significantly eclipse the electricity consumption growth of any other sector.

In the context of our legally binding national and international climate and energy obligations, the negative consequences versus the benefits of allowing new large electricity users, such as datacentres, to establish in Ireland needs to be considered. If the scale and pace of renewable energy growth cannot exceed that of electricity demand, as was the case in 2023, then renewables are just abating further increases in emissions rather than delivering the absolute reductions in greenhouse gas emissions required.

## 4.3 Additional testing of delivery timeline for renewable generation capacity

### *National Energy Projections electricity results – delivery timeline of renewable capacity*

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[12] EirGrid and SONI 'Generation Capacity Statement 2023-2032'. Jan 2024. [Online]. Accessed from: https://cms.eirgrid.ie/sites/default/files/publications/19035-EirGrid-Generation-Capacity-Statement-Combined-2023-V5-Jan-2024.pdf

Table 2 shows the national targets for variable renewable generation capacity for 2025 and 2030, alongside the National Energy Projections assumptions for each scenario. The installed capacities of solar and wind generation in the WAM scenario were selected to meet the CAP24 Renewable Energy Share in Electricity (RES-E) target of 80% RES-E by 2030. As well as the RES-E target, CAP24 contains KPIs for higher installed capacities, which are likely required to reduce the gap to the sectoral emissions ceiling. For the WEM scenario, a slower rate of delivery of renewable electricity generation was assumed, leading to a RES-E share of ~69% in 2030. The risk scenario installed capacities were derived using forecasts from surveys of expert stakeholders. It represents a plausible worst case deployment scenario for each variable renewable technology, as judged by a pool of expert stakeholders in Q1 2024.

**Table 2: Targets and assumptions for year-end renewable electricity generation capacity**

| Parameter / Variable | Year | CAP24 | WEM | WAM | Risk |
|---|---|---|---|---|---|
| RES-E (%) | 2025 | 50% | 46.4% | 47.5% | 46% |
| *Onshore Wind Capacity (GW)* | *2025* | *6* | *5.6* | *5.8* | *5.2* |
| *Offshore Wind Capacity (GW)* | *2025* | *n/a* | *0.03* | *0.03* | *0.03* |
| *Solar PV Capacity (GW)* | *2025* | *5* | *2.2* | *2.2* | *2.2* |
| RES-E (%) | 2030 | 80% | 68.9% | 80.1% | 54.7% |
| *Onshore Wind Capacity (GW)* | *2030* | *9* | *6.8* | *7.2* | *6.2* |
| *Offshore Wind Capacity (GW)* | *2030* | *5* | *2.7* | *4.0* | *0.03* |
| *Solar PV Capacity (GW)* | *2030* | *8* | *5.7* | *6.5* | *5.1* |

The plots below illustrate the assumptions used for the roll-out of offshore wind, onshore wind, and solar PV (rooftop through to utility-scale projects) for the NEP'S WEM, WAM and risk scenarios, compared to those used in core CB scenarios. As a high-level approximation of project build-out across a given year, the installed capacities are simulated to increase at the end of each quarter (March, June, September, December).[13] The core CB scenarios show an increase in the deployment of all three technologies, especially in offshore wind and solar PV. While the solar PV risk scenario below shows that it is more likely we could see somewhat higher rates of deployment than assumed in the WEM and WAM scenarios, the spread between the deployment rate of offshore wind in the risk scenarios versus those resulting from the 350Mt scenario below show the same is not likely for offshore.

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[13] If a quarterly increase would be less than the typical size of a project, it is deferred to a biannual or annual increase as appropriate. Cumulative capacity limits are placed on each technology to reflect national spatial constraints; however, these limits are not hit prior to 2040.

**Figure 11: Variable renewable energy installed capacity assumptions – offshore wind**

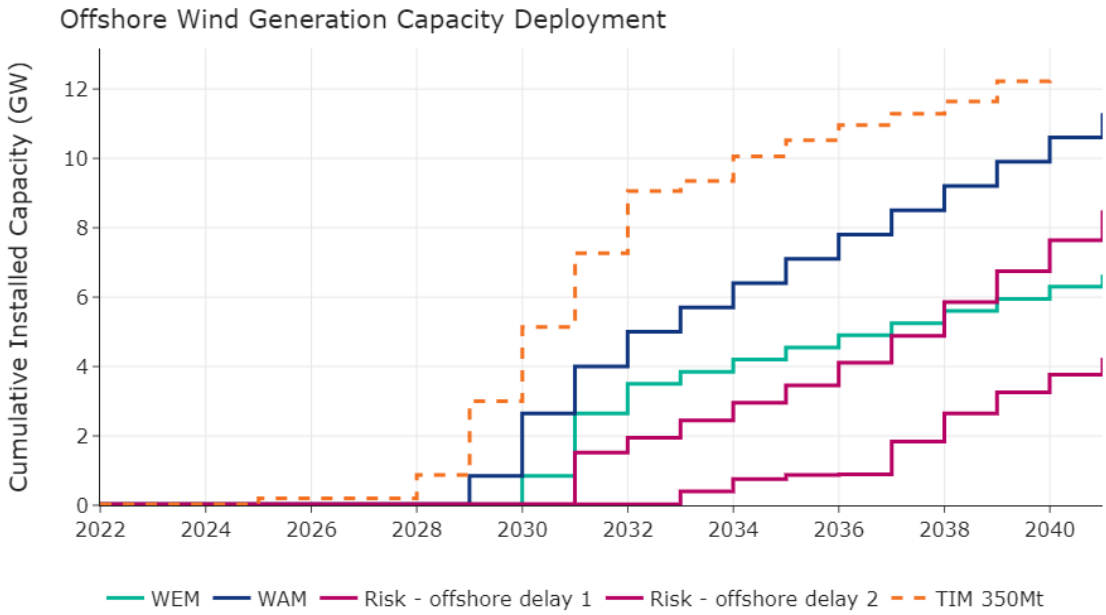



**Figure 12: Variable renewable energy installed capacity assumptions – onshore wind**

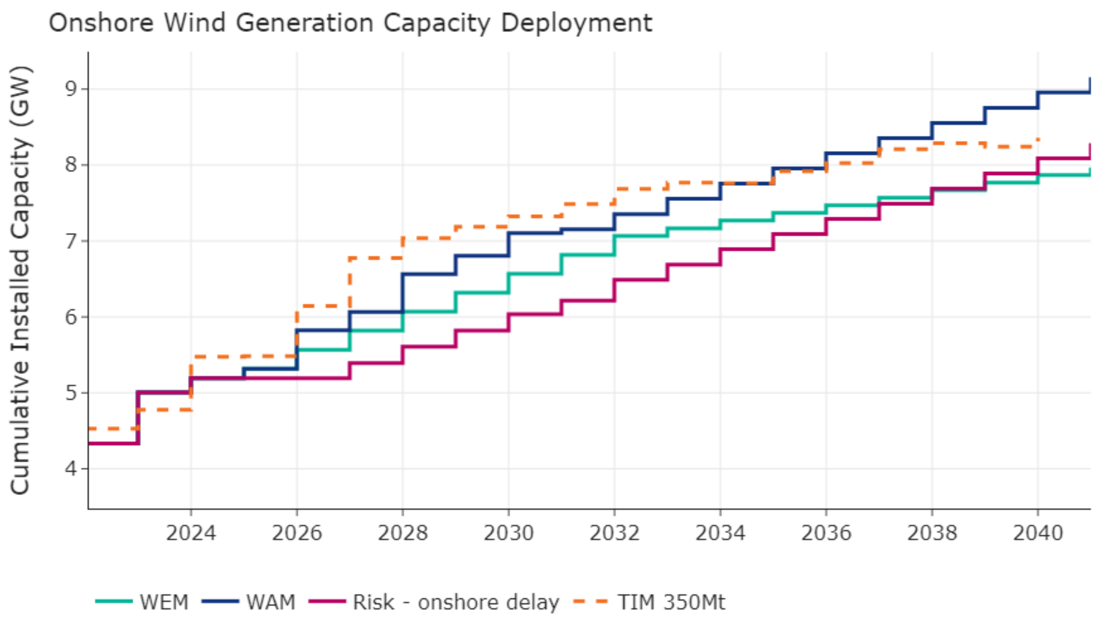
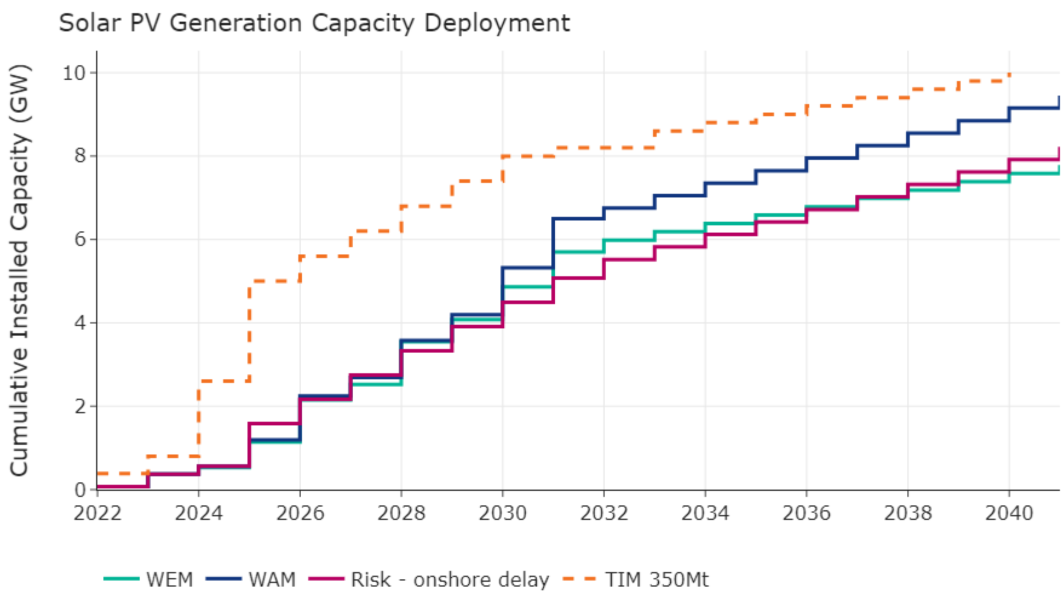


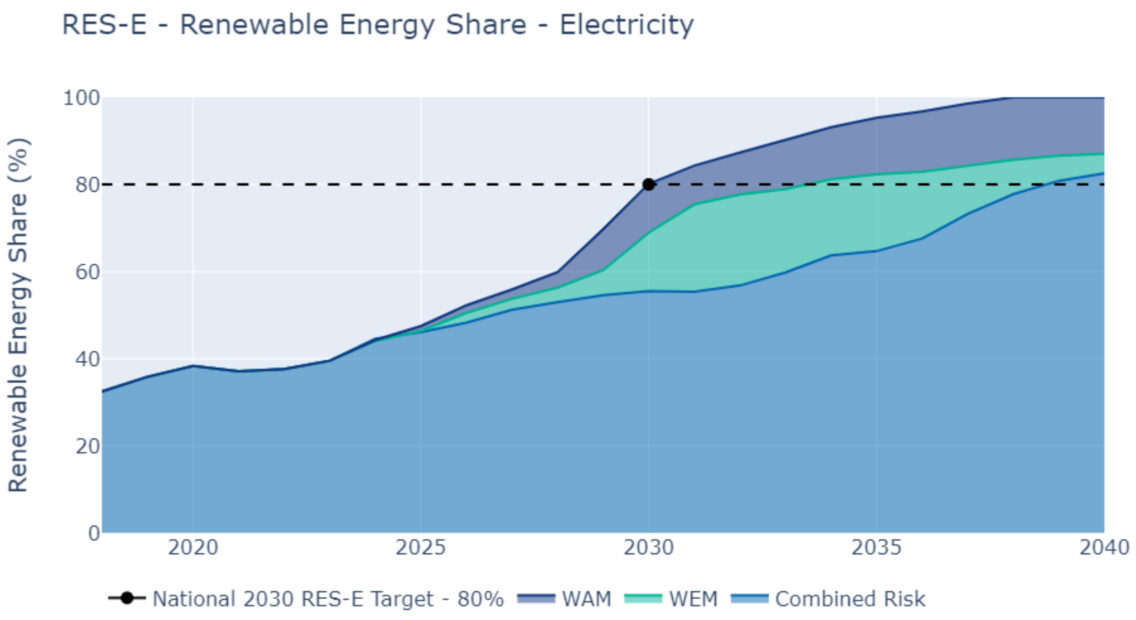
**Figure 13: Variable renewable energy installed capacity assumptions – solar PV**




The survey results used to build the risk scenario indicate that the risk of under-delivery of CAP24 targets is highest for offshore wind (5 GW under-delivery by 2030 in the more conservative risk scenario), followed by solar PV (2.9 GW under-delivery by 2030) and onshore wind (2.8 GW under-delivery by 2030), which, given offshore wind's high capacity factor, is most onerous from a RES target achievement perspective.

Combining the more conservative risks of delay in onshore and offshore installed capacity, Figure 14 shows the potential for a shortfall from the national RES-E 2030 target of as much as 24 percentage points, with the 80% target not being reached until 2039. This is driven mainly by the assumed delay in offshore wind and illustrates just how critical the timely delivery of all planned renewable installed capacity for electricity generation is to the achievement of Ireland's national and EU targets. This also impacts on the capacity to deliver on electrification goals across all sectors.

**Figure 14: Impact of widespread delays (risk scenario) on progress to national RES-E target**




### *Comparison of electricity outputs aligning installed capacity assumptions with TIM*

When SEAI aligned the assumed installed capacities from variable renewable energy (VRE) generators with the core CB scenario outcomes from TIM, the most significant difference in modelled outputs for electricity was the amount of gas-fired electricity generation post-2030. This was determined to be most likely due to the way the alternative model methodologies captured how net load would be met in the electricity system.

Net load refers to electricity demand minus the output from VRE generators, e.g. wind, wave, and solar PV. Projected net load therefore depends on:

- The methodology used to construct electricity demand (historical electricity demand, electrification of heat and transport, new housing demand, etc.)
- The methodology used for constructing availability profiles for offshore wind, onshore wind, and solar PV.
- The level of VRE dispatch-down exhibited in the modelled scenario, which depends on many other assumptions.

Net load is a critical metric in power system planning studies, as it has a strong influence in defining the requirement for resource adequacy and flexibility. The resource adequacy requirement is particularly difficult to solve without conventional, dispatchable generation, which currently combust fossil fuels, hence the 2 GW of gas generation being sought by the Transition System Operator (TSO), though energy storage and interconnection imports will also play an important role.

Figure 15, using empirical data from July 2024[14], illustrates how hourly VRE variability propagates into net load variability.

How the net load curve is met determines the emissions of an electric power system. Further, given its variability and uncertainty (errors in forecasting) over multiple time horizons, at a certain point,

[14] EirGrid Group 'Smart Grid Dashboard'. 2024. [Online]. Accessed from: https://www.smartgriddashboard.com/#roi

adding more and more VRE yields diminishing returns with respect to decarbonisation (carbon dioxide abatement per installed capacity addition).

**Figure 15: Hourly net load profile, July 2024**

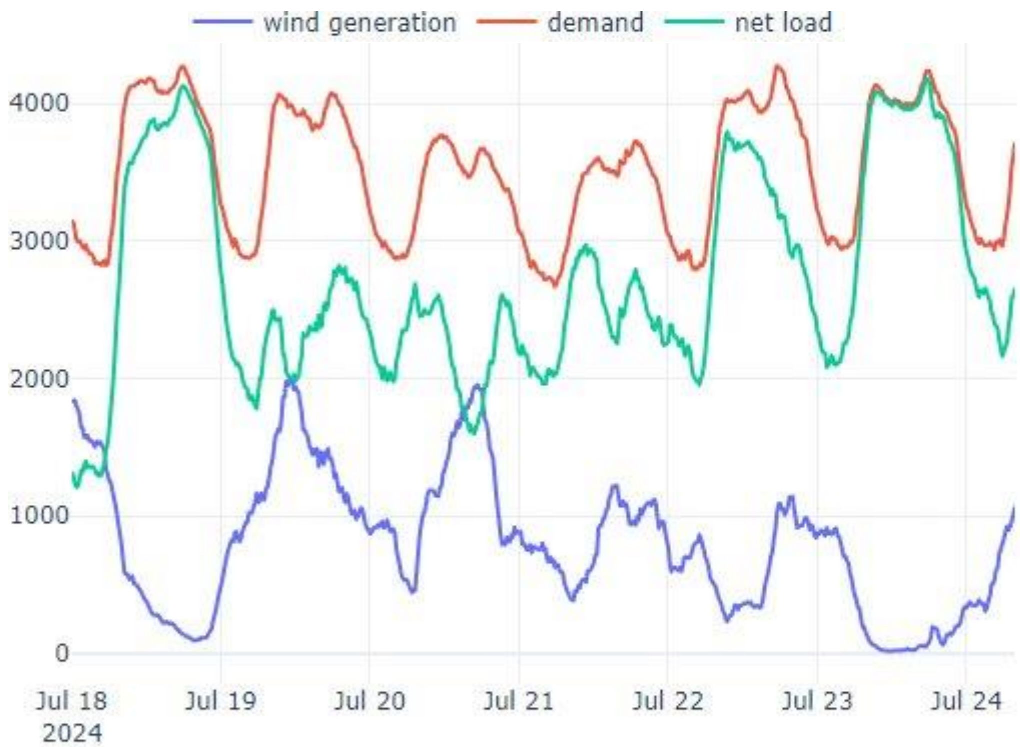



Figure 16 illustrates how net load changes in the NEMF annually when installed capacities in the NEMF are aligned with the 400Mt scenario from TIM. It shows hourly net load data, with each hour of the day averaged across the year. Some parts of the average net load reduce as more VRE capacity is added, with the lowest net load occurring when solar output highest, supplementing the wind output, and when demand is naturally lower in summer (less lighting and heating). However other periods increase due to demand growth. Net load will be met by a combination of interconnector imports, storage discharging, demand-side response, and most notably for emissions, fossil fuel-fired generation (e.g., natural gas, non-renewable waste, and oil).

When the installed capacities of solar and wind are aligned with the 400Mt scenario, approximately 3 Mt of $CO_2$ emissions in 2030, attributable to gas-fired generation, was simulated in the NEMF, see **Error! Reference source not found.** 17. Further, SEAI hourly modelling of the power sector shows some gas use persists out to 2040 to meet net load requirements.

**Figure 16: Future average hourly net load, using TIM 400Mt CB scenario's VRE capacity assumptions in NEMF**

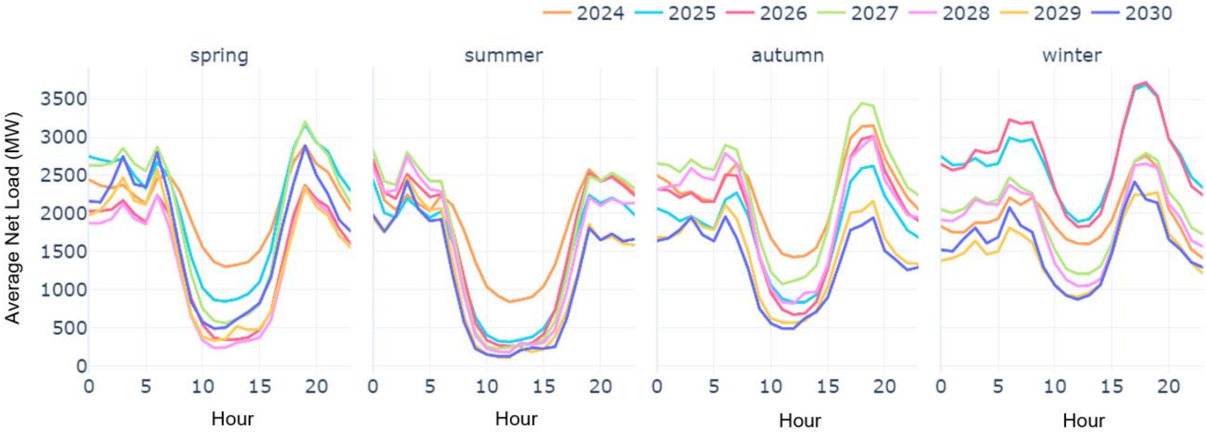
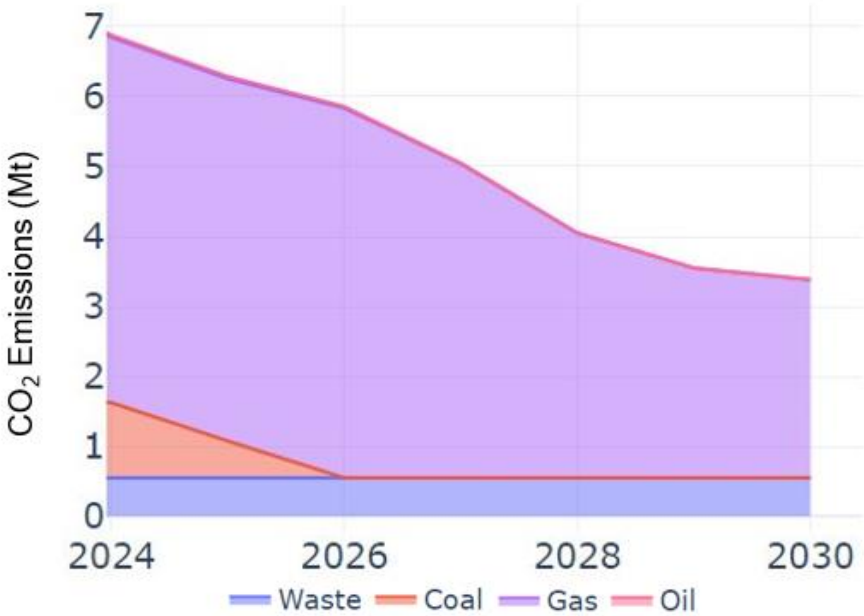



**Figure 17: $CO_2$ emission results, using the TIM 400Mt CB scenario's VRE capacity assumptions in NEMF**




Other aspects of power system operation to note that are not captured currently in either TIM modelling or NEMF modelling and that can drive emissions are as follows:

- **Operational security constraints**: when the schedule from the day-ahead and intra-day markets cannot be physically realised due to congestion on transmission lines or other system security reasons[15], conventional generators or storage need to be re-dispatched in the balancing market to fill the mismatch left by VRE dispatch-down.
- **VRE uncertainty**: forecast errors on the magnitude and/or timing of a weather front can lead to additional fossil fuel generators being switched on.

[15] SEMO 'TSO Responsibilities'. 2024. [Online]. Accessed from: https://www.sem-o.com/publications/tso-responsibilities/

# 5. Feasibility considerations and carbon budget implications

This report has discussed how the core carbon budget scenarios for energy require a scale and pace of emissions reductions in the rest of this decade and throughout the 2030s exceeding that projected to be delivered by the implementation of measures outlined in current government plans. The gap between WEM and WAM, as well as the SEAI risk scenarios point to very likely delays in the achievement of CAP targets by 2030, increasing the likely carbon budget overshoot in 2030, necessitating even steeper reductions in the following decade and making compliance with the potential third and fourth carbon budgets less feasible. The carbon budget pathways produced by UCC's EPMG demonstrate the challenge facing Ireland to achieve its share of the global emissions reduction required to limit global warming to 1.5°C. If the level of cuts in the core carbon budget scenarios cannot be achieved in the 2030s due to Ireland following the WAM or combined risk trajectory to 2030, compliance would require more extreme cuts, an increase in the reliance on negative emissions technologies, an increase in the cost of mitigation, and an increase in the likelihood of additional unabated emissions. Unfortunately, this may be the reality Ireland is face with in 2030.

The most recent SEAI projections indicate that even with a massively scaled effort for technology deployment across all sectors, it is now likely too late to meet climate obligations through technology change alone. It must be paired with innovation of the economic, market and social systems which drive continued growth in energy demand. Unprecedented technology change must be combined with strong policies and measures to reduce energy demand in all sectors and to disincentivise behaviours and practices that incur wasteful energy use in all parts of society.

In addition to our current technology strategy, Ireland must begin to embrace measures that seek to meet a wide range of personal and societal needs at a reduced rate of consumption.

- Invest in infrastructure that supports people to live more energy efficient lifestyles.
- Disincentivise consumer behaviours that incur wasteful energy use.
- Limit the establishment of new large-energy-users in Ireland between now and 2030.
- Build a policy environment that paves the way for sustainable circular economy goods and services.
- Expand focus beyond near-term targets for 2030 to the goal of a sustainable, and net-zero, circular economy.

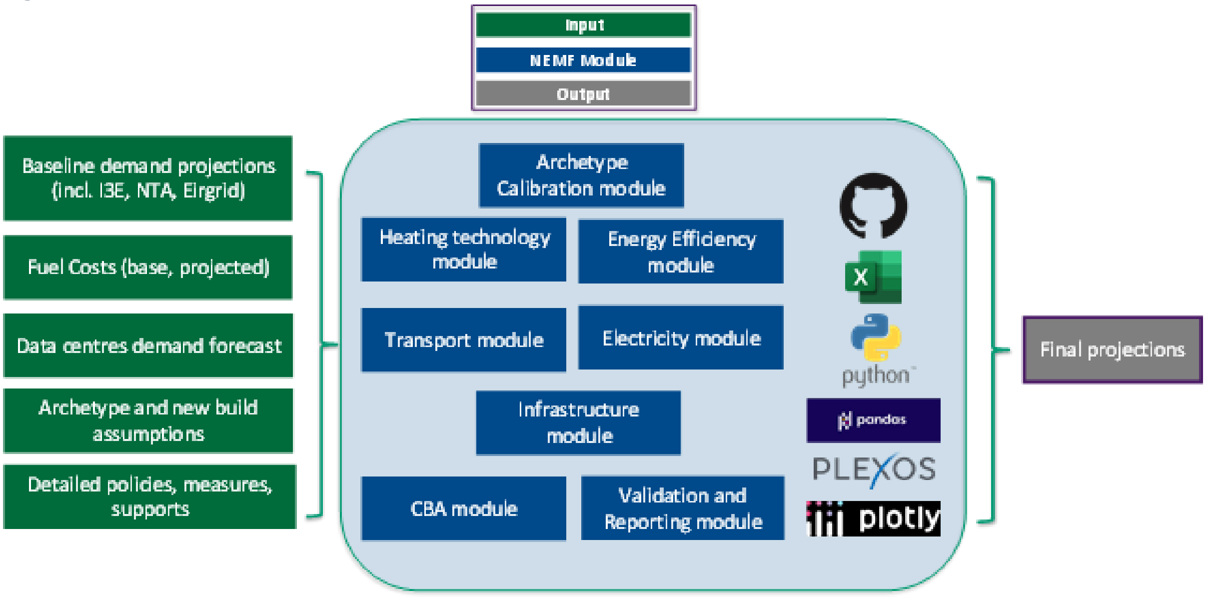
This will require planning policy to 2050 which innovates Ireland's economic, market and social systems to meet the needs of people while living within planetary boundaries.

More information and analysis from SEAI's Energy Modelling Team can be found in SEAI's forthcoming 2024 National Energy Projections Report, shortly to be published on the SEAI website.

# Appendix: National Energy Modelling Framework

The National Energy Modelling Framework (NEMF), developed and maintained by SEAI, is a full national energy-economy model that is used to assesses the impacts of packages of energy policies and measures on future energy supply and demand. It combines several SEAI sectoral models to produce policy-rich outlooks for the whole energy system. A high-level outline of NEMF inputs and modules is shown in Figure 18.

**Figure 18: NEMF schematic**




The NEMF has separate but interlinked modules focused on modelling of the heat, transport, and electricity sectors.

The heat sector model is based on a detailed set of archetypes representing all buildings and industries in Ireland. The NEMF contains 680 individual heat demand archetypes, representing a combination of physical and consumer attributes, which in turn provide a detailed description of demand in residential, services and industry sectors, as well as agricultural energy use. Technology suitability and performance are mapped to each archetype. The NEMF can be used to examine variation in technology readiness, technical suitability, cost data, and performance data to assess various scenarios (including potential decarbonisation paths) in Ireland. The model also contains representations of bioenergy and hydrogen resources and fuel supply chains as well as an infrastructure module that calculates the costs of infrastructure deployment linked to technology uptake.

The model uses this techno-economic data to generate payback and lifetime cost estimates for the various technology options available, accounting for policy incentives, taxes, and regulations. This payback and lifetime cost information is used with other data on consumer decision-making behaviour to simulate how much uptake may result in various scenarios and in response to policy measures.

Where technology deployment is based on centralised decisions, these are accounted for outside of the consumer decision-making framework: district heating and industrial Carbon Capture, Utilisation and Storage (CCUS) are dealt with in this way.

A detailed description of the methodology, data-sources and assumptions used to generate the archetypes within the NEMF is provided in the National Heat Study report "Heating and Cooling in Ireland Today".[16]

A detailed description of the heating and cooling technologies within the NEMF is provided in the National Heat Study report "Low Carbon Heating and Cooling Technologies".[17]

[16] SEAI 'National Heat Study – Heating and Cooling in Ireland Today'. 2022. [Online]. Accessed from: https://www.seai.ie/data-and-insights/national-heat-study/heating-and-cooling-in-ir/

[17] SEAI 'National Heat Study – Low Carbon Heating and Cooling Technologies'. 2022. [Online]. Accessed from: https://www.seai.ie/data-and-insights/national-heat-study/low-carbon-heating-and-co/

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