Aligning National Energy System Models with 1.5˚C Pathways in an Era of Overshoot

44th International Energy Workshop, June 2026
University of Cape Town

Prof. Hannah Daly, University College Cork

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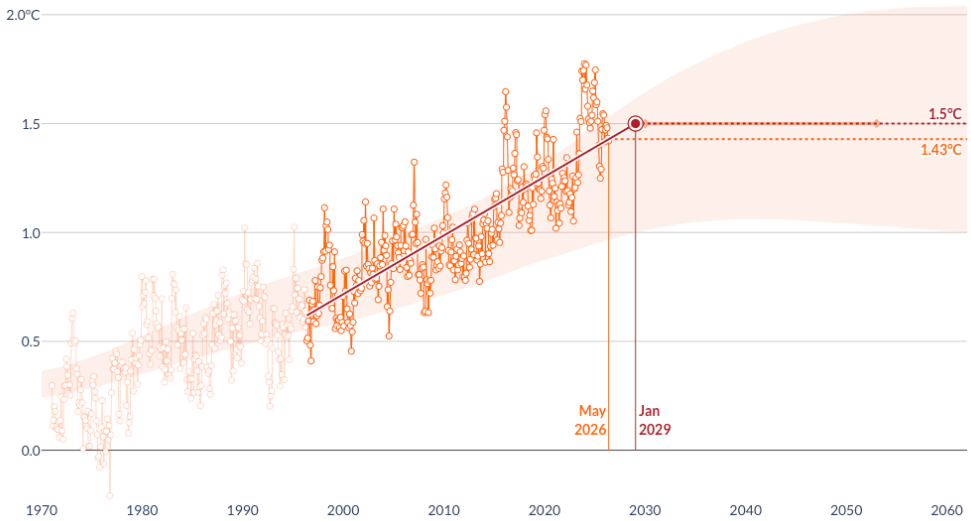
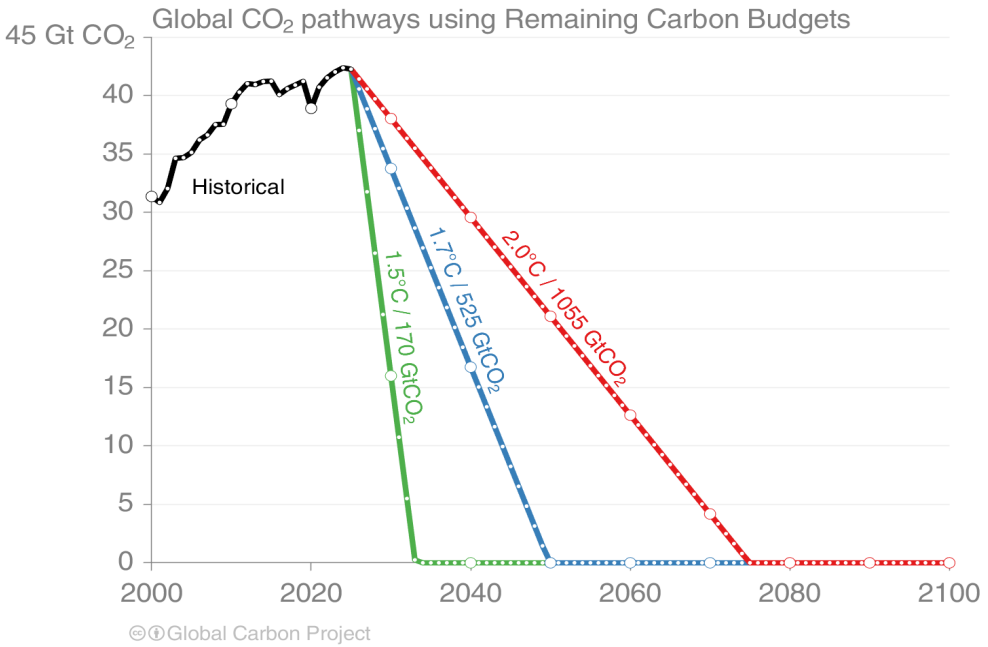
Is 1.5˚C still possible?





Sources: C3S global temperature trend monitor Friedlingstein et al 2025; Global Carbon Project 2025 Peters 2024

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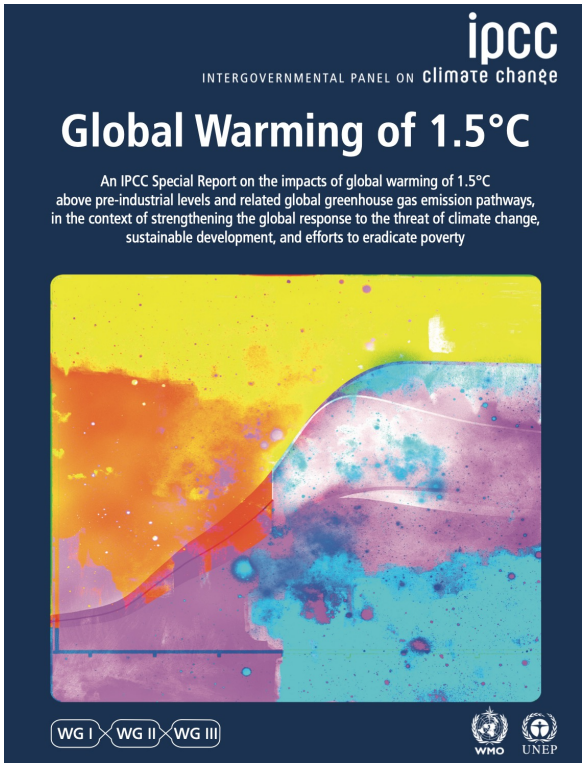
"As for the future, it is not a question of foreseeing it, but of making it possible."



« Pour ce qui est de l'avenir, il ne s'agit pas de le prévoir, mais de le rendre possible. »

Antoine de Saint Exupéry, *Citadelle*, 1948

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Three reasons 1.5°C remains the objective after overshoot

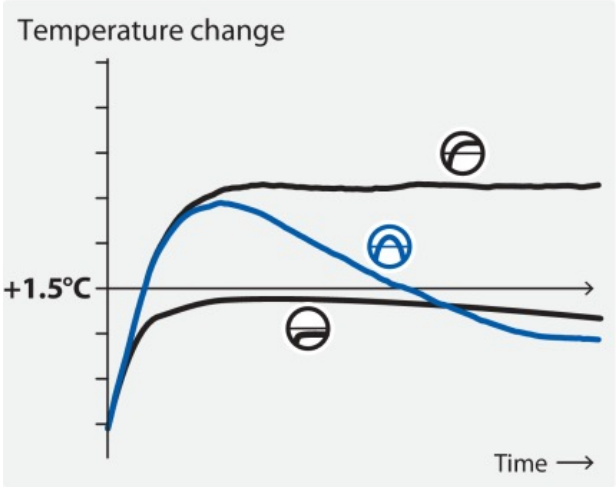
1. Scientific: impacts rise rapidly with peak warming.

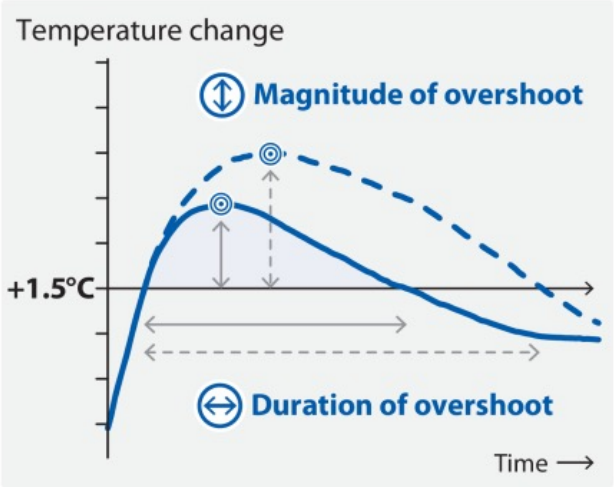
2. Legal: Paris Agreement and ICJ opinion still require efforts to limit warming to 1.5°C.

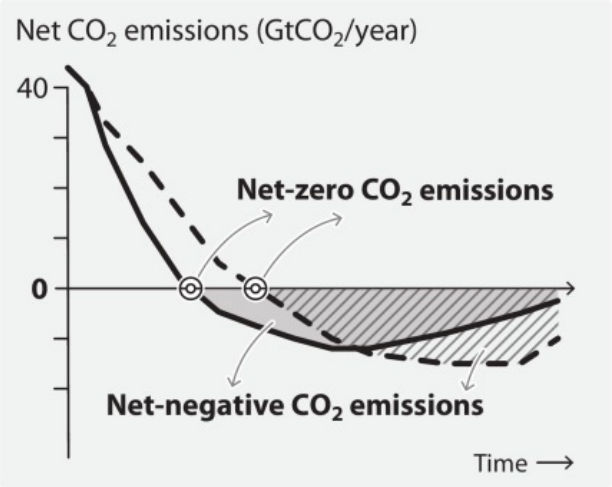
3. Ethical: exceeding 1.5°C does not remove responsibility to minimise harm.

States are required to pursue their "Highest Possible Ambition" in NDCs

Net-zero is necessary but not, alone, sufficient to return to 1.5°C following overshoot







The goal is not net-zero, not temperature stabilisation, but about minimising the extent, duration and magnitude of warming as far as possible

Reisinger et. al., 2025

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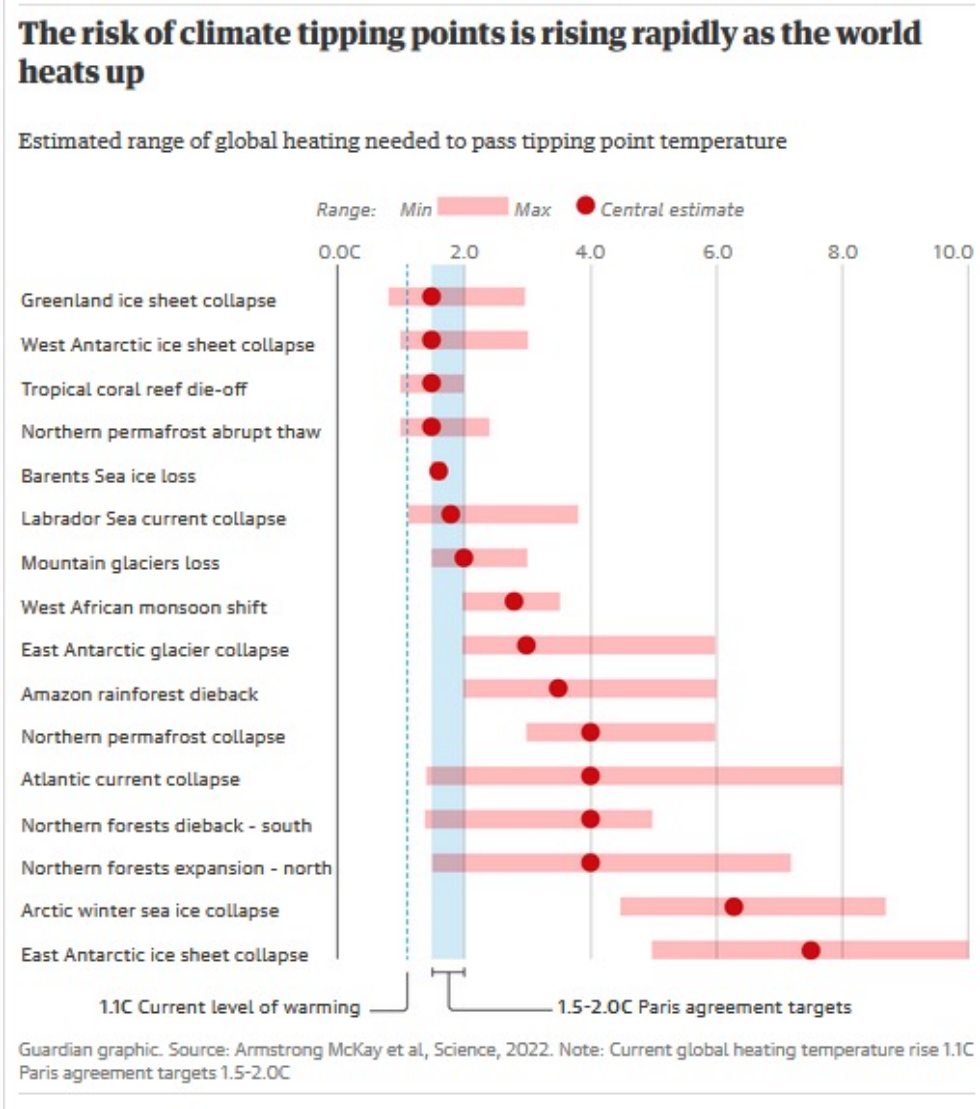
Importance of minimising *extent* and *duration* of temperature overshoot



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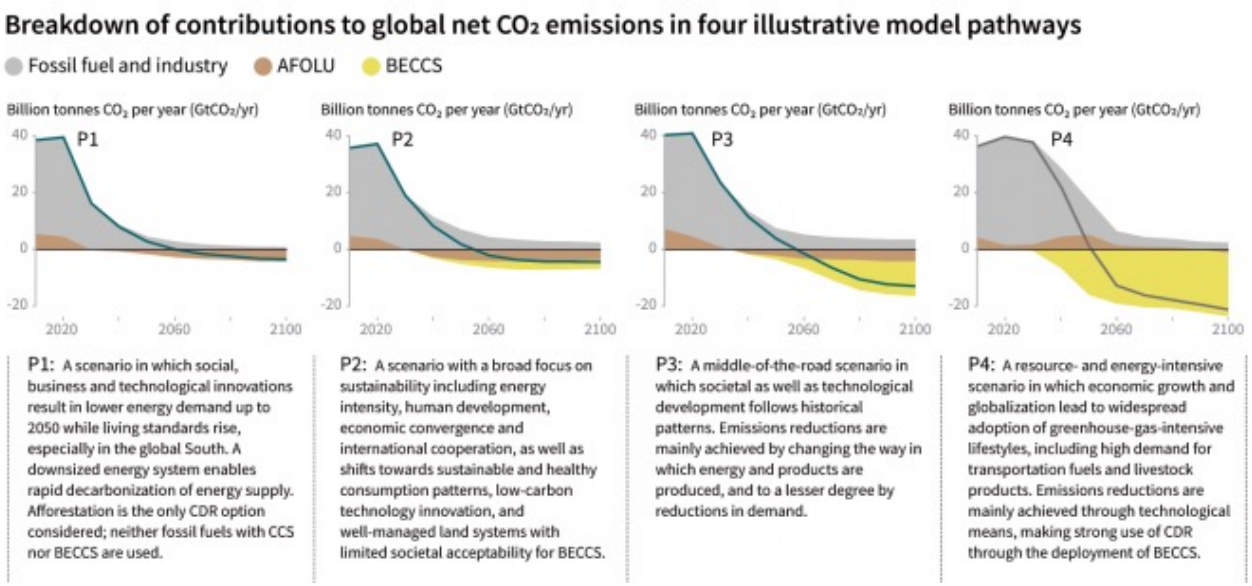
Is 1.5°C still possible?

Returning to 1.5 ˚C after overshoot requires radical mitigation measures that are mainly implemented **at the national level**

Global IAMs guide & provide boundary conditions

National scenarios operationalise ambition & hold to account



Sources: IPCC SR1.5 Peters 2024

Energy modelling & Ireland's carbon budgets

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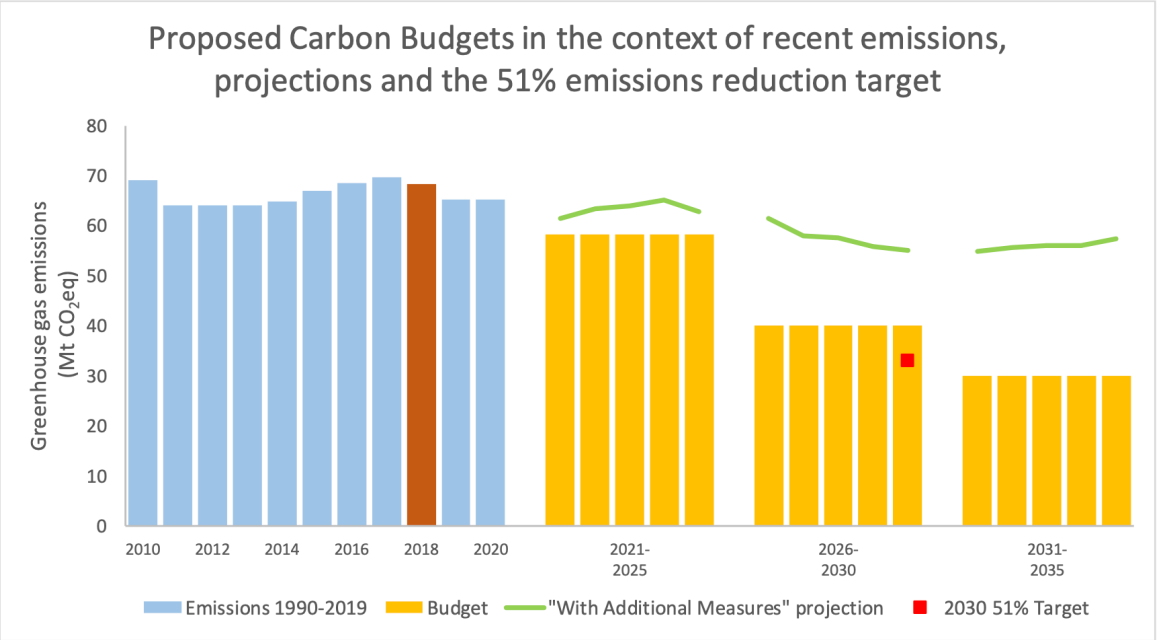
"The State shall, so as to reduce the extent of further global warming, pursue and achieve, by no later than the end of the year 2050, the transition to a climate resilient, biodiversity rich, environmentally sustainable and climate neutral economy"

Climate Act requires that carbon budgets be consistent with:

- **Paris Agreement Art. 2, Art. 4.2**
- **EU Law**
- **Art. 2 UNFCCC 2009**



Balyk, O., et al (2022): TIM: Modelling pathways to meet Ireland's long-term energy system challenges with the TIMES-Ireland Model (v1.0), *Geoscientific Model Development*, https://doi.org/10.5194/gmd-2021-359

Daly, H., et al. (2024*). Pathways for Ireland's energy system to 2050: Modelling analysis to support the Climate Change Advisory Council on the Second Carbon Budget Programme* (TIMES-Ireland Model Report). Climate Change Advisory Council. https://doi.org/10.5281/zenodo.17192991

CCAC 2021

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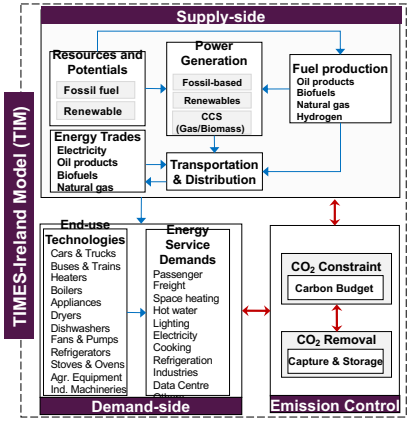
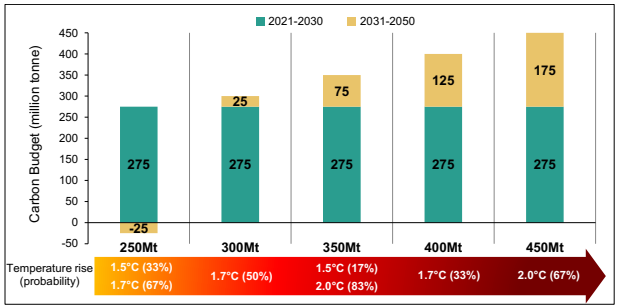
Energy transition scenarios compatible with carbon budgets

– how can this inform return from overshoot?

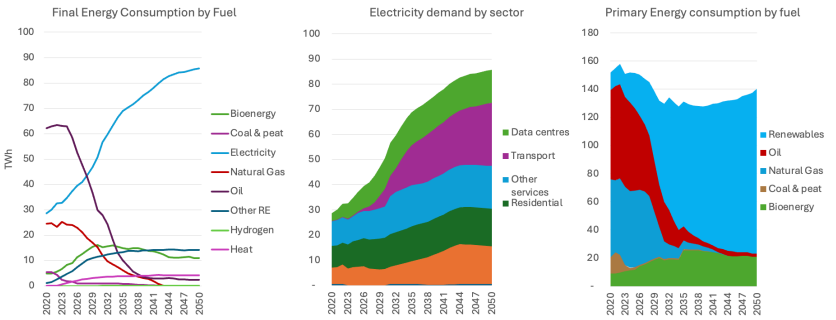




TIMES-Ireland Model

Downscaled global carbon budget

Energy transition scenarios



Impact assessment:

- Biodiversity
- Macroeconomic
- Jobs
- Just transition

https://epmg.netlify.app/TIM-Carbon-Budget-August_2024/results/overview/primary-energy?scen1=mitigation_cb2024-300mt&scen2=null&diff=false

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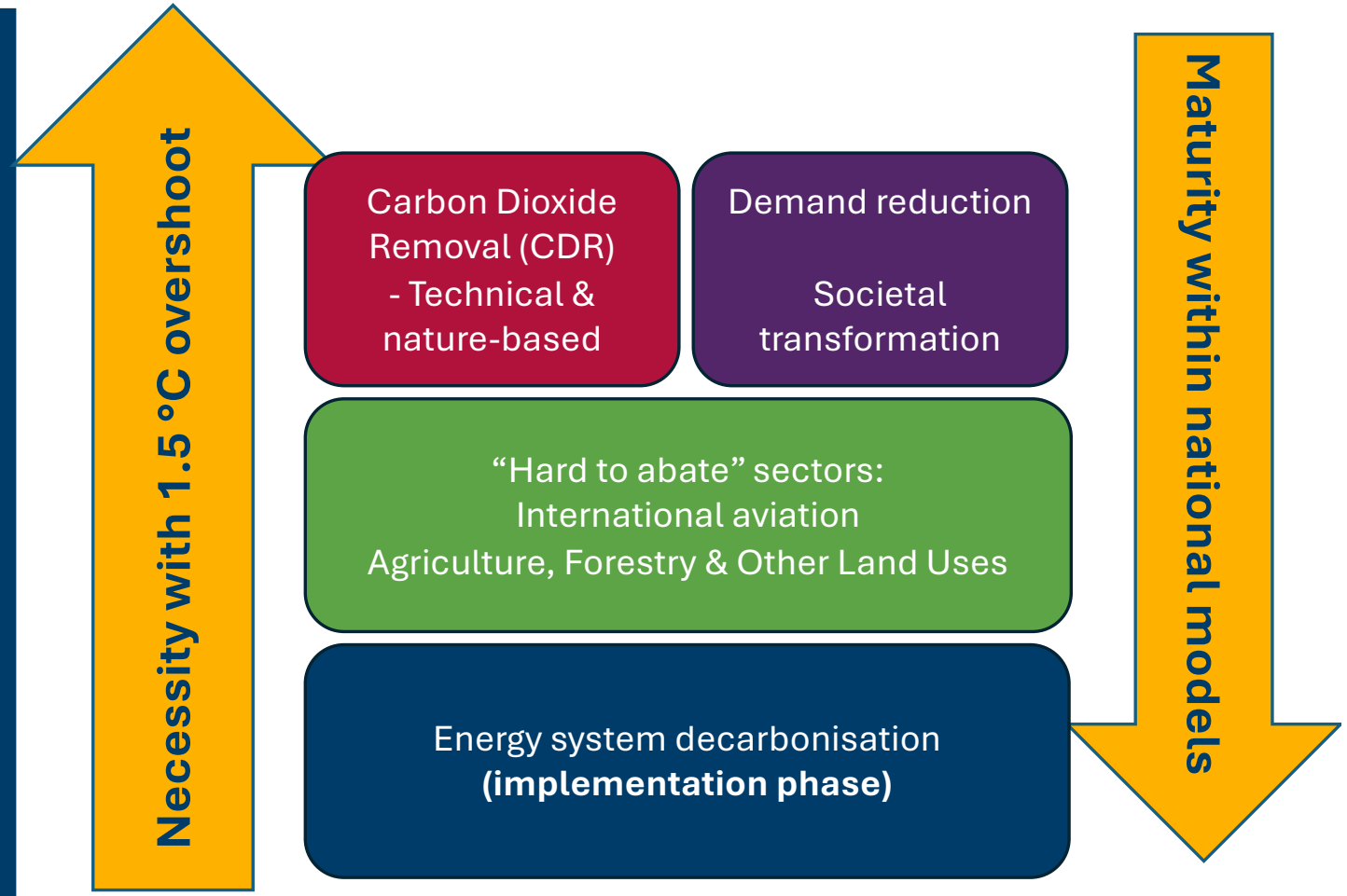
Returning to 1.5 °C after overshoot requires a **broader mitigation agenda**



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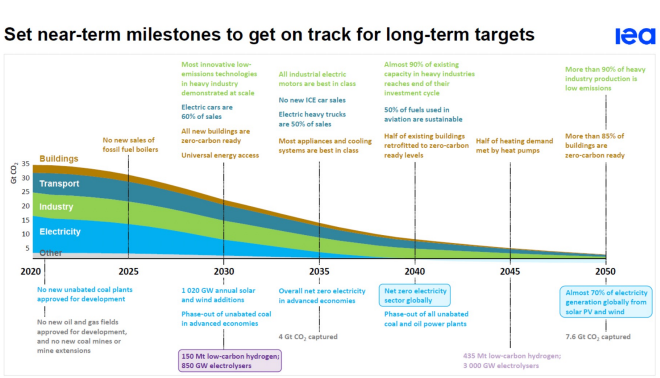
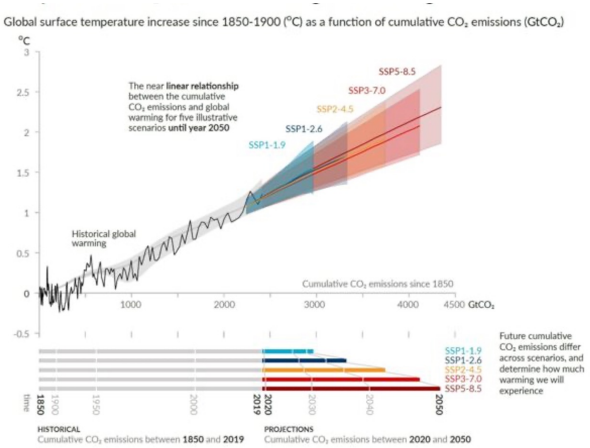
Four tests for a credible national 1.5˚C return scenario:

Highest Possible Ambition

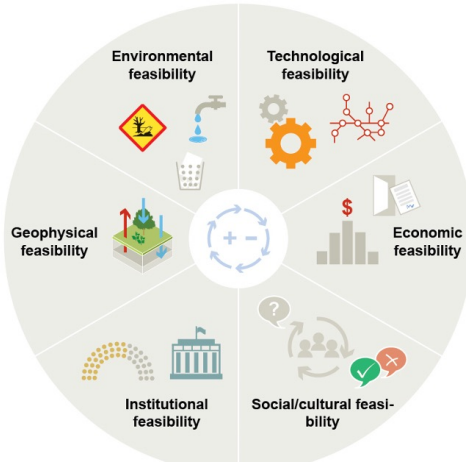
What has to happen?



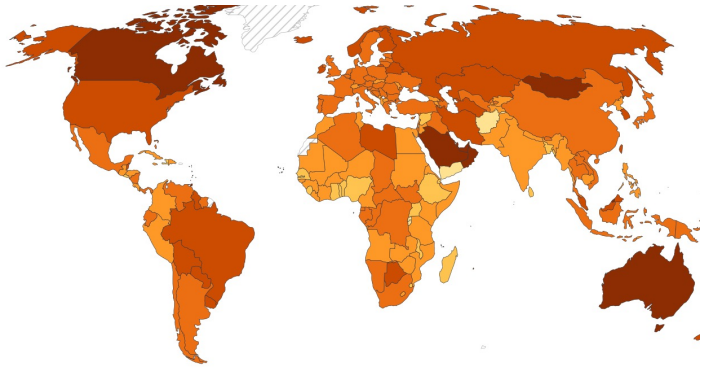
Impact on warming?



Is it feasible?



Is it a fair contribution?



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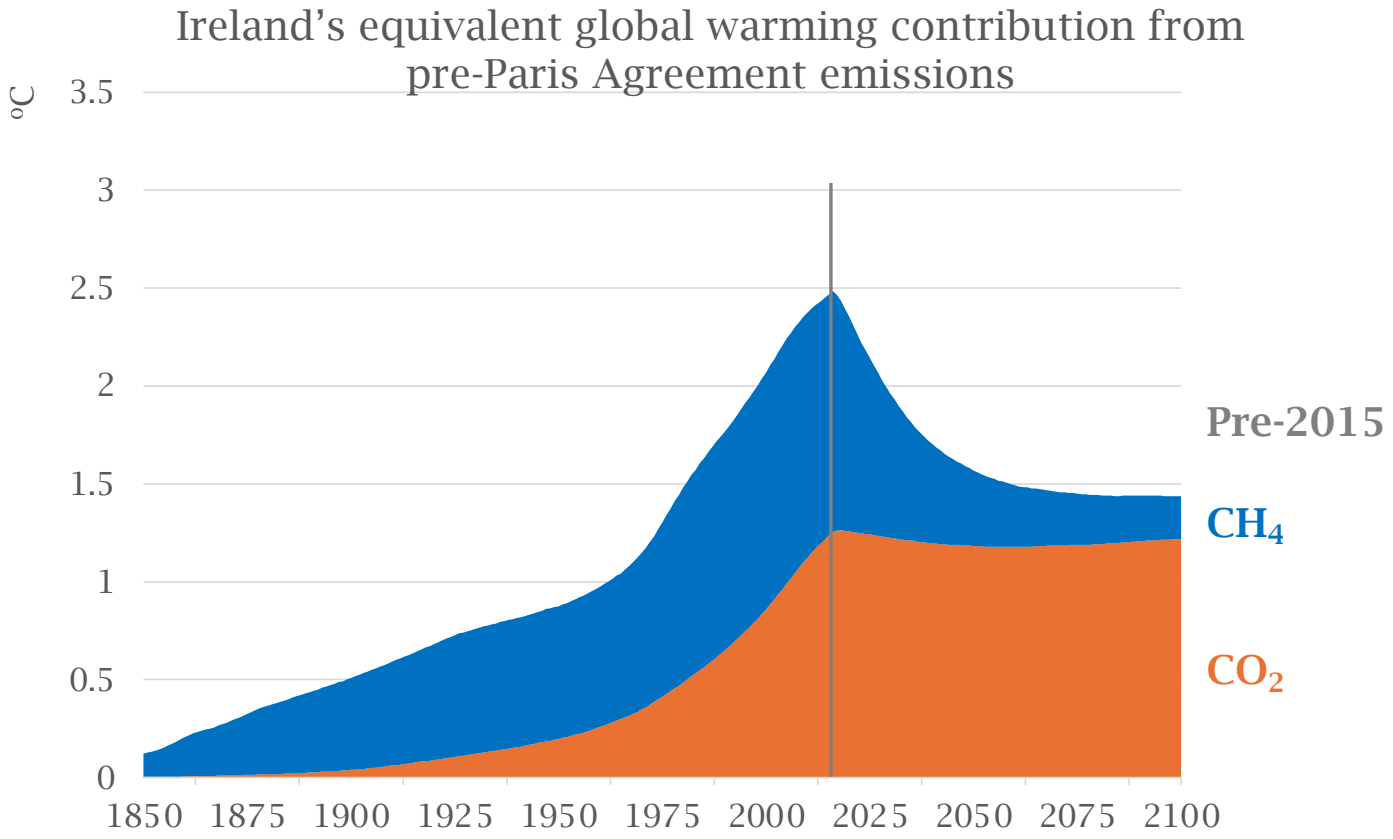
Climate outcome;

Fairness;

Overshoot

Many countries have already overshot their fair share of safe warming



Methodology: Global temperature impact of Ireland's pre-2015 CO_2 & CH_4 emissions using FaIR, scaled up by current share of global population

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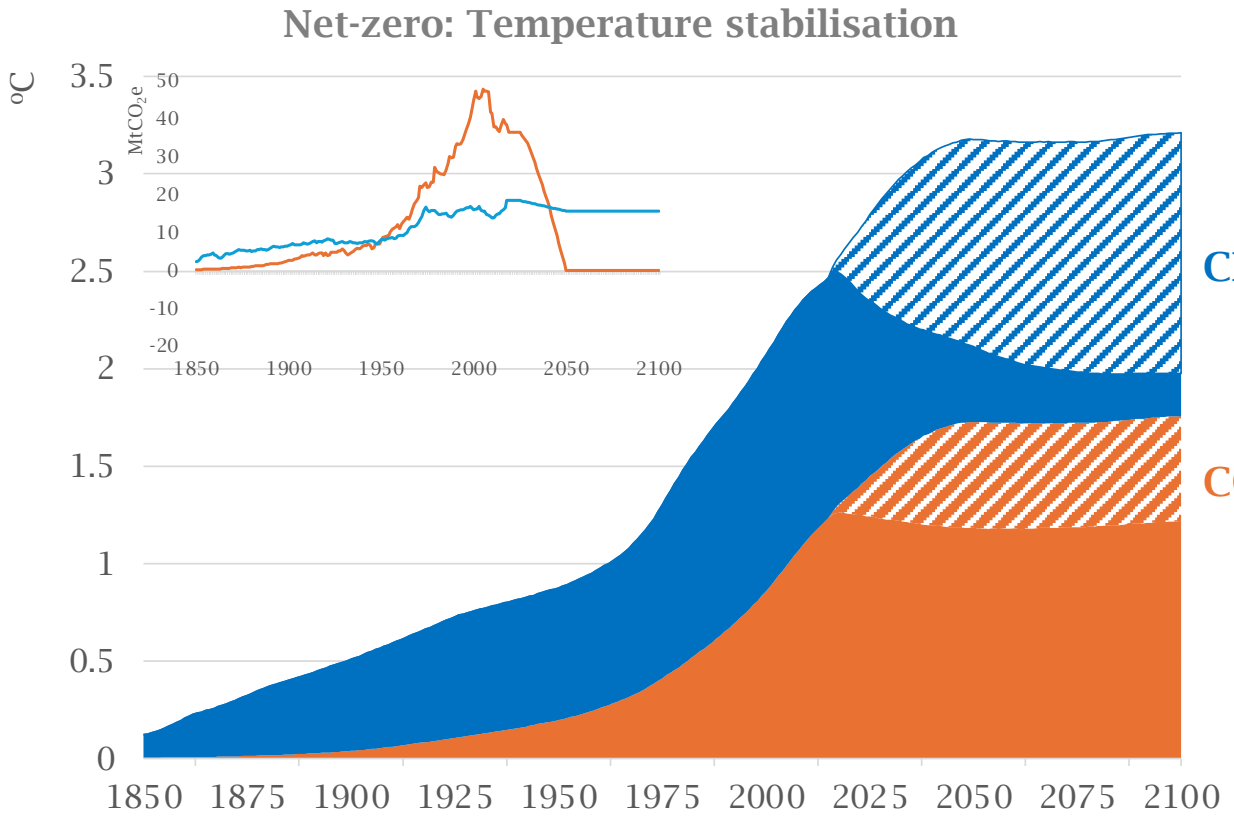
Stabilising warming impact – net-zero CO_2 – commits to large permanent overshoot

Adequacy: Return to 1.5°C following overshoot?



CH_4 **-10% by 2050**

CO_2 **Net-zero by 2050**
Stable thereafter

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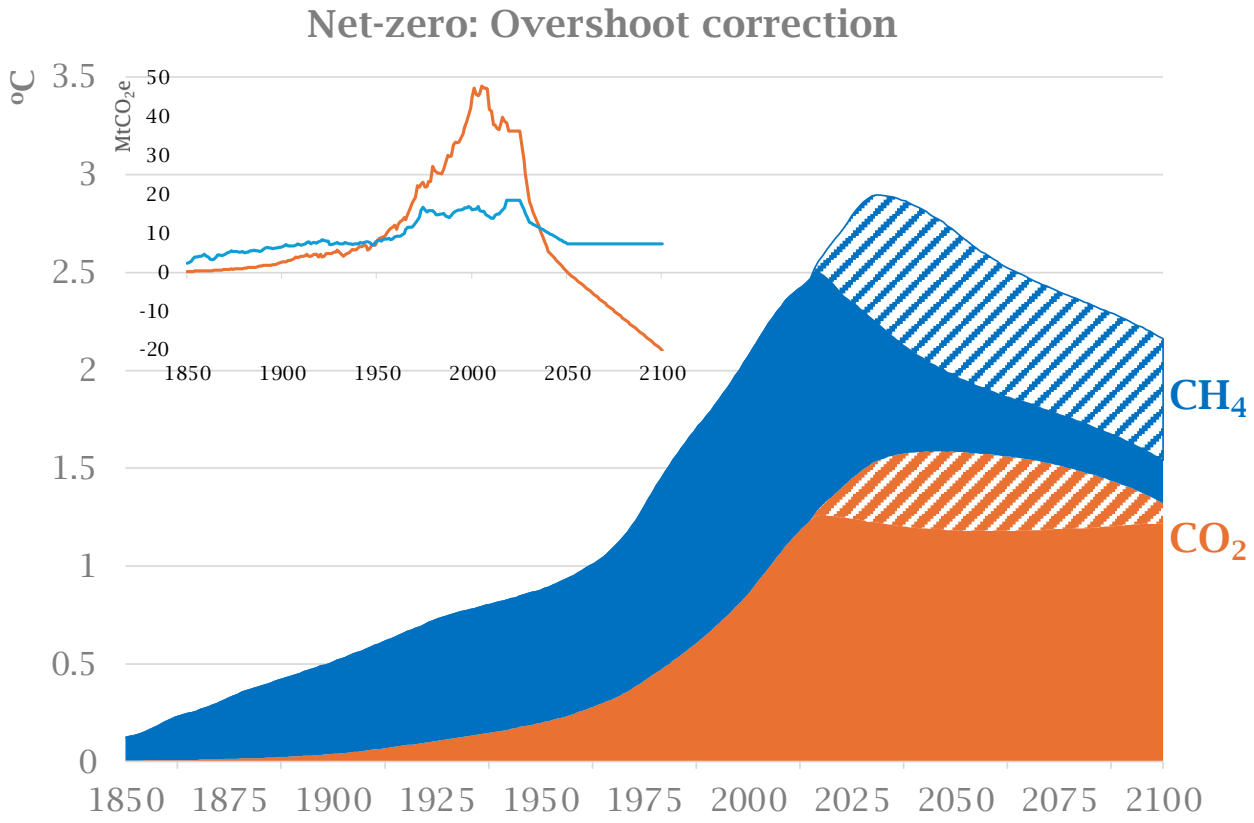
Early CO_2 mitigation, CDR post-2050, and mitigation of non-CO_2 cuts overshoot

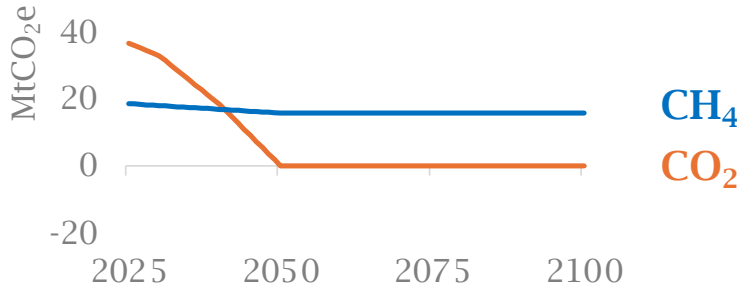
Adequacy: Return to 1.5°C following overshoot?

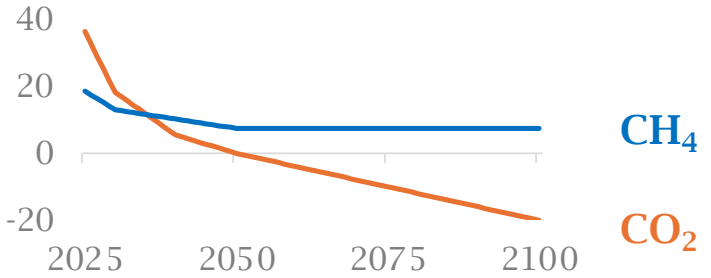


-30% by 2030,
-60% by 2050

-50% by 2030
-85% by 2040
-100% by 2050
Net-negative >2050

Feasibility & fairness: Two “net-zero” pathways, very different outcomes





Temperature stabilisation	Overshoot correction
Permanent overshoot	Return from overshoot
“Conventional ambitious” net-zero scenario	Under-explored in mitigation scenarios
Back-loaded CO_2 mitigation	Front-loaded CO_2 mitigation
Marginal non-CO_2 mitigation	Transformational land use change
Focus on technology & fuel transition	Wider economic & societal transformation
Final demands are fixed	Sufficiency, low-demand scenarios
Stops at 2050	Looks beyond 2050
CDR to balance residual CO_2 in 2050	CDR to correct overshoot

Structural features & practices in energy systems modelling can weight towards delay

1. The problem of carbon accounting:

A tonne of CO_2 is not just a tonne of CO_2

- **Overshoot causes extra, long-lasting** and sometimes irreversible harms
  - **It can trigger self-reinforcing climate feedbacks and tipping elements**
  - Thermodynamic reversibility not equal to damage reversibility

- Carbon accounting can **underestimate the value of early action**
  - .. **And obscure damages during overshoot** even if removals materialise
  - Emphasising net-zero overlooks peak and timing risks
  - Future removals are uncertain, limited and risky

- **Overconfidence in overshoot is a moral and policy risk**
  - It increases the chance of worse outcomes for vulnerable people
  - Prudent policy minimises peak warming and cumulative CO_2

Bourban 2026 https://doi.org/10.1177/096327192614219
Schleussner, et al (2024). https://doi.org/10.1038/s41586-024-08020-9

2. Biased against Highest Possible Ambition?

Common model features favour back-loaded mitigation

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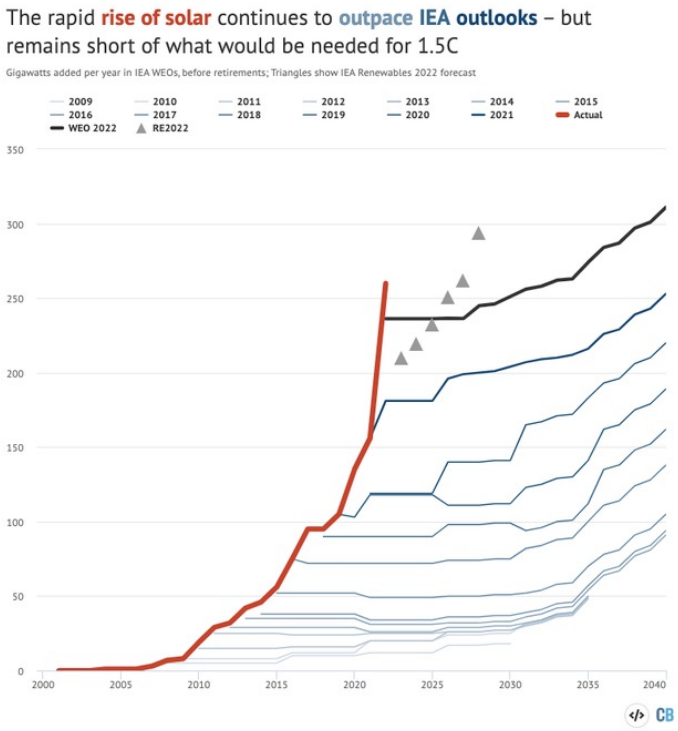
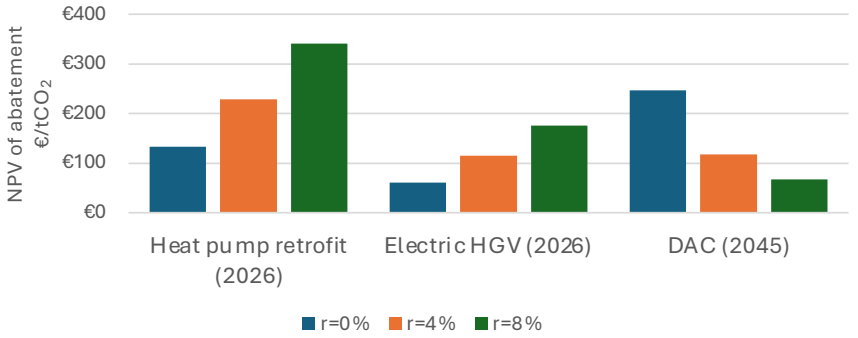
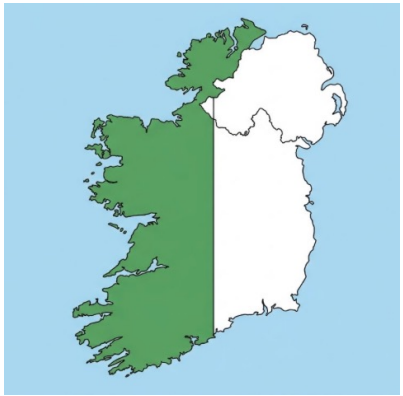
1. Deployment constraints: under-estimating "feasibility"?



2. Discount rates favour later investment

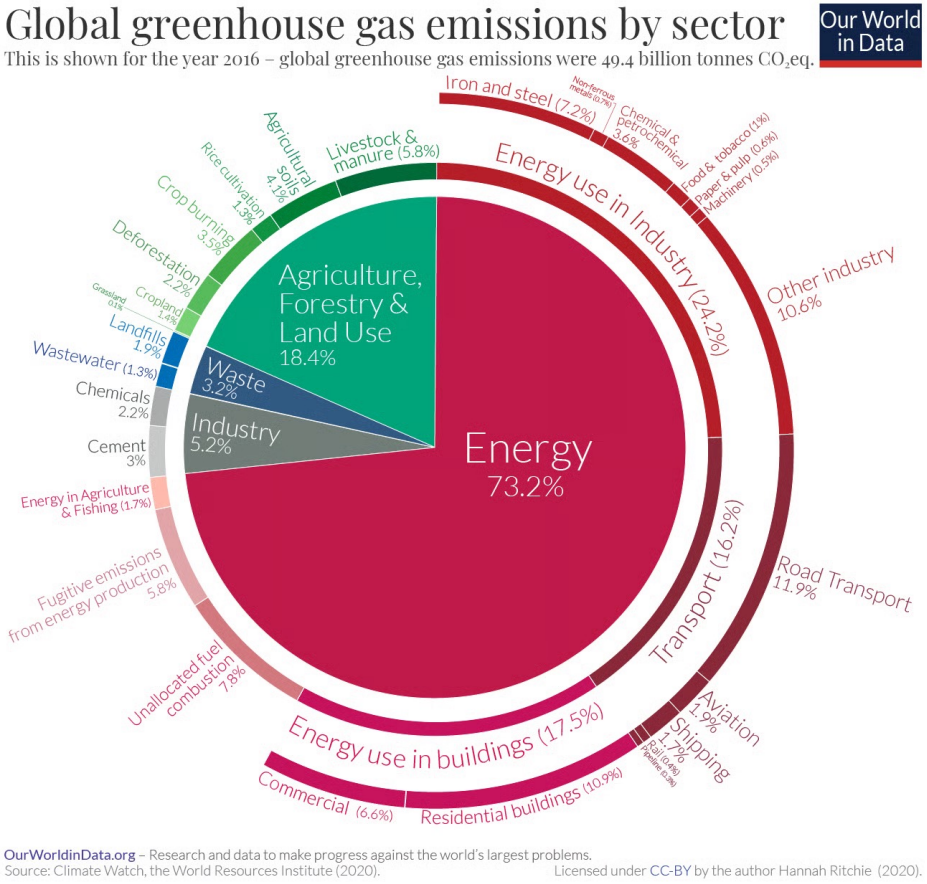


3. Over-confidence in CDR feasibility



3. Lacking a full picture of the problem

Addressing overshoot demands more than an energy transition



- National models are typically limited or lacking in:
  - Non-energy GHGs
  - International aviation & shipping
  - Embodied GHGs in international (energy) trade
  - Agriculture, forestry and other land uses (AFOLU)
  - Carbon & land use accounting; carbon cycle dynamics, e.g., biomass
  - Warming dynamics of GHGs

A research agenda for advancing energy systems models in an era of overshoot

Beyond the energy transition:
Transformative scenarios that reflect “Highest Possible Ambition”

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1 Represent the whole climate problem

- Include all GHGs
- Include all sectors - AFOLU
- Longer time horizons
- Temperature outcomes

2 Represent the whole solution space

- Maximum plausible mitigation uptake
- Demand reduction & sufficiency
- Non-market policies
- Diverse CDR & deep mitigation portfolios

3 Address carbon accounting

- Reflect overshoot damages
- Reflect carbon and land opportunity costs
- Paris-consistent benchmarks beyond net-zero: Peak warming & overshoot outcomes

Working towards overshoot-aware mitigation modelling in Ireland

TIMES-Ireland Model

Freely available model, scenario explorer & policy impact

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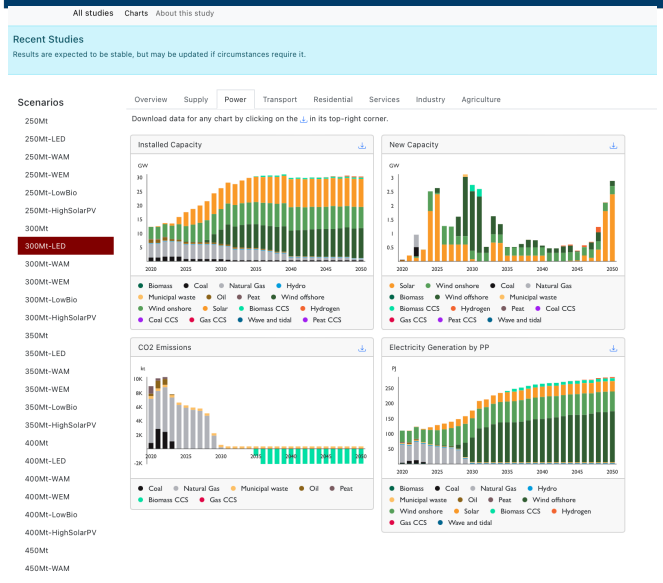

EPMG
ENERGY POLICY & MODELLING GROUP

https://epmg.netlify.app/TIM-Carbon-Budget-August_2024/results/

zenodo

https://zenodo.org/records/14337533

MaREI-EPMG

https://github.com/MaREI-EPMG/times-ireland-model

PATHWAYS FOR IRELAND'S ENERGY SYSTEM TO 2050

Modelling analysis to support the Climate Change Advisory Council on the Second Carbon Budget Programme

Prof. Hannah Daly, Dr Vahid Aryanpur, Bakytzhan Suleimenov & Dr. Paul Deane

Energy Policy and Modelling Group, University College Cork

September 2024

CLIMATE CHANGE ADVISORY COUNCIL

https://www.climatecouncil.ie/carbonbudgets/carbonbudgetsworkinggroup2023-2024/

https://doi.org/10.1038/s44168-024-00181

Implications of accelerated and delayed climate action for Ireland's energy transition under carbon budgets

Check for updat

Vahid Aryanpur[1,2], Olexandr Balyk[3], James Glynn[4], Ankita Gaur[1,2,5], Jason McGuire[1,2,6] & Hannah Daly[1,2]

npj | climate action

https://www.nature.com/articles/s44168-024-00181-7

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TIM-LEAF

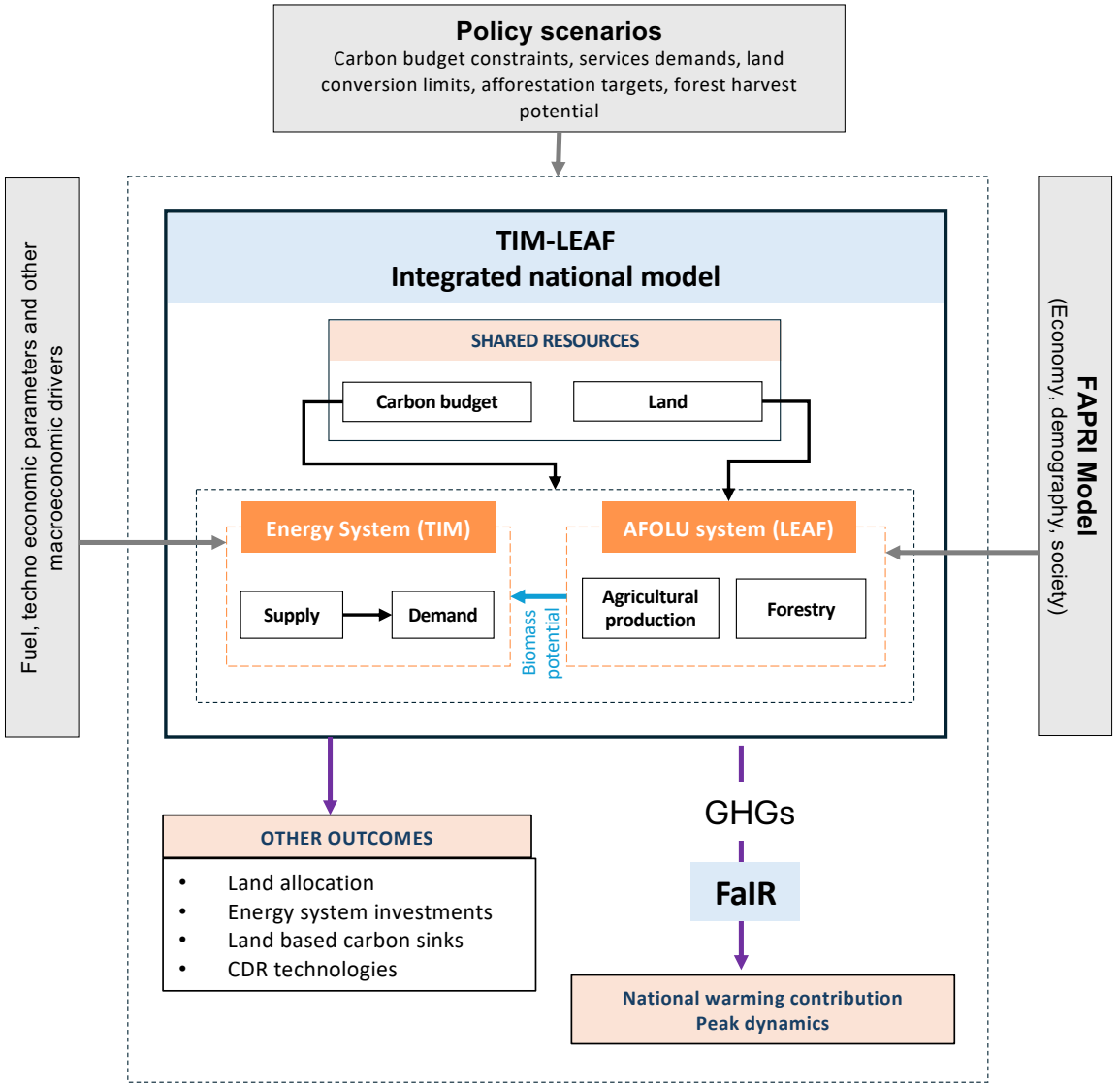
Integrated national model:

Energy-AFOLU

GHG dynamics

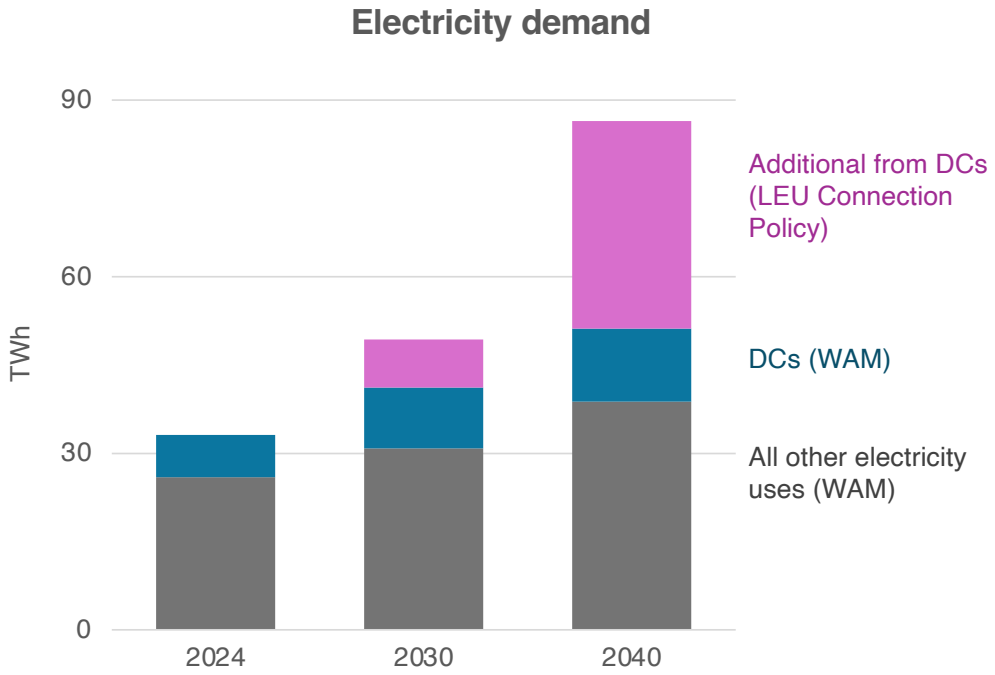
Temperature outcomes

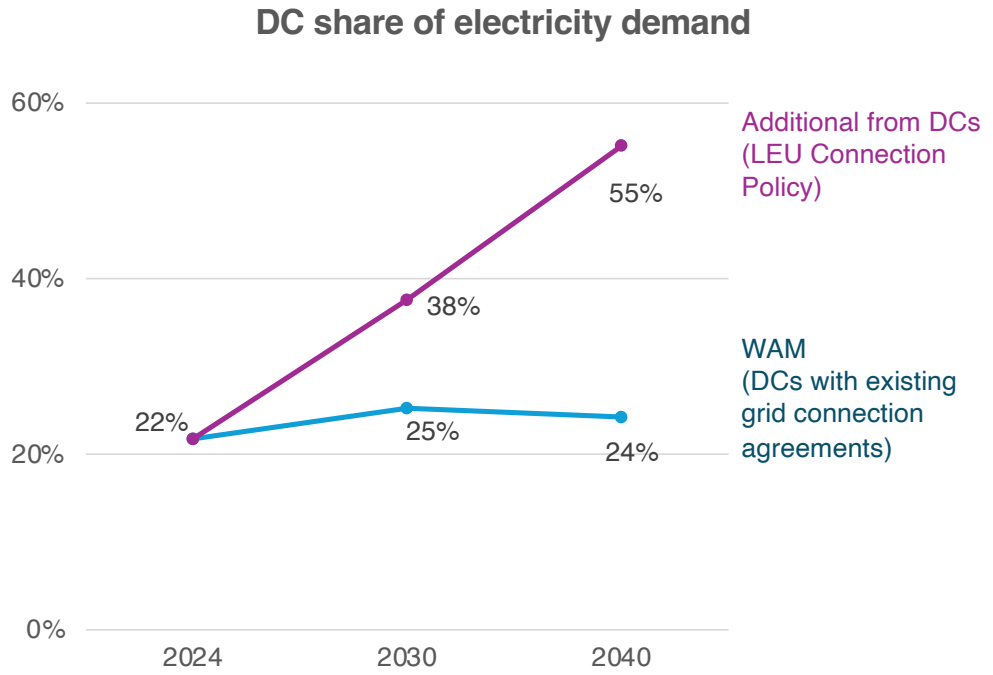
Land-use dynamics



Jaggeshar et. al. (in preparation) Towards a national integrated model for land, energy, agriculture and forest systems (TIM-LEAF)

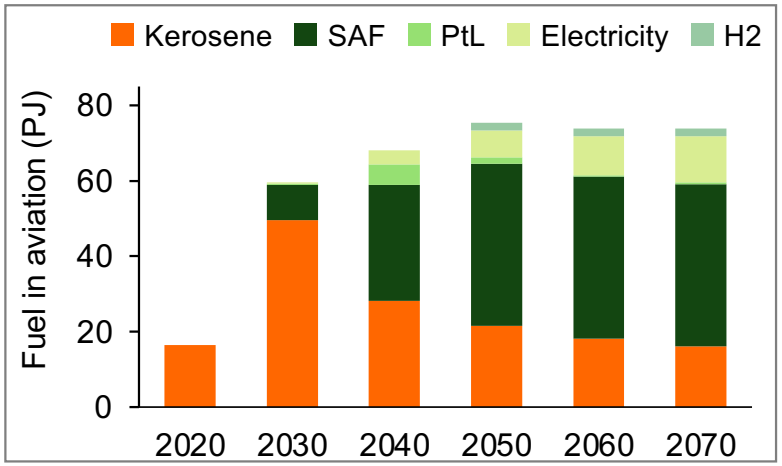
Data centres: Industrial policy

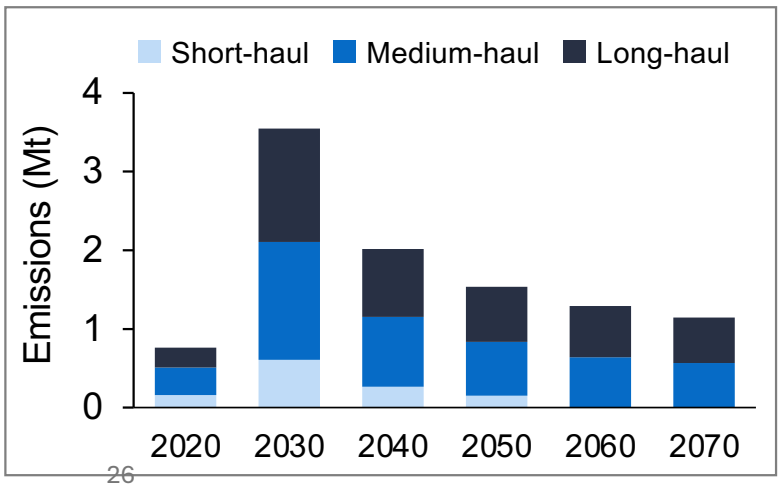


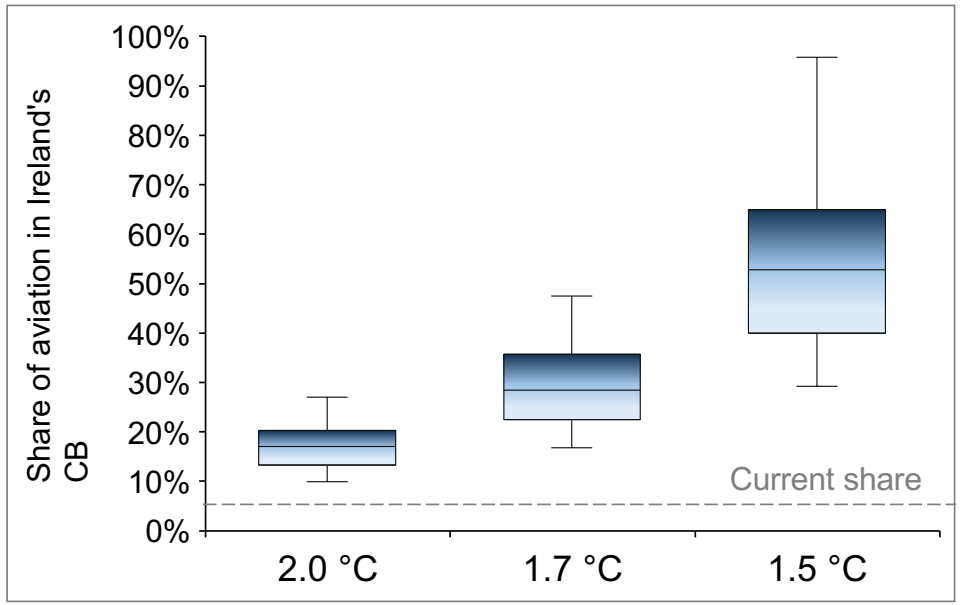


Bonserio, T., & Daly, H. (2026). Data centre expansion in Ireland: the conflict between grid connection policy and national energy and climate targets. Working Paper. Zenodo. https://doi.org/10.5281/zenodo.20585450

Integrating international aviation in energy system & climate accounting



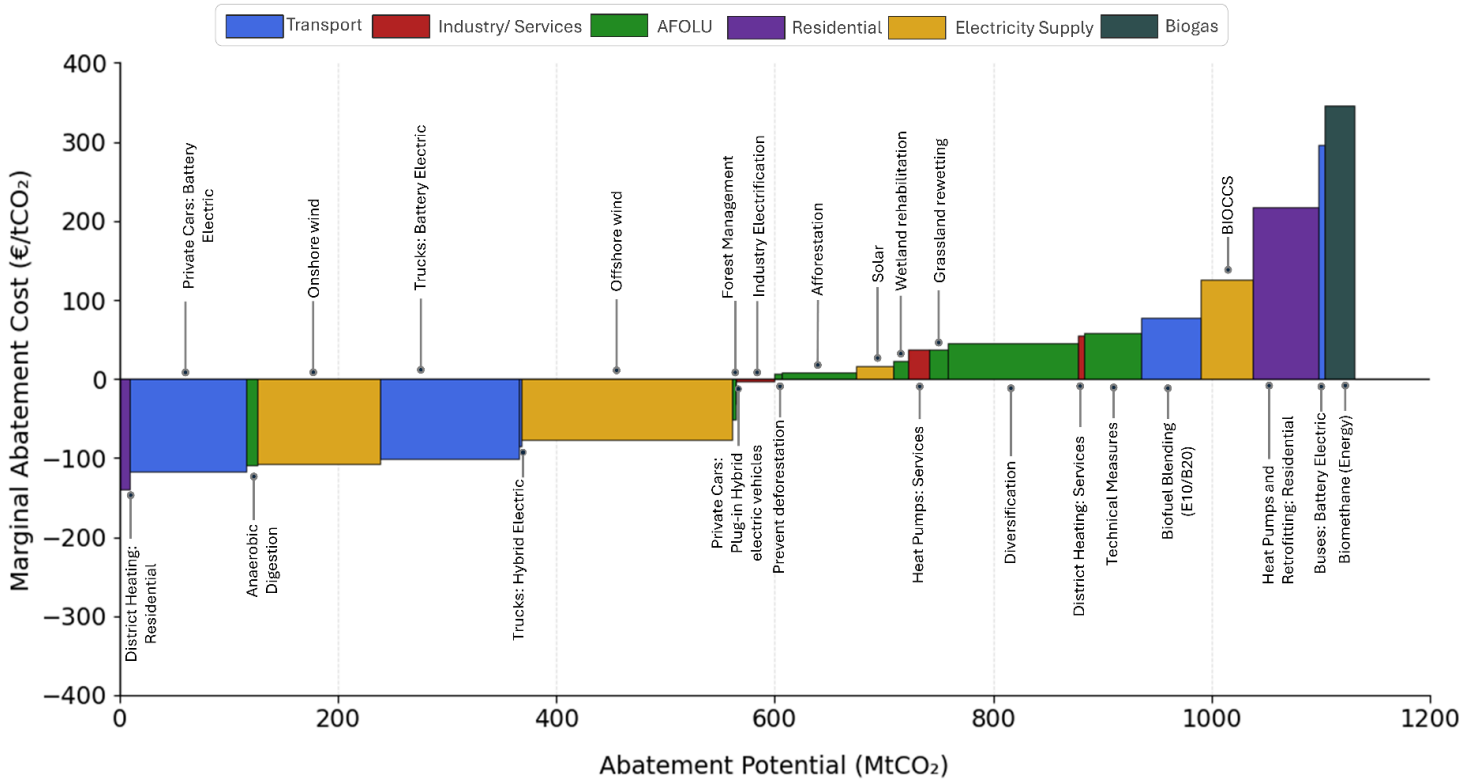




- Int. aviation consumes 3-9× current carbon share (50% likelihood of meeting the T. targets)

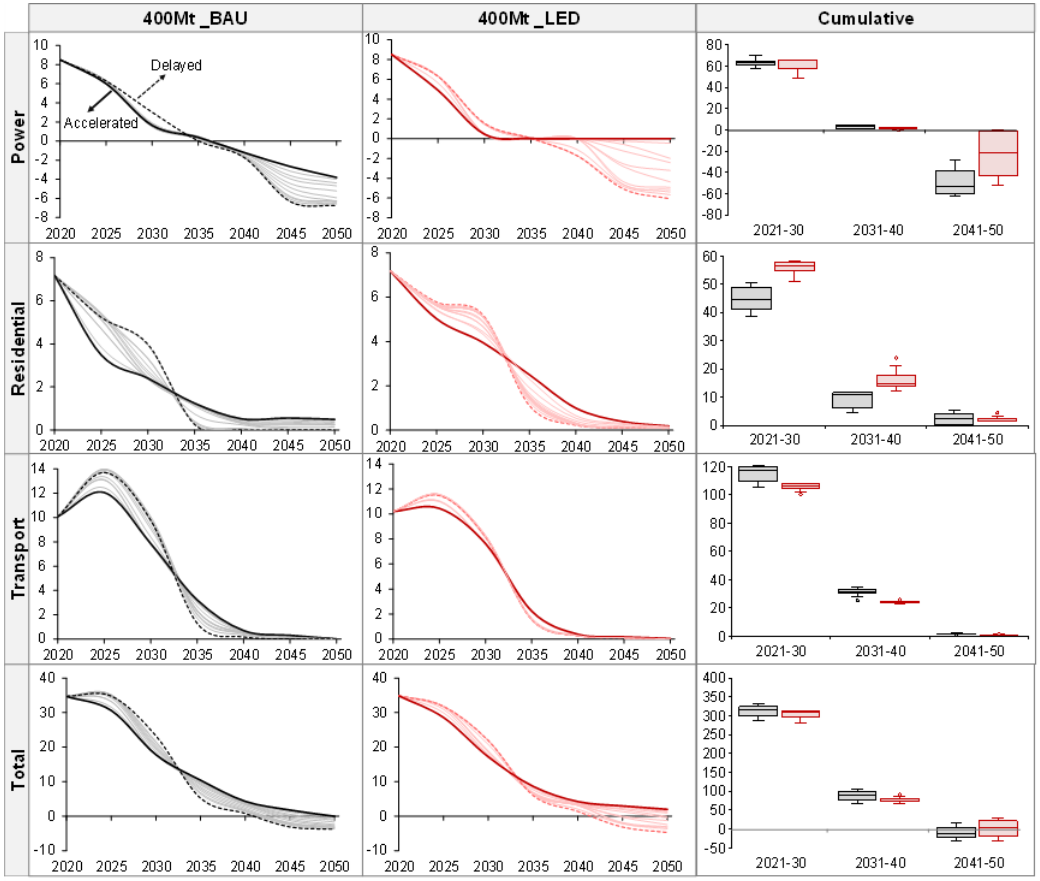
Aryanpur et. al., (in review). Integrating aviation into national carbon budgets reveals critical risks to Paris-aligned energy transition

Integrated energy-AFOLU Marginal Abatement Cost Curve



Daly et. al., 2026. A new integrated Marginal Abatement Cost Curve for Ireland.

Illustrate cost of delay



Delayed mitigation

Brings forward net-zero target by 5 years

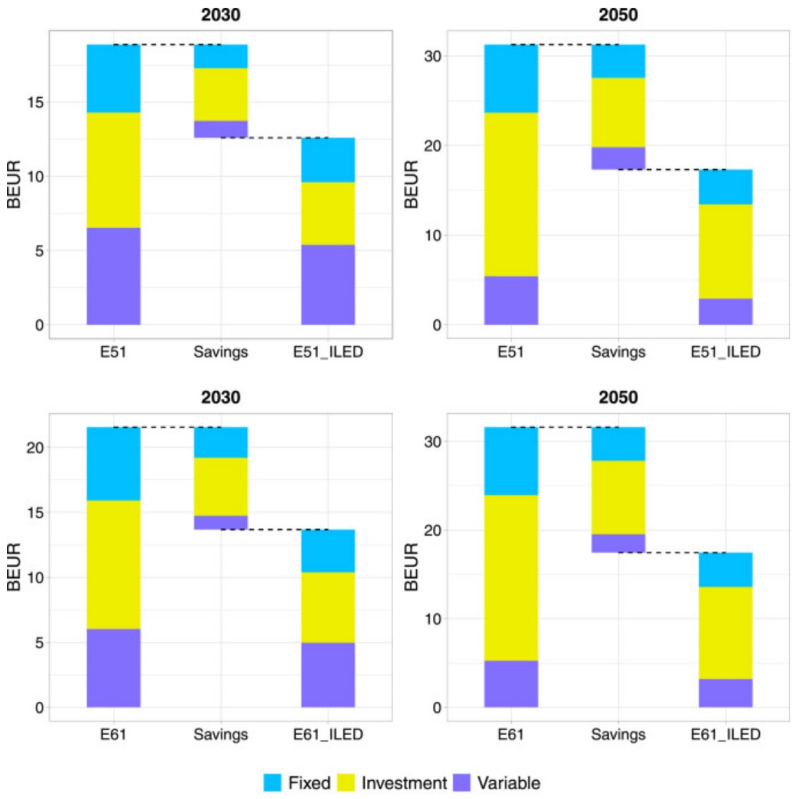
Risks carbon lock-in & stranded assets

Increase reliance on CDR

Leads to higher long-term mitigation costs

Aryanpur, V. *et al.* Implications of accelerated and delayed climate action for Ireland's energy transition under carbon budgets. *npj Clim. Action* **3**, 97 (2024). https://doi.org/10.1038/s44168-024-00181-7

Lower demand & transformative pathways



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Renewable and Sustainable Energy Transition

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Low energy demand scenario for feasible deep decarbonisation: Whole energy systems modelling for Ireland

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[d] Economic and Social Research Institute, Sir John Rogerson's Quay, Dublin, D02 K138, Ireland
[e] Trinity College Dublin, Ireland

Gaur, A., et. al., (2022) Low energy demand scenario for feasible deep decarbonisation: Whole energy systems modelling for Ireland. *Renewable and Sustainable Energy Transition* https://doi.org/10.1016/j.rset.2022.100024

Gaur et. al., (2024): Dispersed settlement patterns can hinder the net-zero transition: Evidence from Ireland. Energy Strategy Reviews vol 51. https://doi.org/10.1016/j.esr.2024.101296

Zhao et. al., (2026) Ireland's carbon emission trends and degrowth opportunities: Based on modified Tapio-LMDI model. Energy Policy https://doi.org/10.1016/j.enpol.2025.114943

Policy engagement on Ireland's long-term climate goal

IOP Publishing Environ. Res. Lett. 20 (2025) 094019 https://doi.org/10.1088/1748-9326/adf12d

ENVIRONMENTAL RESEARCH
LETTERS

LETTER

National temperature neutrality, agricultural methane and climate policy: reinforcing inequality in the global food system

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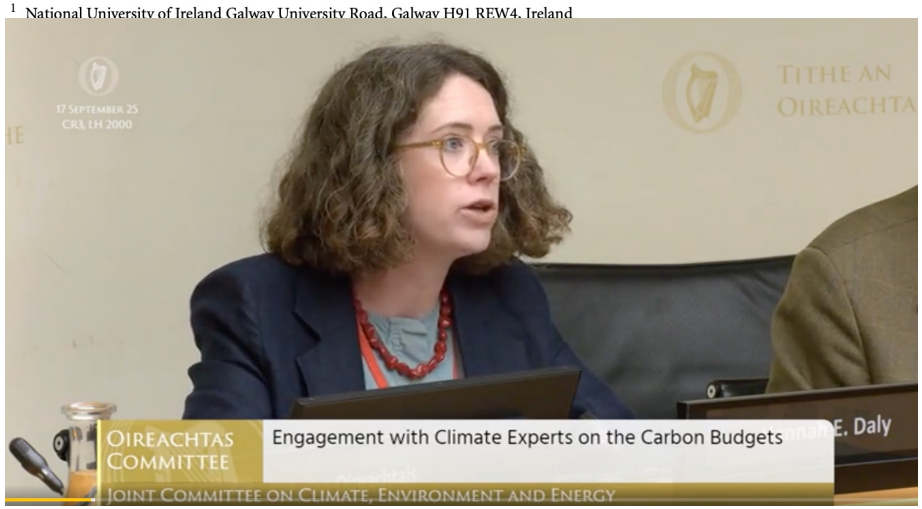

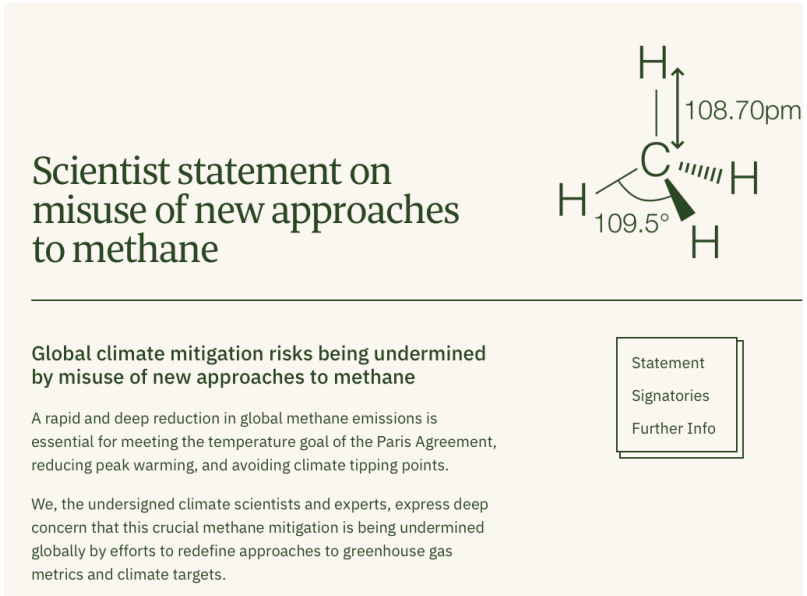

- Moriarty & Daly, 2025. Basing Ireland's carbon budgets on temperature neutrality would undermine obligations under the Paris Agreement
- Duffy et. al., 2025. National temperature neutrality, agricultural methane and climate policy: reinforcing inequality in the global food system
- Open scientists statement: Global climate mitigation risks being undermined by misuse of new approaches to methane. methanescience.org

Thank you

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