Climate Change Advisory Council Secretariat

Carbon Budgets Working Group

Meeting No. 15
28th June 2024
13:30 – 17:00

Agenda

Time	Agenda Item
13:30	1. Opening of Meeting
13:35	2. Analysis of warming impact of selected core scenarios (2^{nd} iteration)
14:35	3. Presentation of the macroeconomic impacts of core scenarios
15:20	Break
15:25	4. SEAI Decarbonised Electricity System Study
16:05	5. Aviation and Maritime emissions
16:45	6. Carbon Budget Work Plan
16:50	7. Next Steps and Agenda for next meeting
16:55	8. AOB
17:00	Meeting Close

1. Opening of Meeting

Action Number	Date Raised	Description	Owner	Due	Status
19	22/03/24	Secretariat to schedule trilateral discussion with NTA, TIM and SEAI CBWG members.	CCAC Secretariat	May 2024	Propose to Close Trilateral discussion with NTA, TIM and SEAI CBWG members scheduled for Monday the 27^{th} of May

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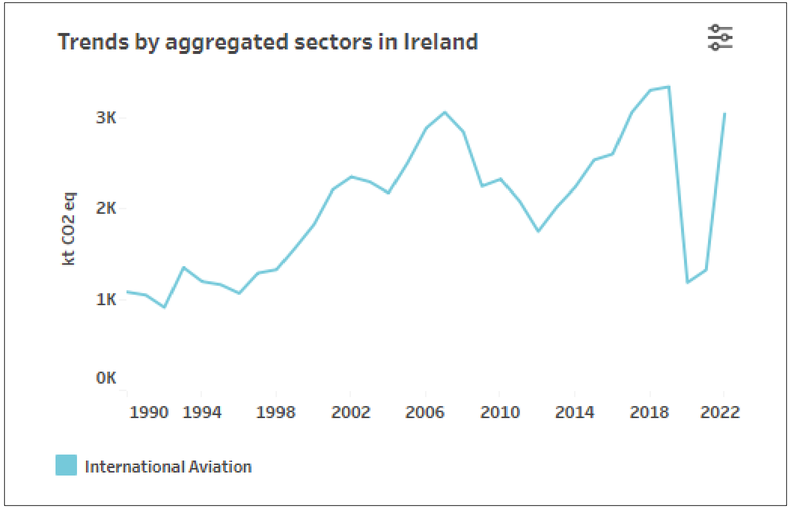
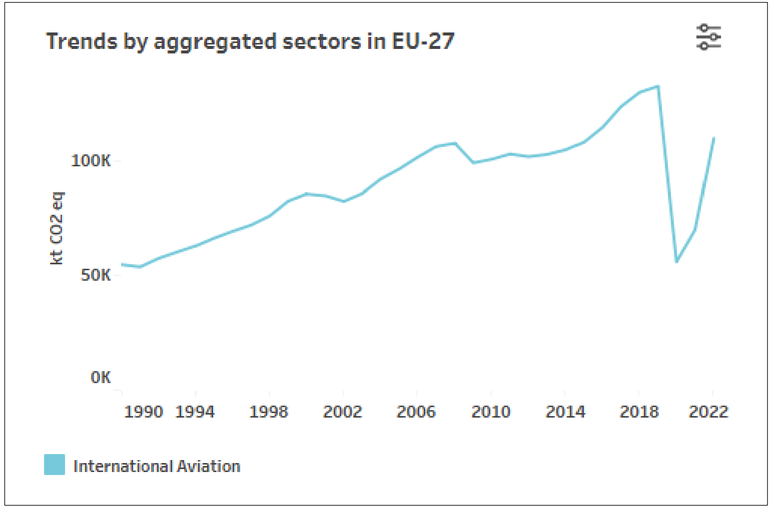
5. Aviation and Maritime Discussion – Aviation Emissions

- 3.25% of EU 27 emissions in 2022, ~2% of emissions globally.
- 3.05 Mt CO_2 in 2022 in Ireland - ~4.5% of emissions (transport emissions excluding international aviation were 11.75 Mt CO_2).
- 1.36 billion litres of jet kerosene used in 2023 - highest recorded annual energy demand for air travel to date.
- Reported as a memo item in the National Inventory and not included in Carbon Budgets.





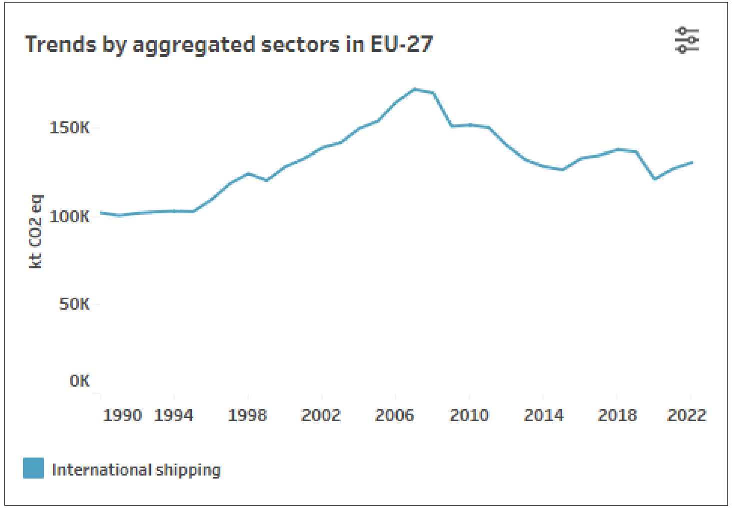
https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

5. Aviation and Maritime Discussion – Aviation Decarbonisation

Efficiency & demand	Alternative fuels & technologies	Regulation and taxation
• Engine and design efficiency • Logistics, traffic efficiency • Flight performance • Practical alternatives & demand management, e.g. corporate travel	• Sustainable Aviation Fuels • Sustainability criteria • Production capacity • Competition with other sectors • Drop in fuels vs aircraft redesign • Supply chain and refuelling	• ICAO 'long-term aspirational goal' of net-zero carbon emissions by 2050 • CORSIA • EU ETS • ETD • ReFuel EU • AFIR • Fossil fuel subsidies; Excise Duty, Carbon Tax, VAT, NORA levy

5. Aviation and Maritime Discussion – Maritime Emissions

- 3.87% of EU 27 emissions in 2022, ~2% of global energy-related CO_2 emissions.
- 0.41 Mt CO_2 eq for Ireland in 2022, 0.6% of emissions (transport emissions excluding international aviation were 11.75 Mt CO_2).
- Emissions grew by 5% globally in 2022 -> mainly driven by increased international trade.
- Projections based on transport demand assumptions – sensitive to trade flows/fossil fuel transport/circular economy/rail freight etc



https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

5. Aviation and Maritime Discussion – Maritime Decarbonisation

Efficiency & demand	Alternative fuels & technologies	Regulation and taxation
• Speed, routing, capacity • Design and size • Long turnover time of ships • Friction • Interface with ports • Regulation on sulphur content	• Biofuels • Electrification (short journeys) • Ammonia and Hydrogen	• In 2023, the IMO adopted a revised strategy which sets a goal of net zero GHG emissions from ships by or around 2050. • EU ETS • ETD • FuelEU Maritime • AFIR

Measures	Potential fuel savings
Light materials	0-10%
Slender design	10-15%
Propulsion improvement devices	1-25%
Bulbous bow	2-7%
Air lubrication and hull surface	2-9%
Heat recovery	0-4%

Measures	CO_2 emissions reduction potential
Speed	0-60%
Ship size	0-30%
Ship-port interface	1%
Onshore power	0-3%

https://www.itf-oecd.org/sites/default/files/docs/decarbonising-maritime-transport-2035.pdf

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6. Carbon Budgets Workplan

CB WG Meeting No.	Proposed Date and Time	Topic(s) for Consideration
16	Thursday 25th July 2024, 13:30 – 16:30 ***In person: SEAI Head Office, 3 Park Place, Hatch Street, D02 FX65***	*SEAI & NTA Additional Analysis Results (based on 1st and 2nd iteration)* *Follow on discussion on Biodiversity Considerations (James Moran)* Follow on discussion on CDR and Carbon Budgets (Oliver Geden) Agree inputs, parameters and assumptions for 3rd Iteration of Modelling
17	Thursday 29th August 2024, 13:30 – 16:30 ***In person: SEAI Head Office, 3 Park Place, Hatch Street, D02 FX65***	3rd *Iteration of Core Modelling Results*
18	Wed 18th September 2024, 13:30 – 16:30	*Additional Analysis & Macroeconomic Modelling Results (based on the 3rd iteration)* Analysis of warming impact of selected core scenarios (3rd iteration) Economic assessment of climate change impacts and adaptation options (ESRI)

6. Carbon Budgets Workplan: 2nd & 3rd Iteration of Modelling & Analysis

Description	2024											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Modelling / Analysis Iteration 2												
Agree inputs, parameters and assumptions												
Core pathways development and modelling												
Paris Test Assessment												
Additional modelling and testing of results												
Post-hoc analysis												
Modelling / Analysis Iteration 3												
Agree inputs, parameters and assumptions												
Core pathways development and modelling												
Paris Test Assessment												
Additional modelling and testing of results												
Post-hoc analysis												

7. Next Steps

1. **Scenario Dialogue Tool**

    - At least 1 scenario in the Scenario Dialogue Tool to be updated by all CBWG members before the 25th of July CBWG meeting
    - Secretariat to schedule calls with CBWG members individually to discuss the scenario dialogue tool
    - Format and approach to be locked down by the 25th of July CBWG meeting
    - Scenario Dialogue Tool to be completed and finalized by the 30th of September

2. Secretariat to schedule a call to discuss **FAPRI scenario results** with Kevin and Trevor (w/c 8th of July)
3. Further **CCAC feedback** for the 3rd iteration of modelling and analysis to be provided following the CCAC meeting on the 18th of July
4. The **3rd and final iteration of modelling and analysis** to commence following the 25th July CBWG meeting

8. AOB

- **Submission:** Jackson and Kelleher (2023) *Ireland's second-generation Climate Act: Still Playing the Laggard during the Climate Crisis?* 70 Irish Jurist 283-321

Warming impact of national emissions scenarios 2

Joe Wheatley

28 June 2024 CBWG

MAGICC7

Emulating coupled atmosphere-ocean and carbon cycle models with a simpler model, Meinshausen, Raper, Wigley 2011

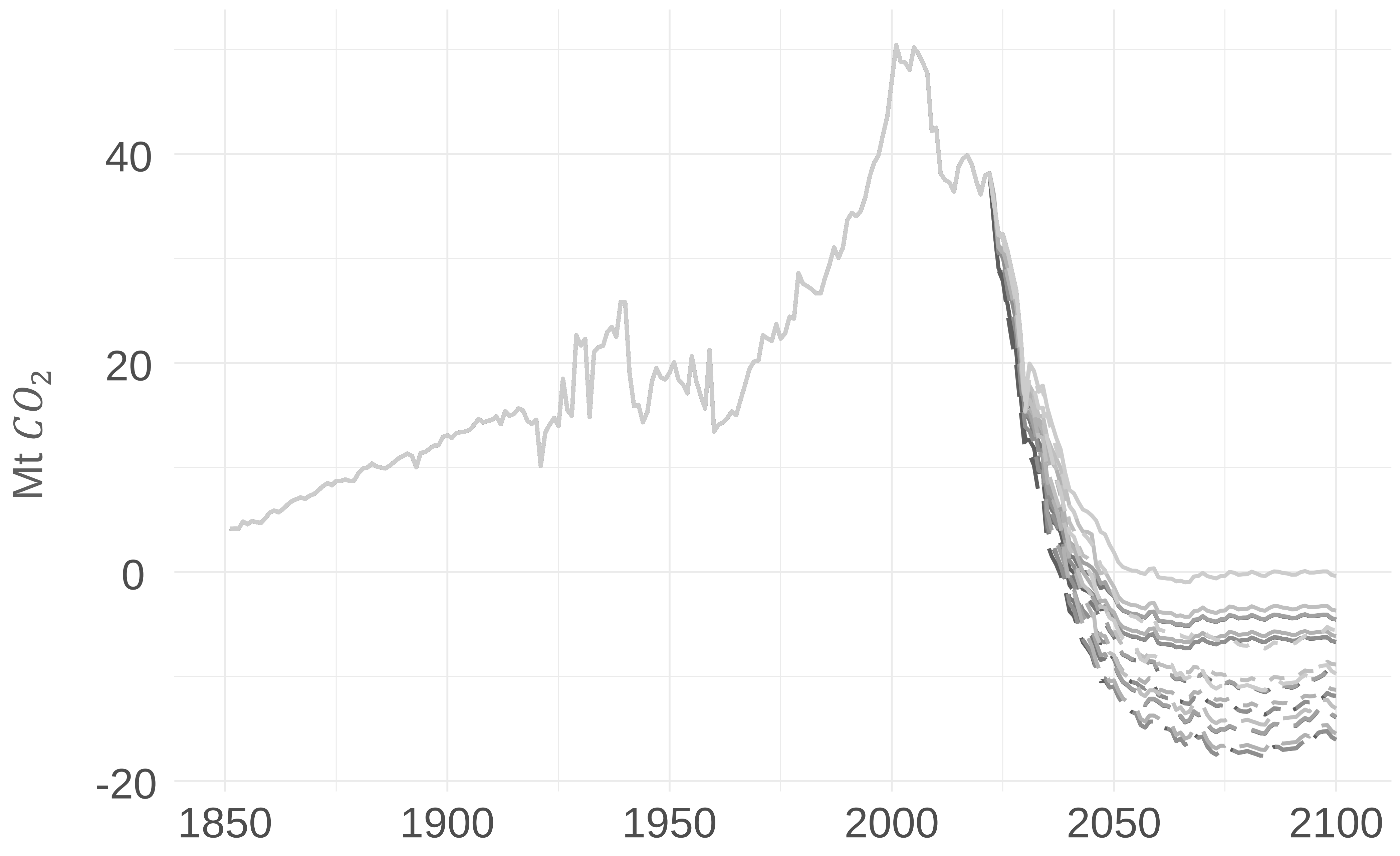
- Influential process model with carbon, methane and nitrogen cycles
- Use in IPCC reports since SAR 1995
- 142 parameters, 64 climate forcing agents (24 forcers relevant for Ireland).
- MAGICC7 600-member drawn-set used in AR6 **Remaining Carbon Budget** assessments

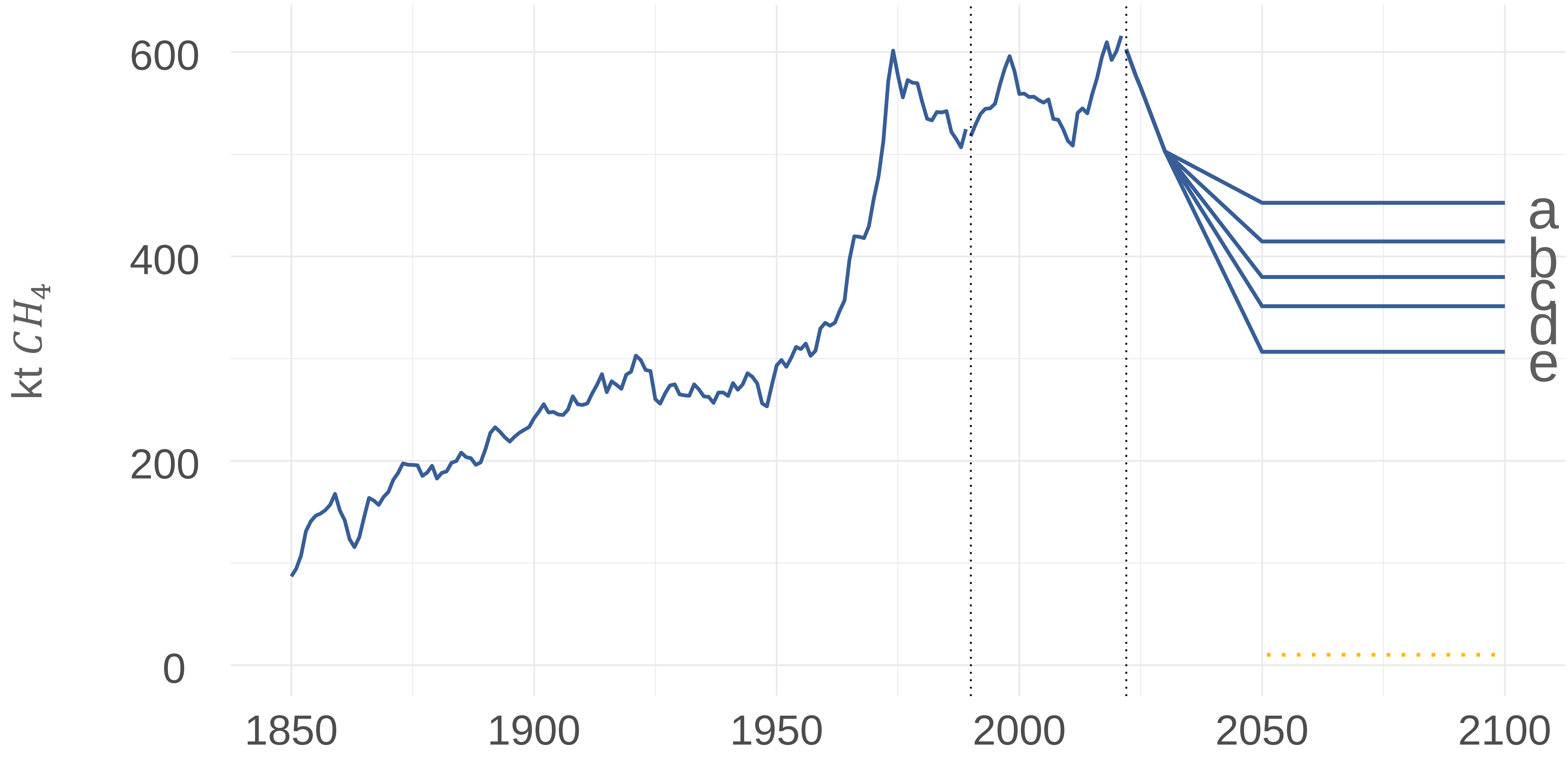
Remaining carbon budget case/update	Base year	Estimated remaining carbon budgets from the beginning of base year (Gt CO_2)				
Likelihood of limiting global warming to temperature limit		17 %	33 %	50 %	67 %	83 %
1.5 °C from AR6 WG1	2020	900	650	500	400	300
+ AR6 emulators and scenarios	2020	750	500	400	300	200
+ Updated warming estimate	**2024**	**450**	**300**	**200**	**150**	**100**
1.7 °C from AR6 WG1	2020	1450	1050	850	700	550
+ AR6 emulators and scenarios	2020	1300	950	750	600	500
+ Updated warming estimate	**2024**	**1000**	**700**	**550**	**450**	**350**
2 °C from AR6 WG1	2020	2300	1700	1350	1150	900
+ AR6 emulators and scenarios	2020	2200	1650	1300	1100	900
+ Updated warming estimate	**2024**	**1900**	**1400**	**1100**	**900**	**750**

Indicators of Global Climate Change 2023 Forster et al 2024

Scenario Inputs

- Global scenarios (SSPs)
- Energy System Model (TIM)
- AFOLU model (Goblin)
- WAM projections f-gases, WASTE-CH4, LULUCF-CH4
- Aerosols, ozone precursors, historical (see 1st iteration)





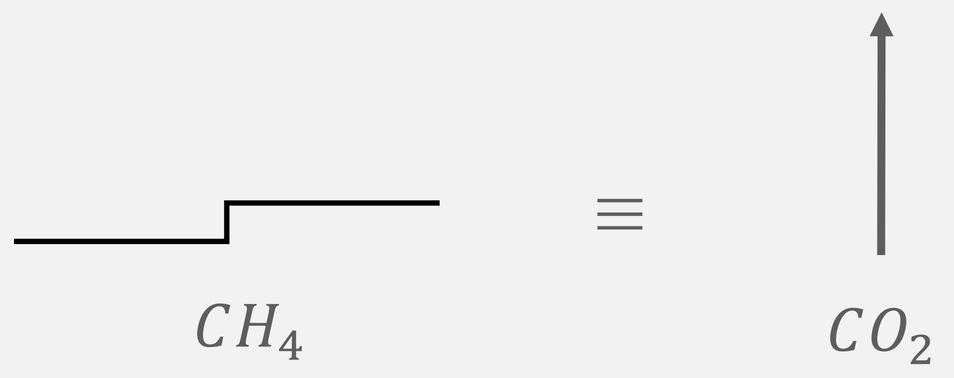
GOBLIN	kt CH_4
a	-163
b	-201
c	-236
d	-264
e	-309

TIM	GOBLIN	Net-Zero CO_2
250mt-led	Sc3d	2038
450mt-bau	Sc2d	2049
450mt-bau	Sc1d	-

Analysis using metrics

Combined-GTP metric for CH_4

+1kt CH_4 step = 2.5 Mt CO_2 pulse



Collins *et al* 2020 *Environ. Res. Lett.* **15** 024018

TIM	GOBLIN	2021-2050 CO_2 + N_2O Mt CO_2-eq	2050 vs 2021 CH_4 drop kt CH_4	2050 vs 2021 CH_4 drop Mt CO_2-weq	TOTAL 2021-2050 CO_2-weq
250mt-led	2b	408	-201	-503	-91
300mt-led	2b	444	-201	-503	-55
300mt-bau	2b	480	-201	-503	-19
350mt-led	2b	494	-201	-503	-5
350mt-bau	2b	498	-201	-503	-1
400mt-bau	2b	548	-201	-503	49
450mt-bau	2b	598	-201	-503	99

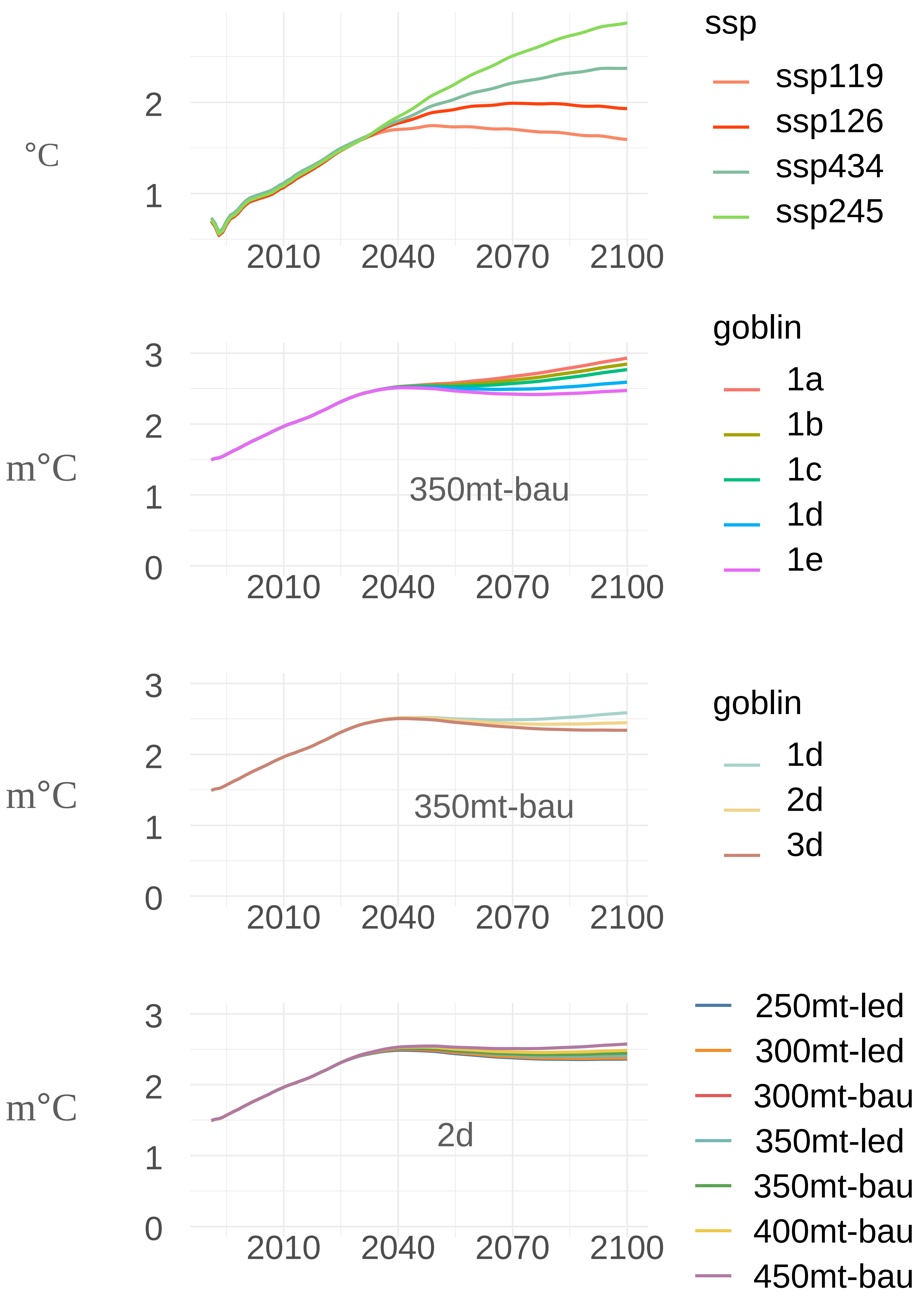
TIM	GOBLIN	2021-2050 CO_2 + N_2O Mt CO_2-eq	2050 vs 2021 CH_4 drop kt CH_4	2050 vs 2021 CH_4 drop Mt CO_2-weq	TOTAL 2021-2050 CO_2-weq
250mt-led	2c	408	-236	-590	-182
300mt-led	2c	444	-236	-590	-146
300mt-bau	2c	480	-236	-590	-110
350mt-led	2c	494	-236	-590	-96
350mt-bau	2c	498	-236	-590	-92
400mt-bau	2c	548	-236	-590	-42
450mt-bau	2c	598	-236	-590	8

200 Mt $CO_2 \approx$ 0.1m °C.

Don’t expect to see much cooling vs historical warming

MAGICC Outputs

- **GSAT**
- Concentrations
- Forcing
- Sea level rise
- TCRE and Net Zero



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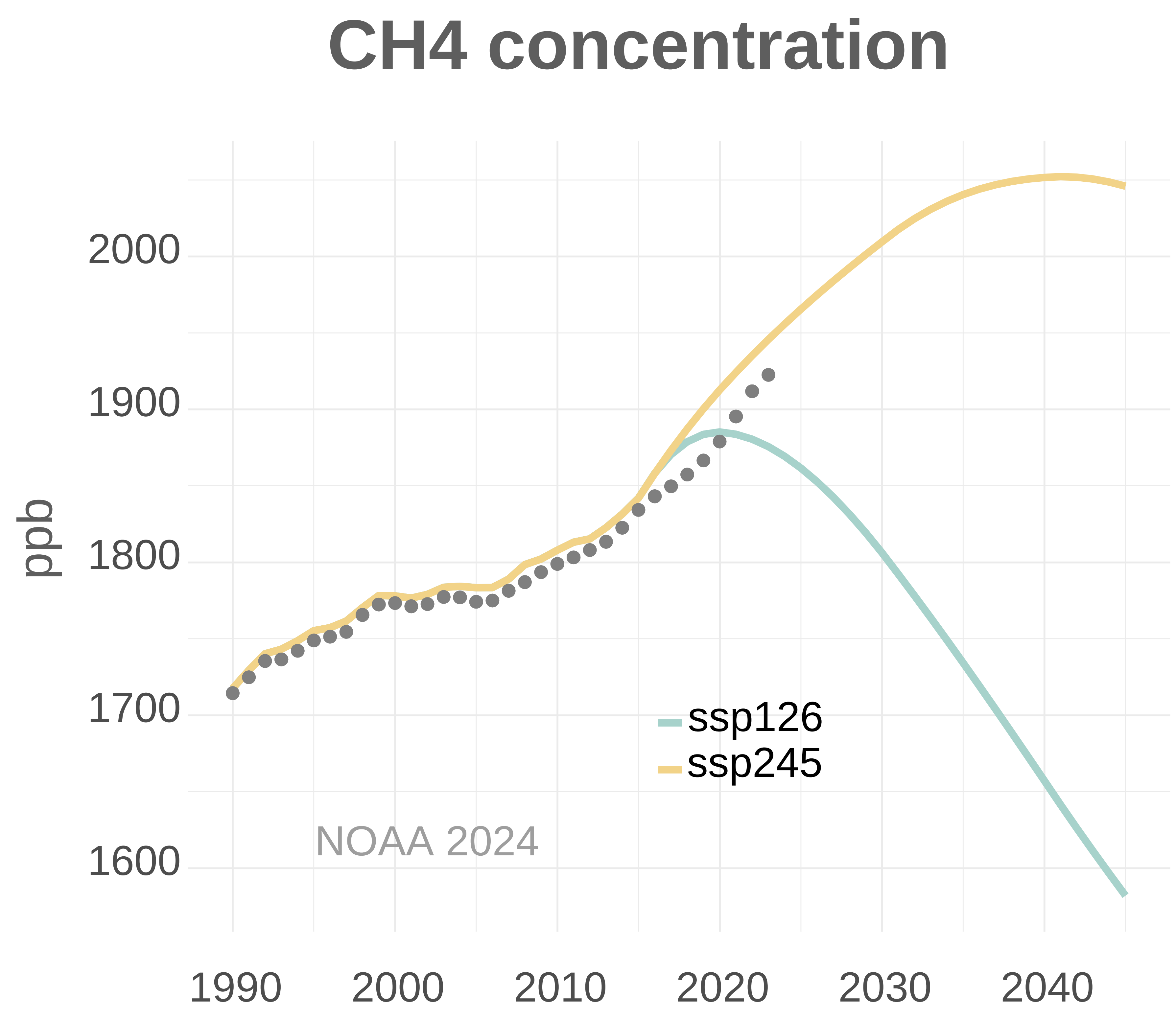

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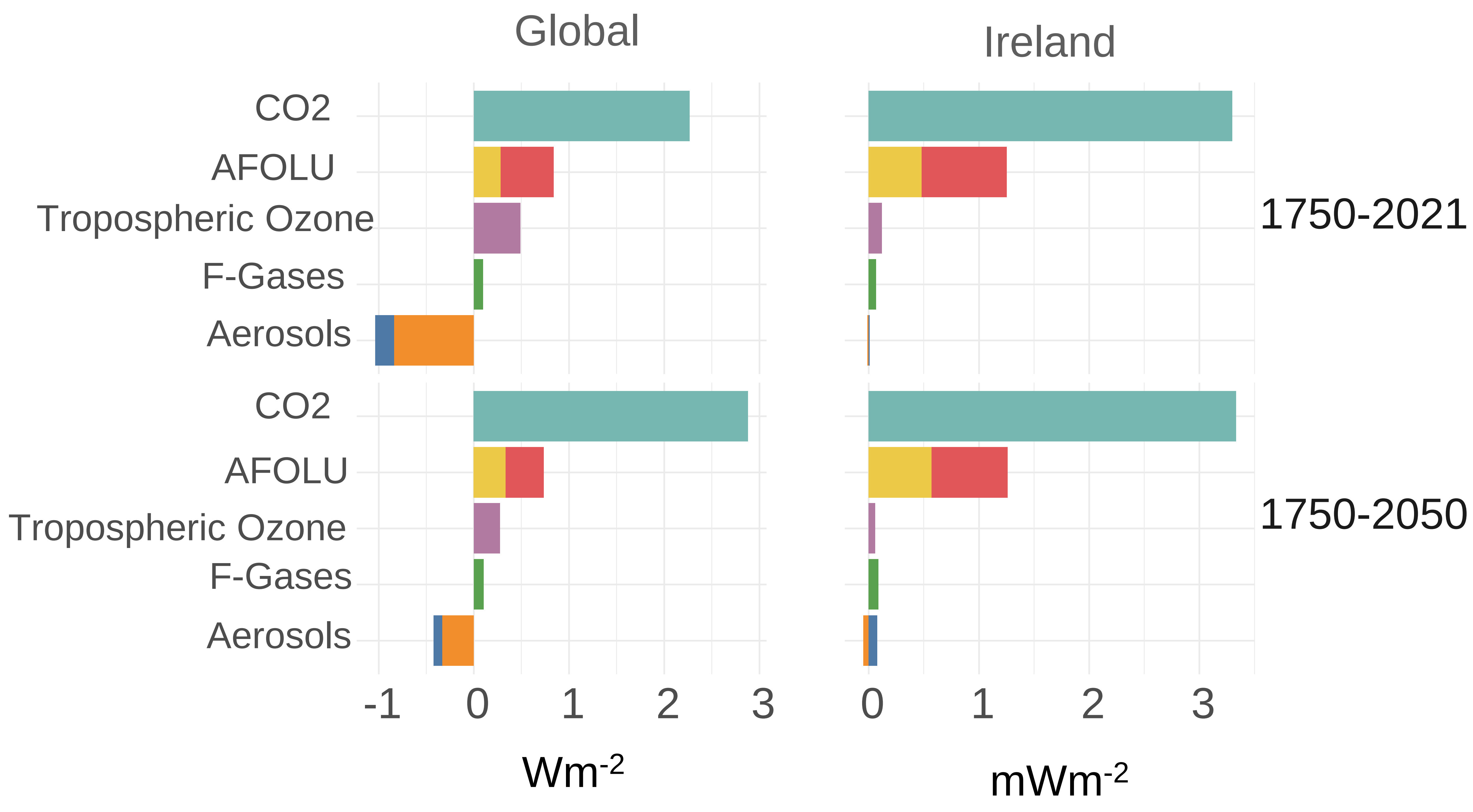
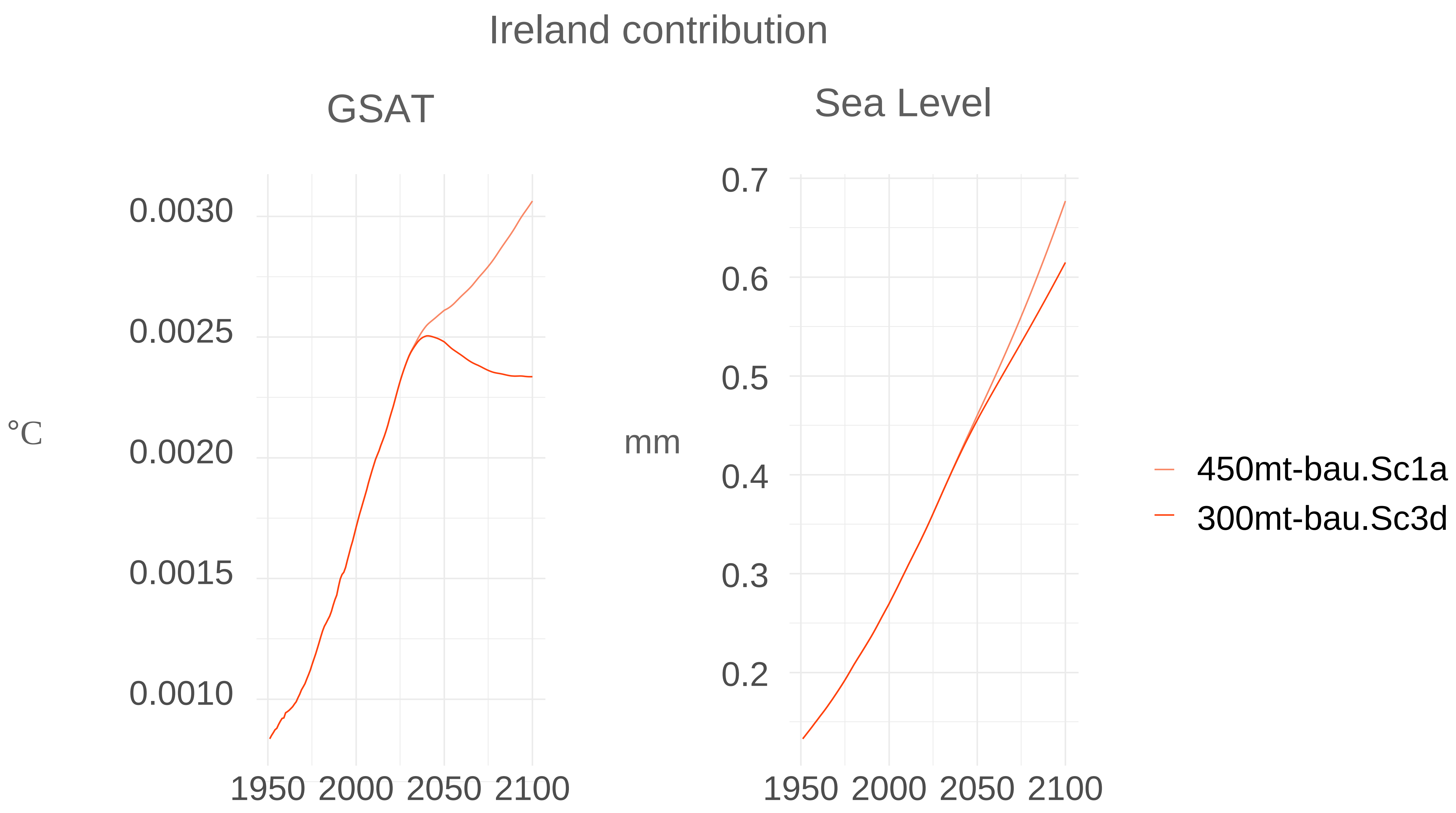


ssp126 250mt-led 2e

MAGICC Outputs

- GSAT
- Concentrations
- Forcing
- **Sea level rise**
- TCRE and Net Zero



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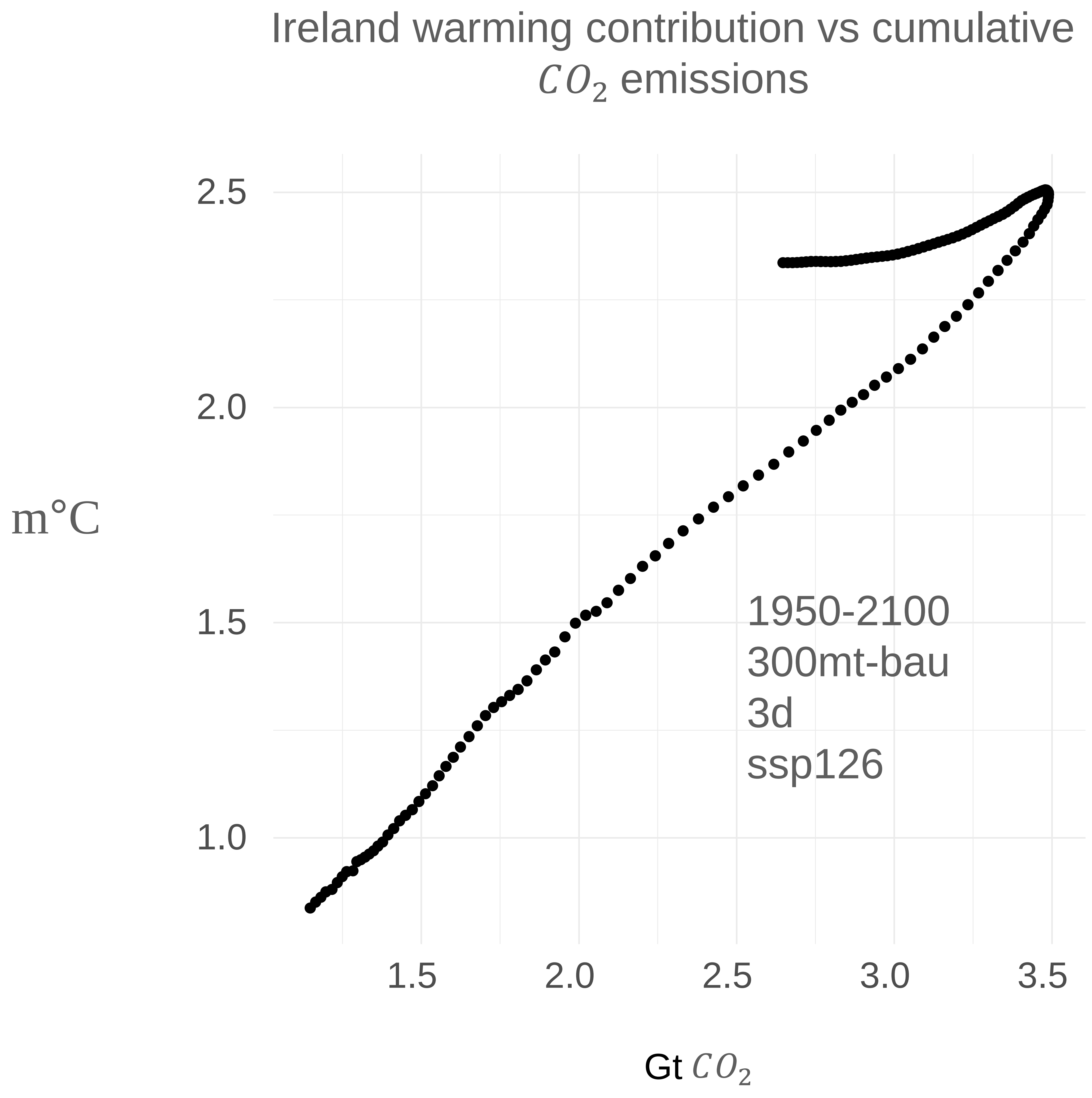
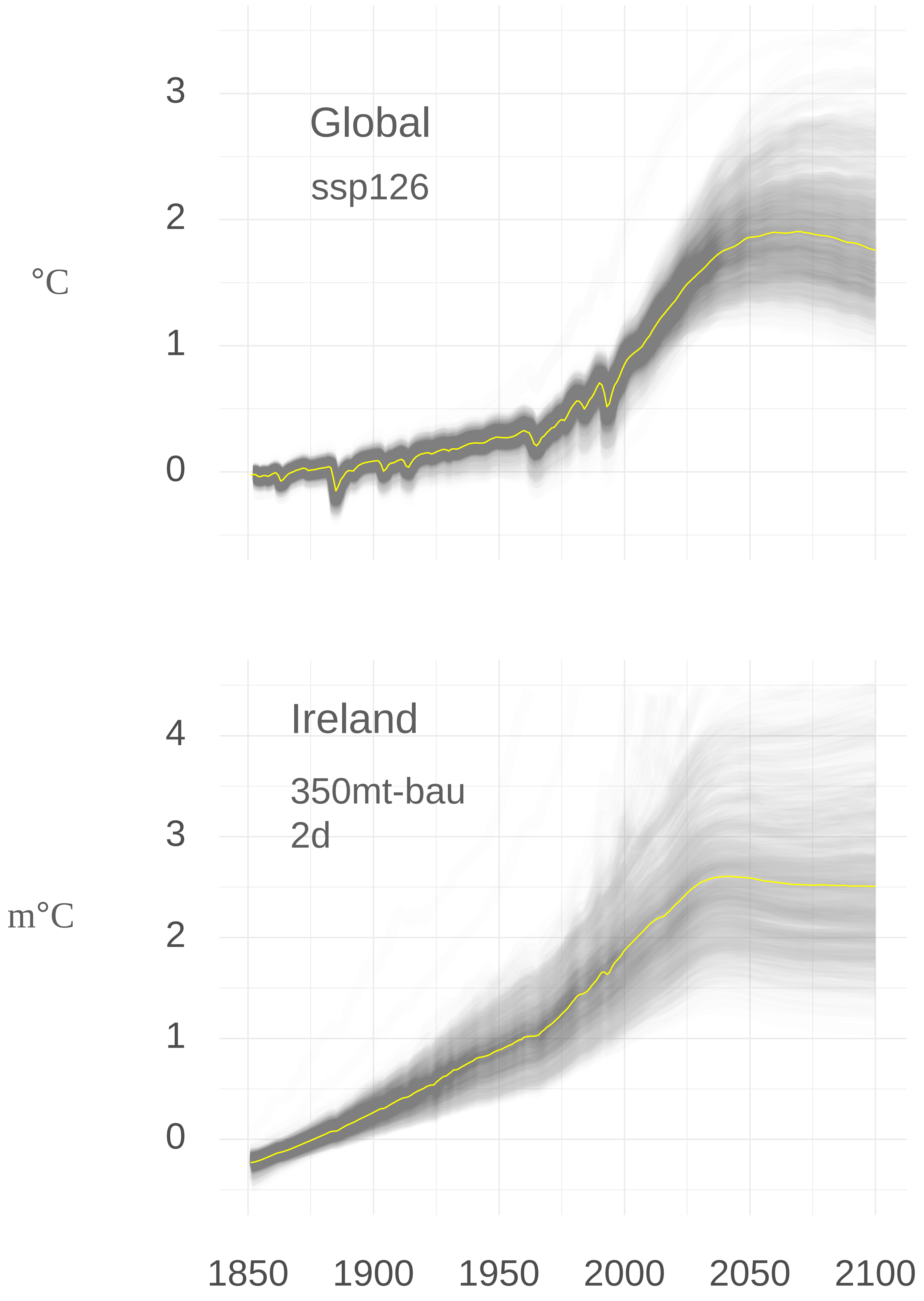
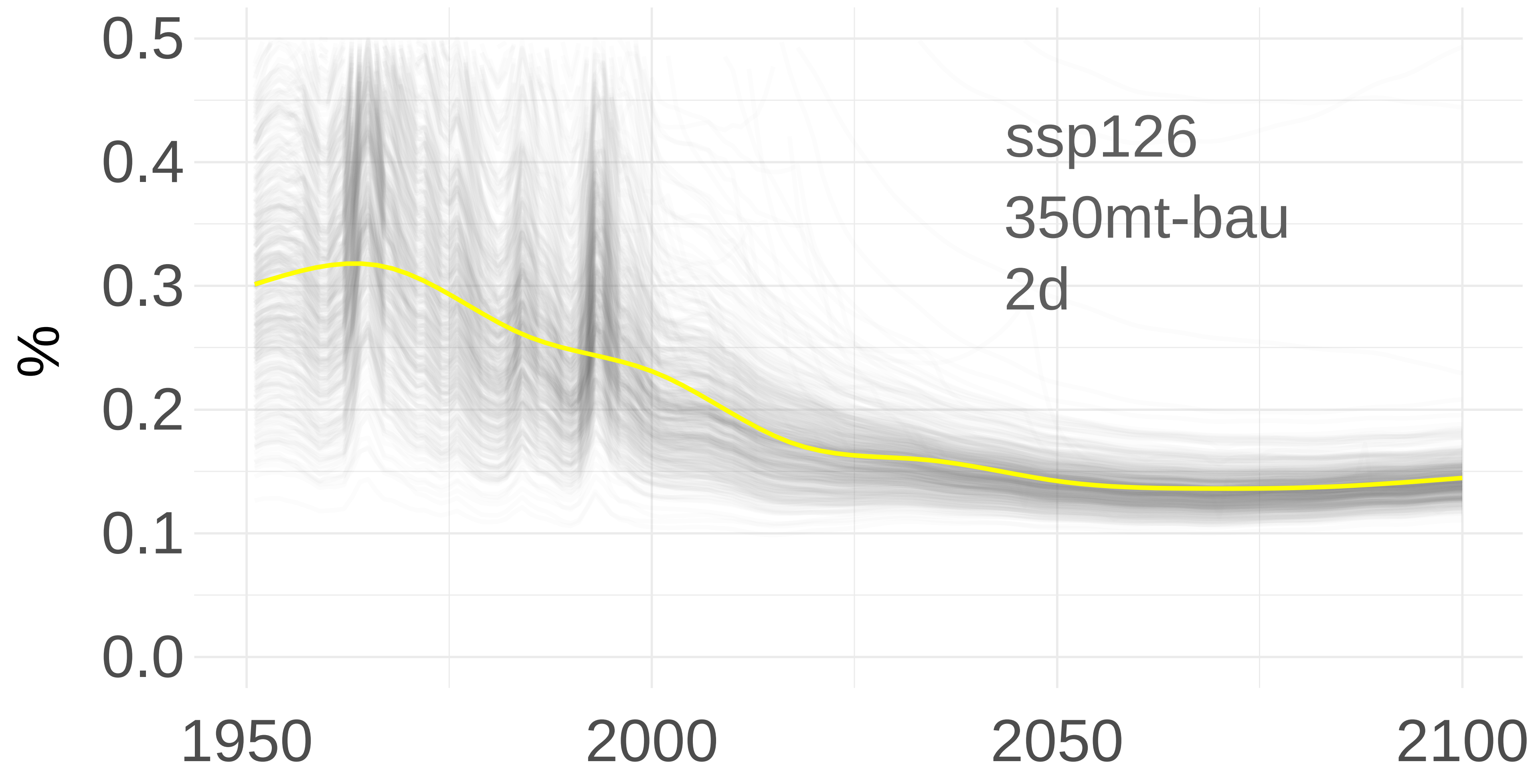


MAGICC7 drawn-set



Ireland contribution to global warming



Stabilises at ~ 0.15% in Paris compatible SSPs

Carbon Budget Constraints with SCMs

1) Share of warming since 1851-1900

- 1.3°C global warming in 2022 (MAGICC7)
- ≈0.17% warming allocation vs population share 0.06%
- Equivalent to 3.7°C – over budget

2) Share of Remaining Carbon Budget

- 2024 global RCB 200 Gt (< 1.5 °C with 50% probability)
- Ireland population share ≈120 Mt CO_2
- Bigger CH_4 cut can increase the budget
- Grandfathering of pre-reference year emissions

3) Neutrality

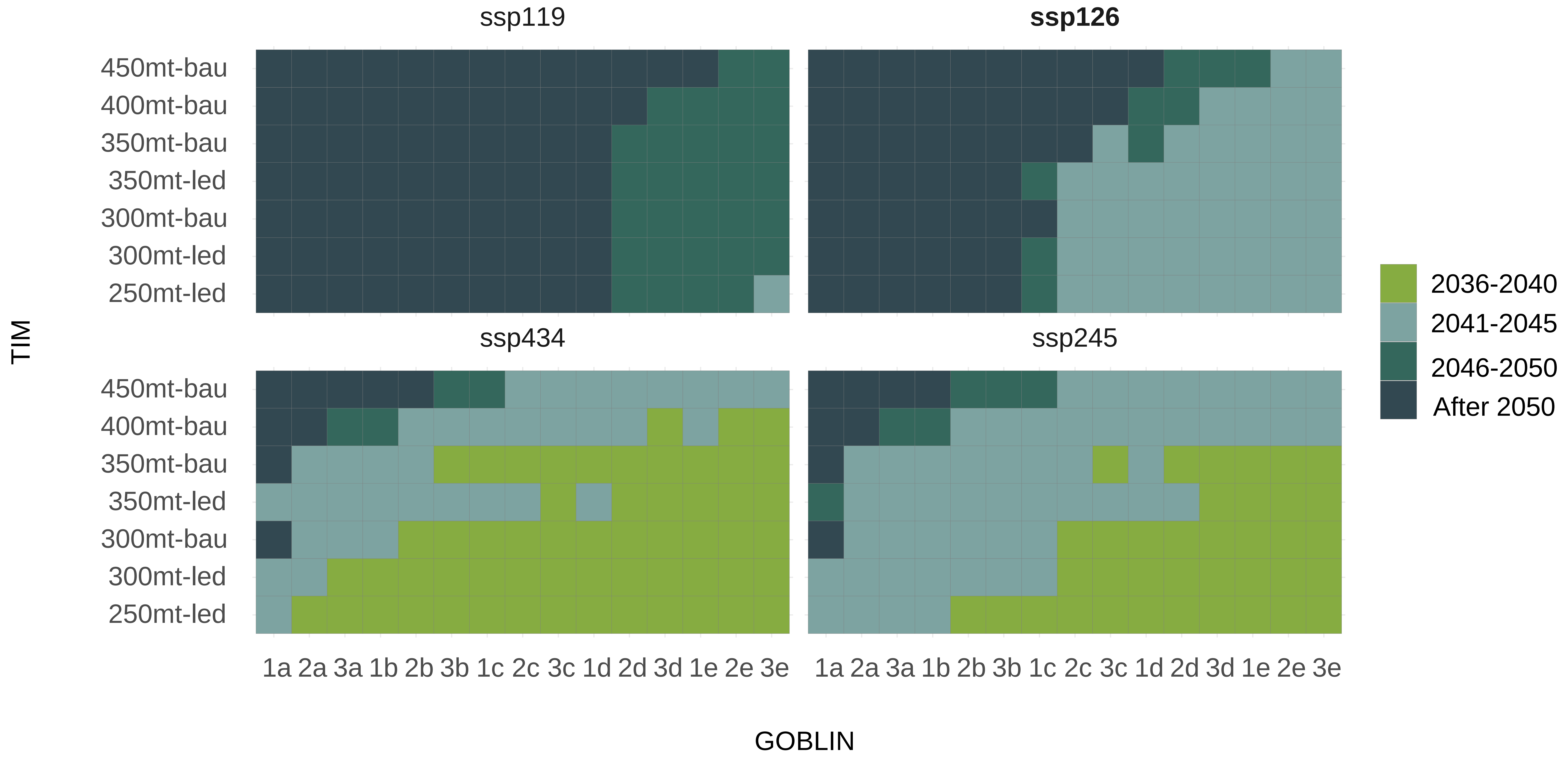
- Constraint depends on target neutrality year (latest 2050)
- May not satisfy Paris equity principles

4) Net-Zero GHG

- Warming impact depends on non-CO_2 gases
- GWPs will change in future

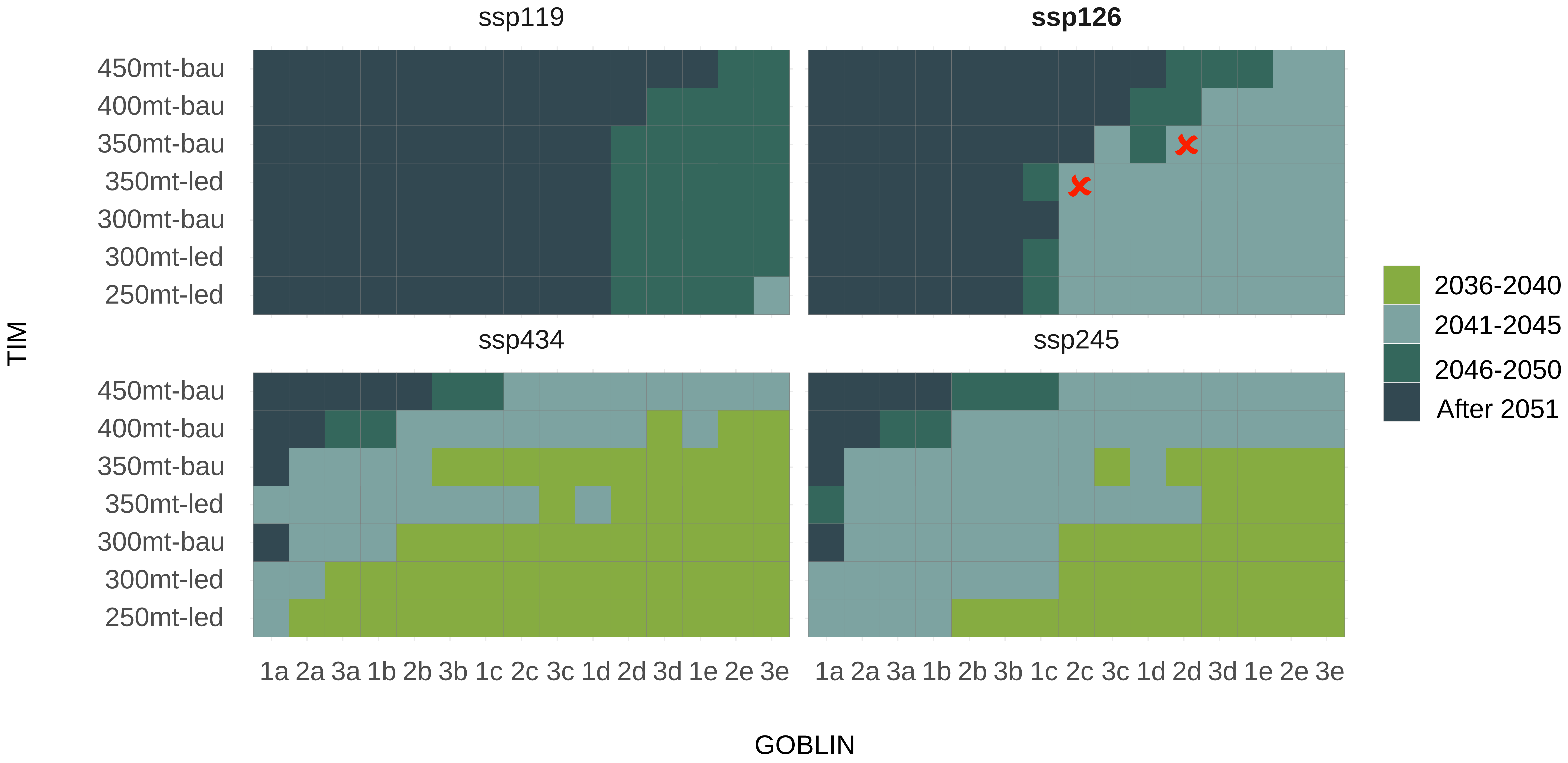
Neutrality Year

MAGICC7 default parameters (≈50% probability)



Neutrality Year

MAGICC7 default parameters (≈50% probability)



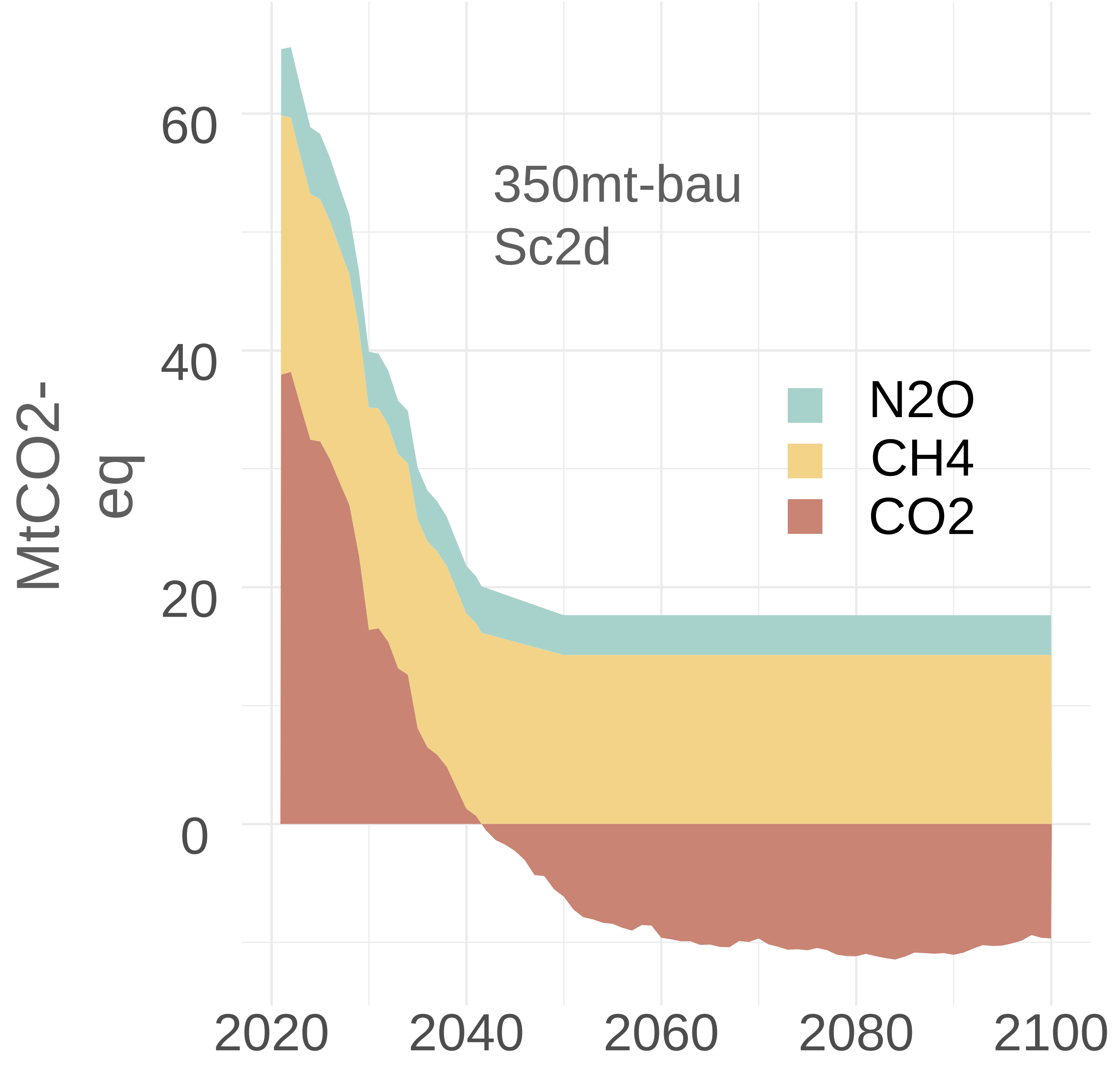
350mt-bau 2d ssp126

-284 kt fall in annual CH_4 emissions 2050 vs 2021

Period	Mt CO_2-eq*
2021-2025	292
2026-2030	224
2031-2035	155
2036-2040	104
2041-2045	70.5
2046-2050	43.3
2051-2055	26.0

*Excludes f-gases

Neutrality	Probability
2050 or before	68%
2045 or before	46%
2040 or before	5%

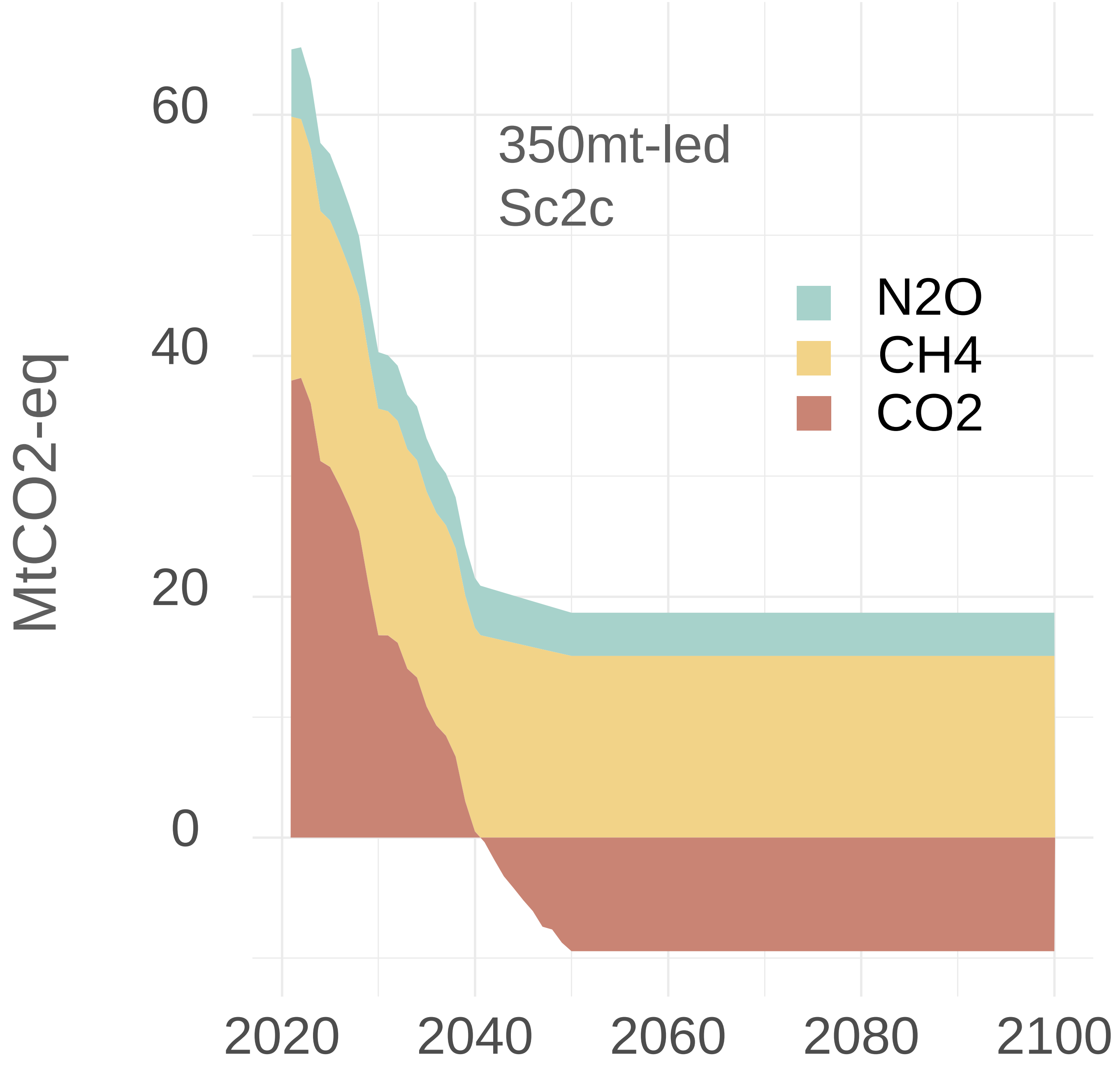


350mt-led 2c ssp126

-236 kt fall in annual CH_4 emissions 2050 vs 2021

Period	Mt CO_2-eq*
2021-2025	308
2026-2030	242
2031-2035	185
2036-2040	136
2041-2045	86.8
2046-2050	56.4
2051-2055	46.1

*Excludes f-gases



Neutrality	Probability
2050 or before	62%
2045 or before	30%
2040 or before	2%

Allocating warming responsibility using SCMs

Two parties A & B global warming $GSAT_{\{A+B\}}$

Leave one in

Warming by A in absence of B $GSAT_{\{A\}}$

Warming by B in absence of A $GSAT_{\{B\}}$

$GSAT_{\{A\}} + GSAT_{\{B\}} > GSAT_{\{A+B\}}$

Disadvantages entity with lower emissions

Leave one out

Warming by A $GSAT_{\{A+B\}} - GSAT_{\{\mathrm{B}\}}$

Warming by B $GSAT_{\{A+B\}} - GSAT_{\{\mathrm{A}\}}$

$2\ GSAT_{\{A+B\}} - GSAT_{\{A\}} - GSAT_{\{B\}} < GSAT_{\{A+B\}}$

Disadvantages entity with higher emissions

"Split the difference"

Warming by A $\frac{1}{2}\left(GSAT_{\{A\}} + GSAT_{\{A+B\}} - GSAT_{\{\mathrm{B}\}}\right)$

Warming by B $\frac{1}{2}\left(GSAT_{\{B\}} + GSAT_{\{A+B\}} - GSAT_{\{\mathrm{A}\}}\right)$

Warming sums to $GSAT_{\{A+B\}}$

Forcing-concentration convexity,
path dependence, aerosols….

Marginal vs “reasonable allocation” warming

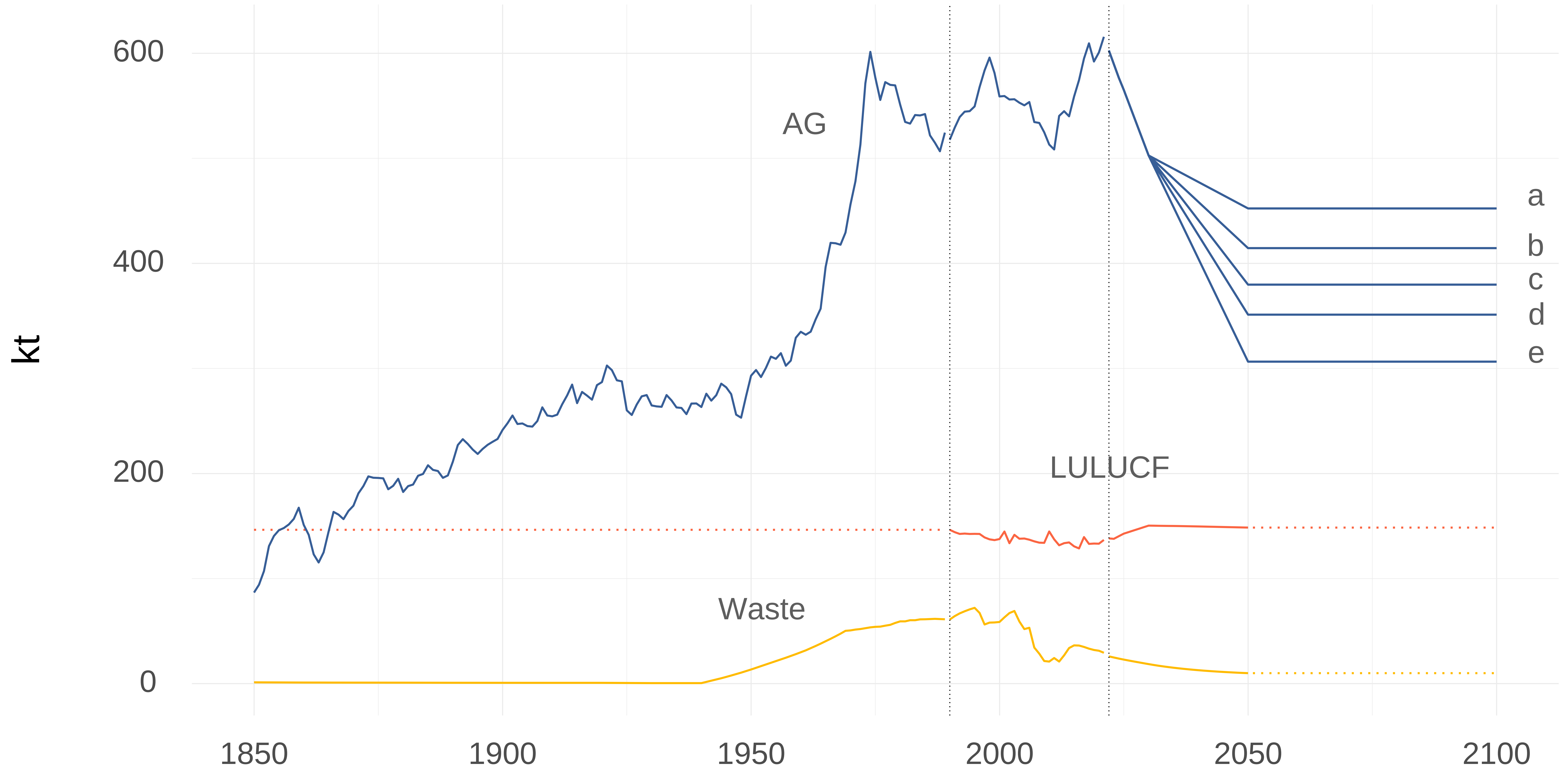
- Difference can be significant when warming assessed relative to older reference periods e.g. 1851-1900
- For Ireland, reasonable allocation is ~10% higher than marginal warming (Hectorv3.1)
- Difference is small when a recent reference period is used.
- For temperature neutrality always safe to use marginal warming

Median peak marginal warming contribution

Range in CBWG scenarios neutral before 2050

Model	Scenarios	Reference Year(s)	Warming to peak (m °C)
FaIR	1st	1851-1900	2.6-2.8
MAGICC	2nd	1851-1900	2.4-2.6
MAGICC	2nd	1990	0.9-1.1
FaIR	1st	2018	0.4-0.6
MAGICC	2nd	2018	0.3-0.5

LULUCF-CH4 Inputs?



To-do list Jan

- **MAGICC7 ✓**
- **Non-marginal warming method ✓**
- **Extension beyond 2050 ✓**
- **Neutrality probability thresholds? ✓**
- **Larger ensembles ✓**
- CFCs ✘

To-do list Jun

- **Preferred SCM for 3rd iteration?**
- **Run 3rd iteration scenarios**
- **Report on findings**
- **Any other suggestions**

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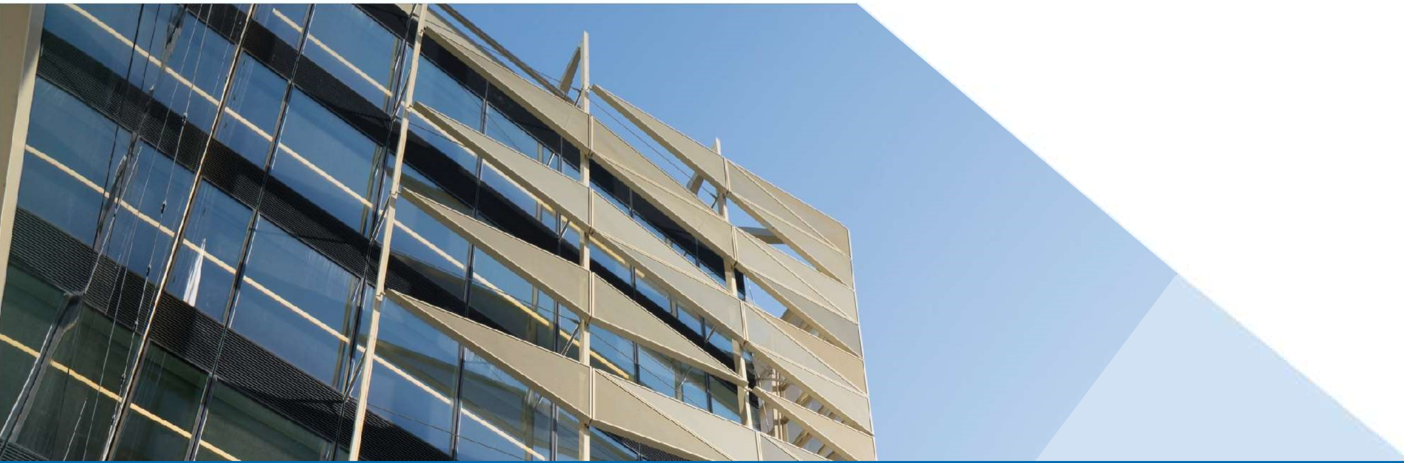
Central Bank of Ireland
Eurosystem



The Macroeconomic Impact of Carbon Budgets in a Semi-Structural Model of the Irish Economy

Niall McInerney

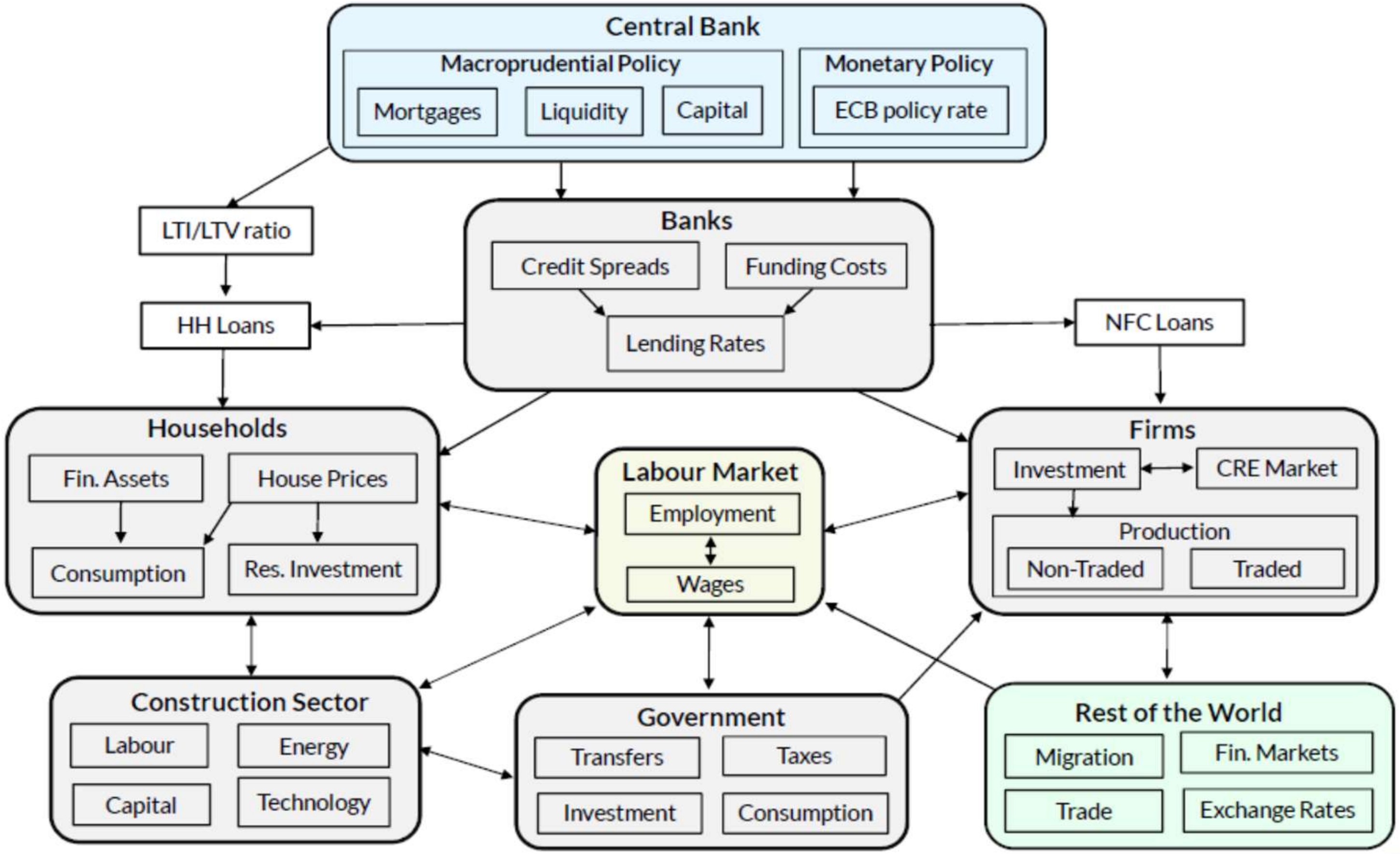
Overview

- Use **COSMO** to analyse the economic impact of transition-related investment on the Irish economy up to 2050
- Key input requirement is the level of investment required to meet decarbonisation targets as provided by **TIM**
- Consider four key issues around path of economy given required level of investment
  - Level of **public** intervention
  - Additional investment stimulus in a **capacity-constrained** economy
  - Financing public share through **taxation** rather than debt
  - Higher equilibrium **interest rates**
- Focus on impact on key macroeconomic variables, implications for **public finances** and international **competitiveness**

COSMO: COre Structural MOdel

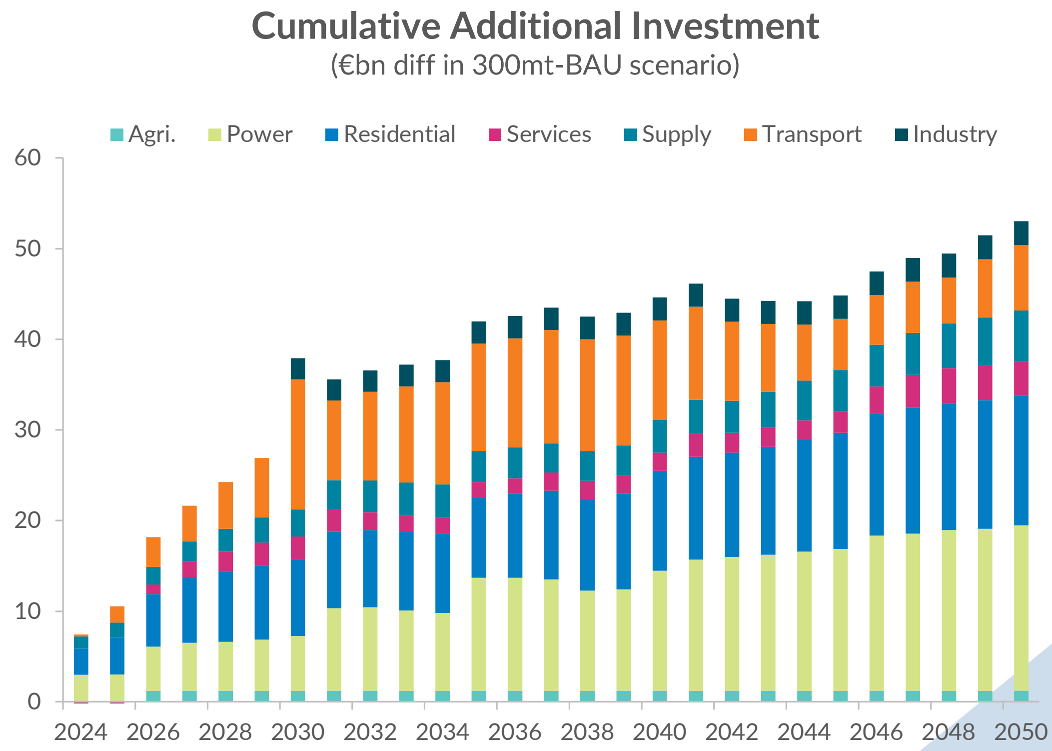
- Medium-scale **semi-structural** (structural econometric) model of the Irish economy
  - Semi-structural nature gives flexibility to incorporate additional features relatively easily
  - Easy integration of international shocks from global models such as NiGEM
- Core model comprises **four sectors**:
  - **Traded** sector depends on **world** demand and Ireland's export prices relative to competitors
  - **Non-traded** sector primarily driven by **domestic** economic conditions
  - **Construction sector** depends on building investment demand from other sectors
  - **Government** sector grows in line with rest of economy in absence of **exogenous policy changes**.
- **Production** in each sector combines capital, energy, labour and (labour-augmenting) technology
- Detailed **linkages** between central bank, banking sector and real economy

Central Bank's Semi-Structural Model



Investment Path for Decarbonisation

- TIM provides investment volumes consistent with different decarbonisation pathways.
- Our analysis uses '300 mt-BAU' **scenario** but can easily be replicated for each of the other scenarios.
- Over €50 billion required up to 2050, mostly front-loaded in next decade.
- Augment with estimates for energy-related **infrastructure**
  - Scale estimates from European Commission (2021) and OBR (2021):
  - Additional €700 bn p.a. up to 2030



Source: UCC TIM model

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Central Bank of Ireland
Eurosystem

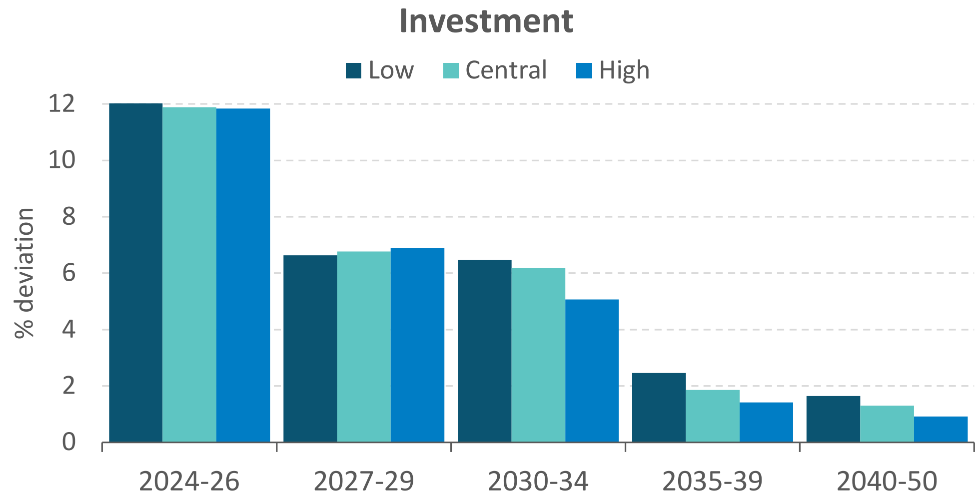
Calibrating public and private shares of Investment

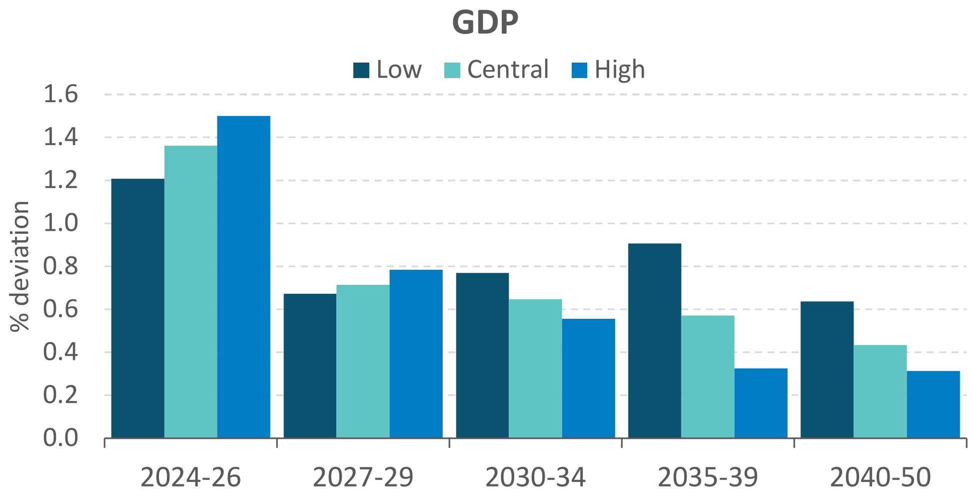
- Optimal **financing mix** for public and private share
  - **Public** intervention typically warranted only in cases where market failures and distortions exist
  - Potential for public to **'crowd-out'** private investment although some has clear public good component.

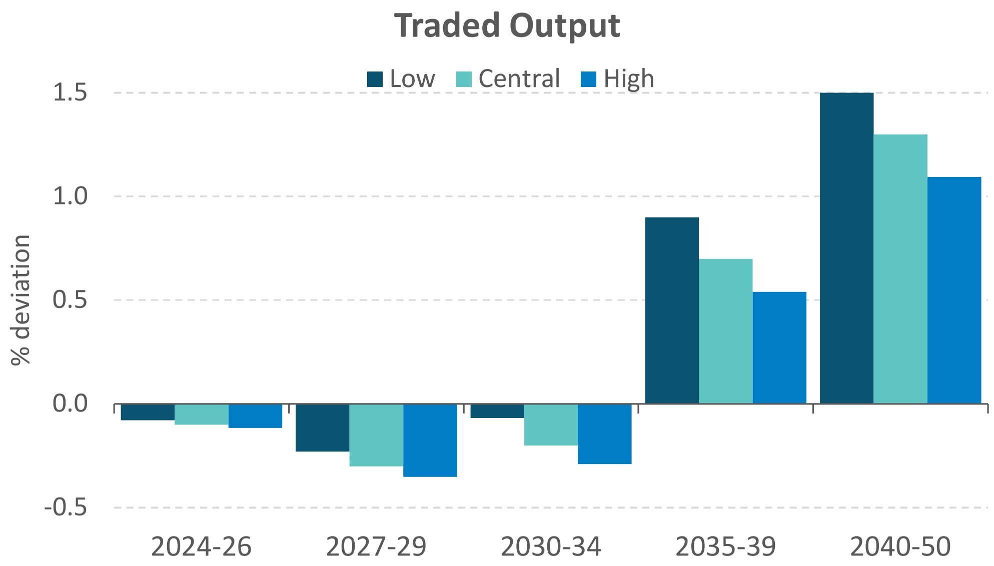
- Literature is inconclusive on particular share of 'green' investment that should be borne by governments:
  - Seghini and Dees (2024): 25-40% for FR, DE, and IT
  - Darvas and Wolff (2022): 28% across EU countries
  - Pisani and Mahfouz (2023) : 50% for France

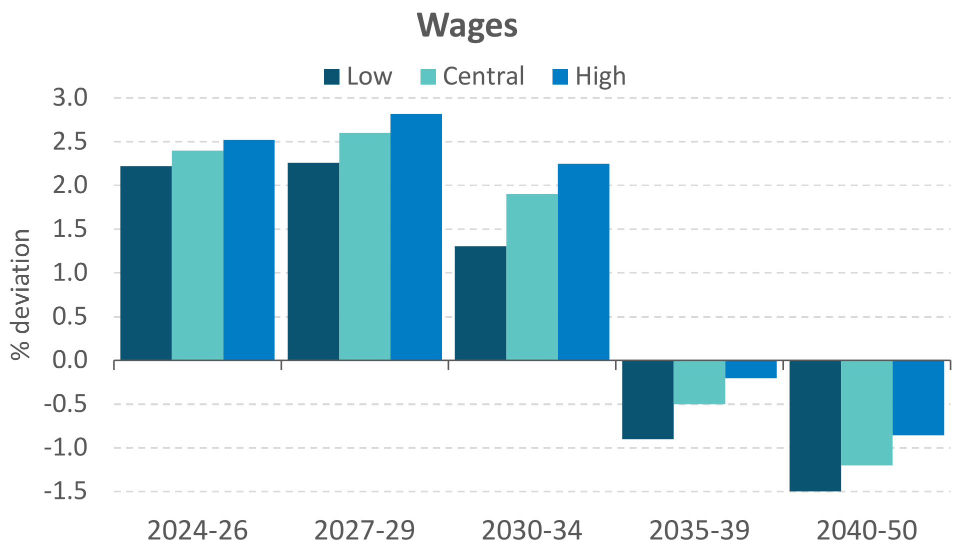
- We use weighted-average public shares from **OBR (2021)**
  - **Low**: 15%, **Central**: 27%, **High**: 41%
  - Simulate scenarios applying these shares to the total investment to calibrate the **public** spending shock
  - Remainder calibrated as **intercept shocks** to investment in the **traded** and **non-trade**d sectors

Impact of Investment Shock by Public Share

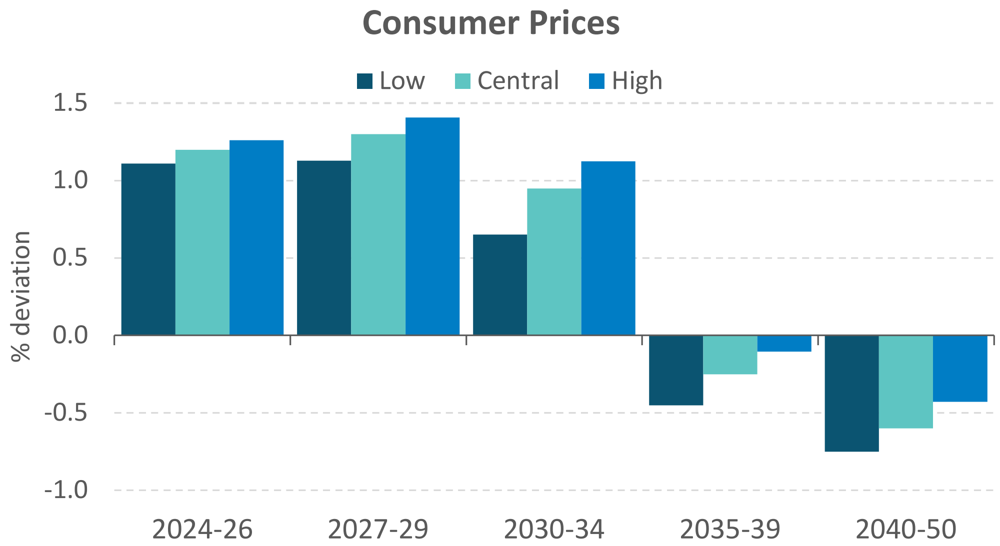


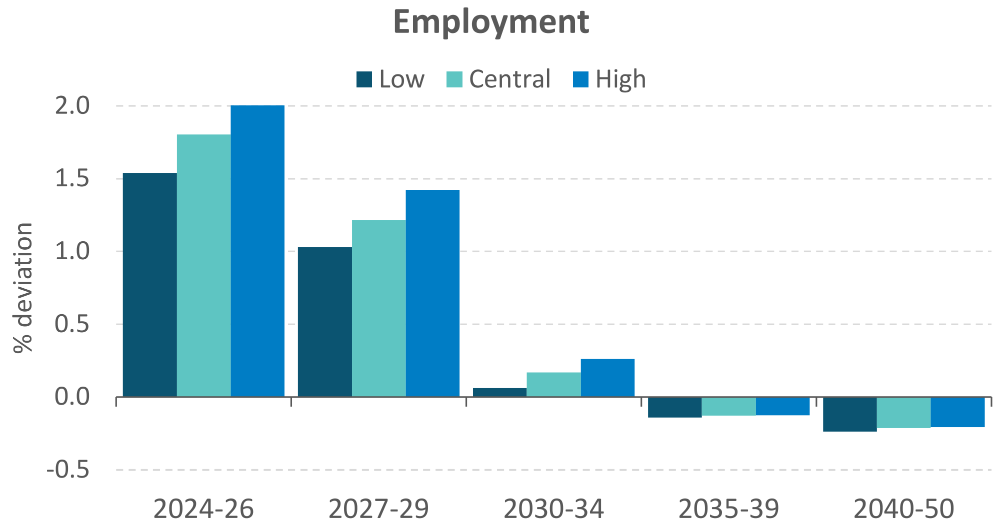


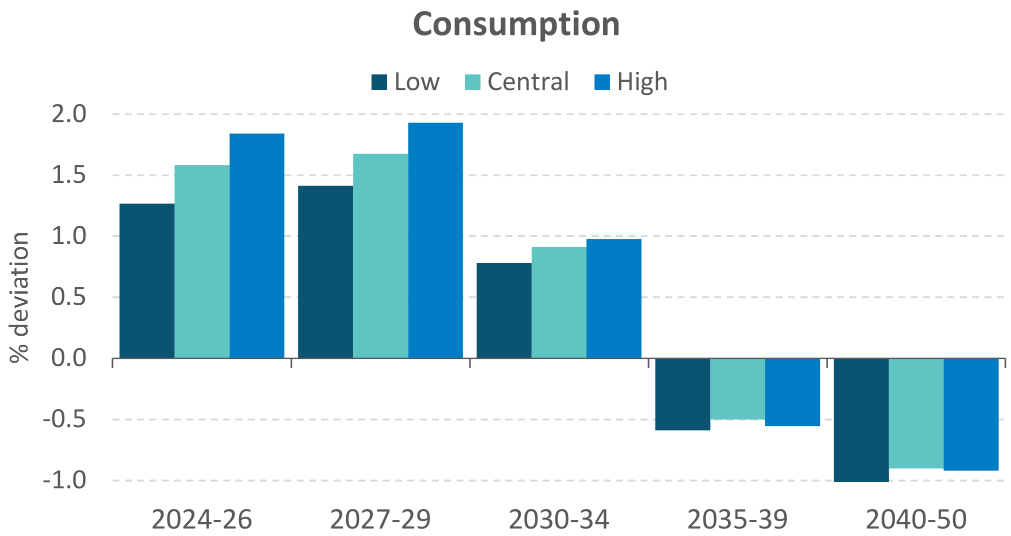


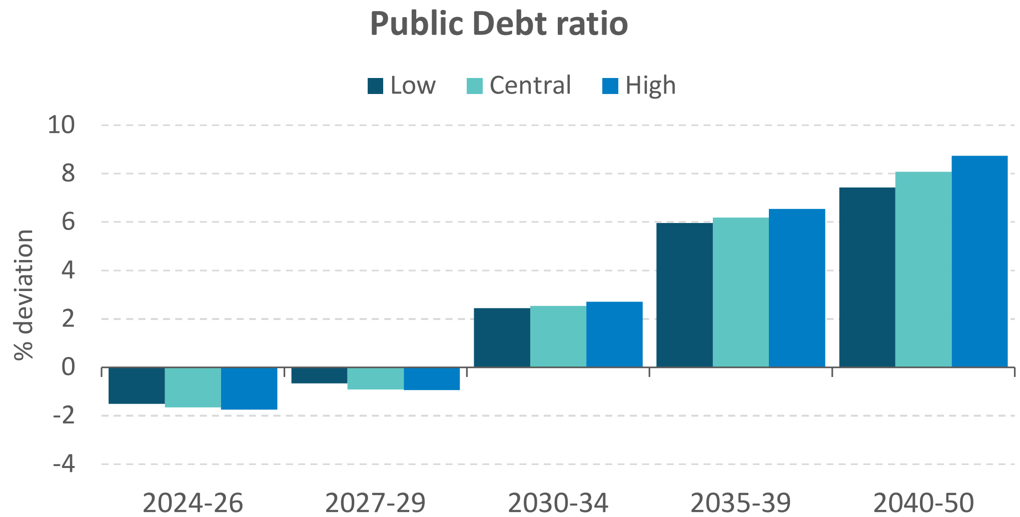


Impact of Investment Shock by Public Share



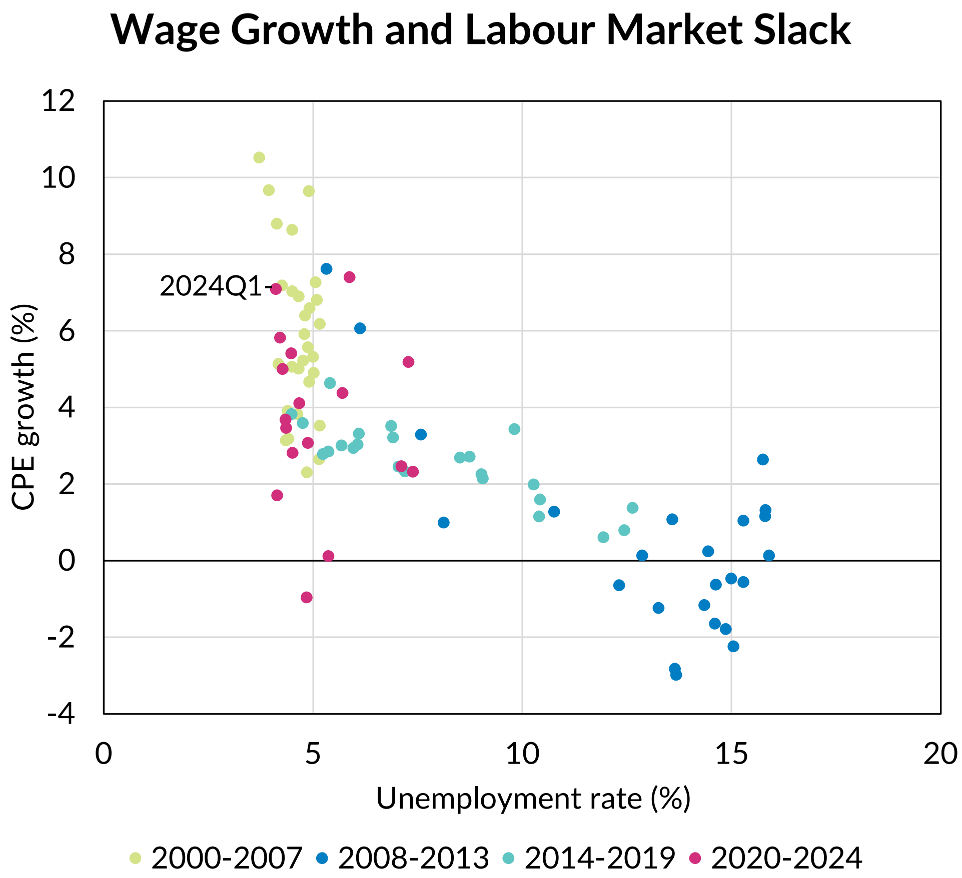






Incorporating Impact of Capacity Constraints

- Irish **labour market** close to full employment for several years
- Additional investment in **capacity-constrained** economy could **crowd-out** other investment
  - Labour shortage particularly acute in **construction** which could absorb workers from other sectors leading to decline in **traded sector** (Morgenroth and FitzGerald, 2006)
  - 24k approx. *additional* construction workers needed for energy investment up to 2030 (Farrell and Lynch, 2024)
  - Exacerbated by demands under *NDP* and *Housing for All*
- Overheating pressures may reduce competitiveness of the economy through adverse **wage-price** dynamics



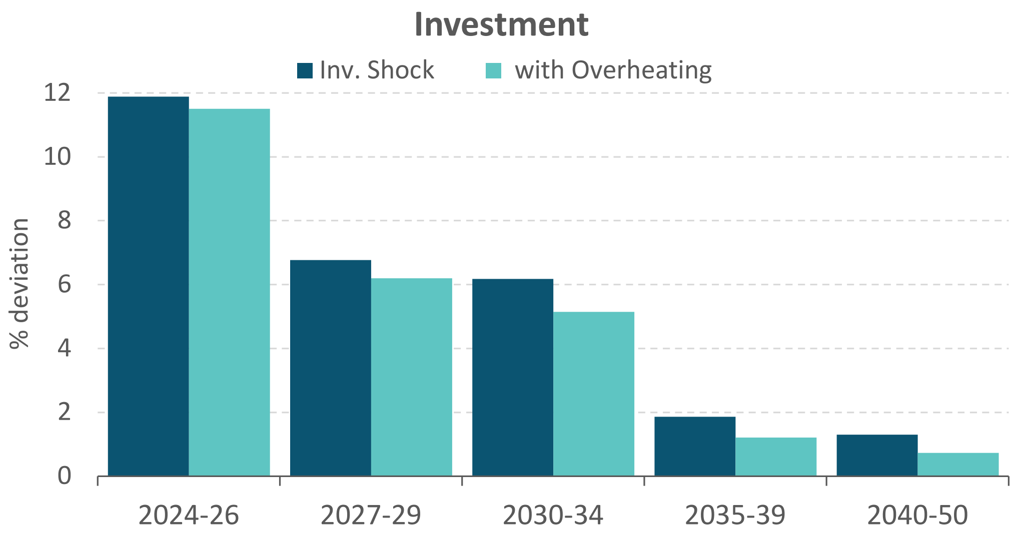
Incorporating Impact of binding Capacity Constraints

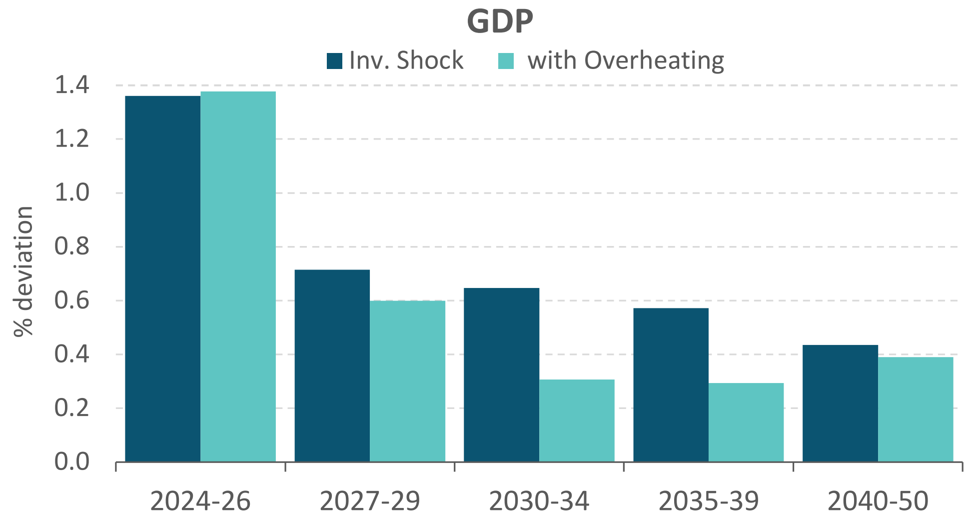
- Need to capture impact of investment stimulus in a **capacity-constrained** economy
- COSMO is essentially **a linear model** and thus does not generally allow ‘state-dependent’ analysis
- Potential solution: incorporate non-linearities in wage- and price-setting through a **‘switch’** in COSMO
- Key parameters of the model change depending on **state** of the economy (output gap) i.e. two ‘regimes’
  - Based on historical episodes when economy has been above potential
- Inflationary impact of additional investment is typically a **short- to medium-term** issue
  - Higher **capital stock** expands **productive capacity** of economy

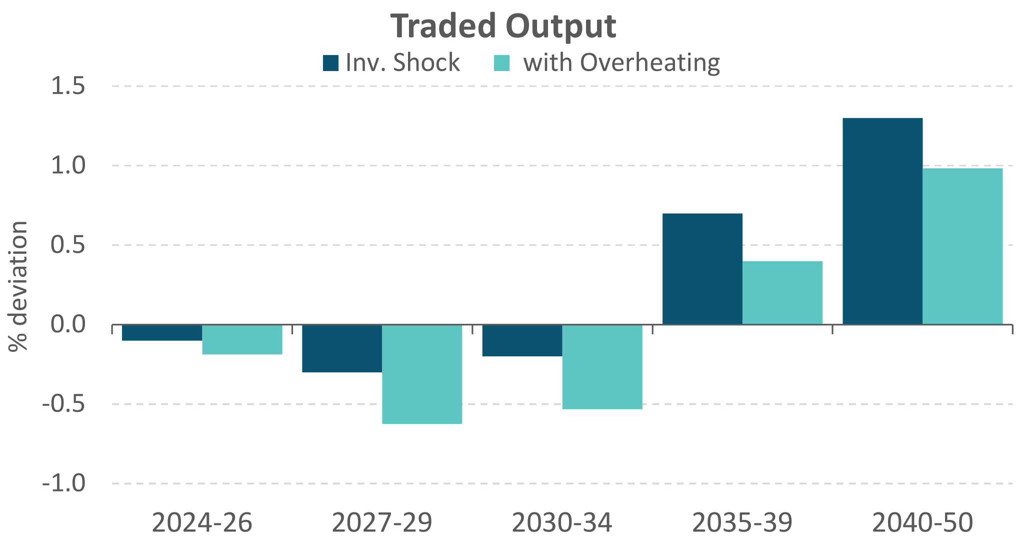
Incorporating ‘Overheating’ Mechanisms

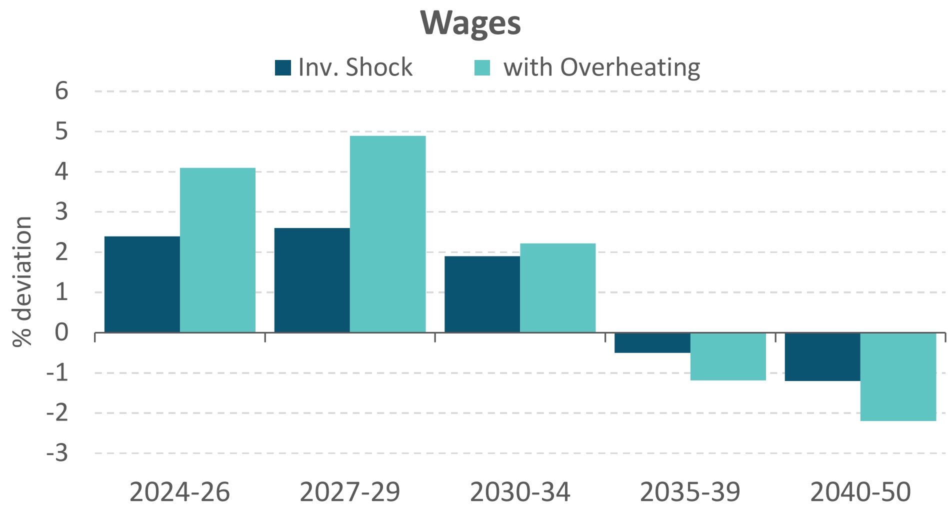
Sector	Equation	Variables	Linear	‘Overheating’
Traded Sector	Wages	**LR:** Labour Productivity, UE Rate **SR:** ΔIncome Tax, ΔCPI, ΔUE Rate	0.13	0.27
	GVA deflator	**LR:** NT Wages, Labour Productivity **SR:** ΔEnergy Prices, ΔWages, YGap	0.54	0.61
Non-Traded	Wages	**LR:** Labour Productivity, UE Rate **SR:** ΔIncome Tax, ΔCPI, ΔUE Rate	0.22	0.36
	GVA deflator	**LR:** NT Wages, Labour Productivity **SR:** ΔEnergy Prices, ΔWages, YGap	0.54	0.75
Construction	Wages	**LR:** Labour Productivity, UE Rate **SR:** ΔIncome Tax, ΔCPI, ΔUE Rate	0.18	0.45
	GVA deflator	**LR:** Construction Wages, Labour Productivity **SR:** ΔEnergy Prices, ΔWages, YGap	0.09	0.21
Household	Consumer Prices	**LR:** Import prices, VAT rate, GDP Deflator **SR:** ΔGDP deflator, YGap	0.06	0.13

Investment with binding capacity constraints

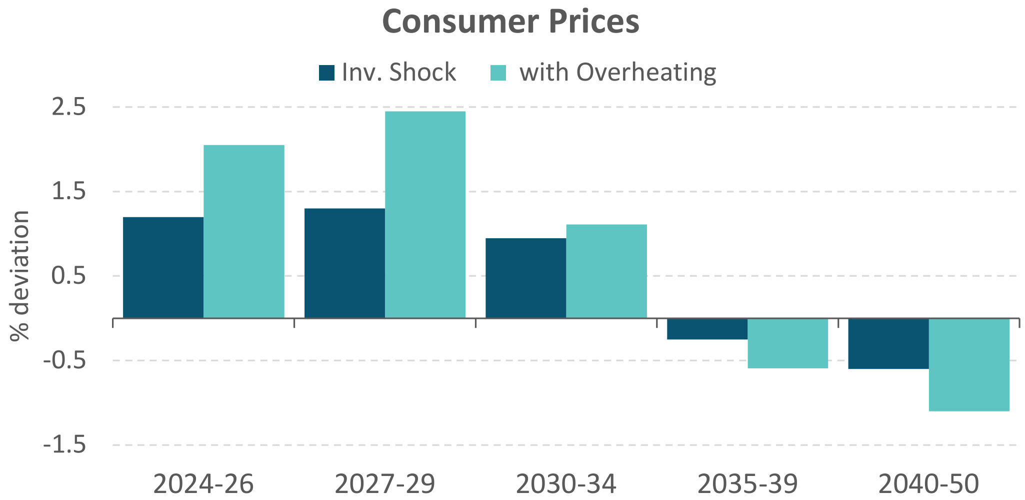


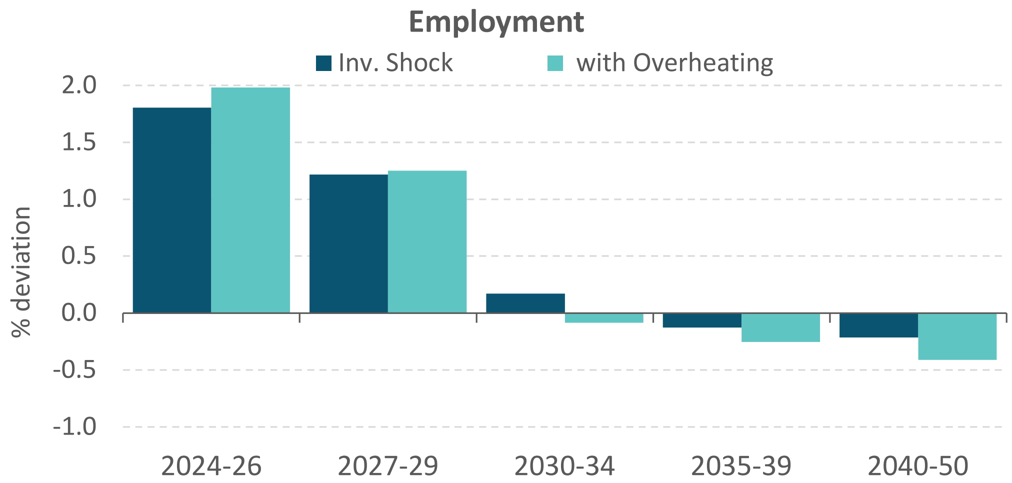


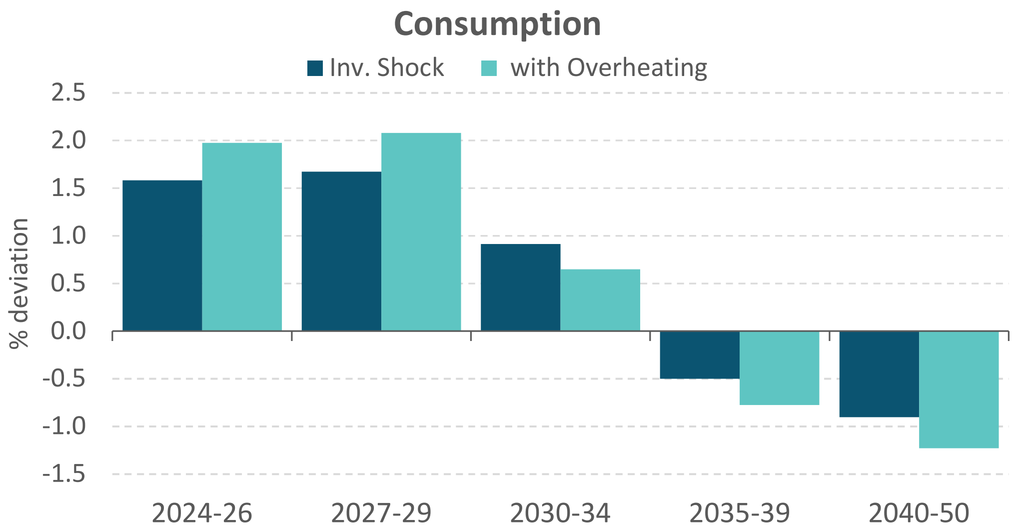


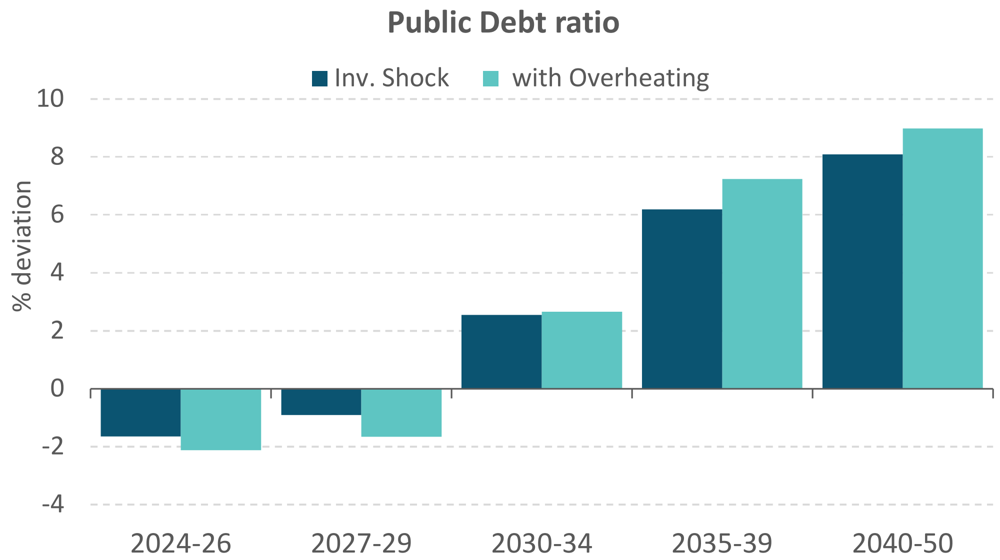


Investment with binding capacity constraints





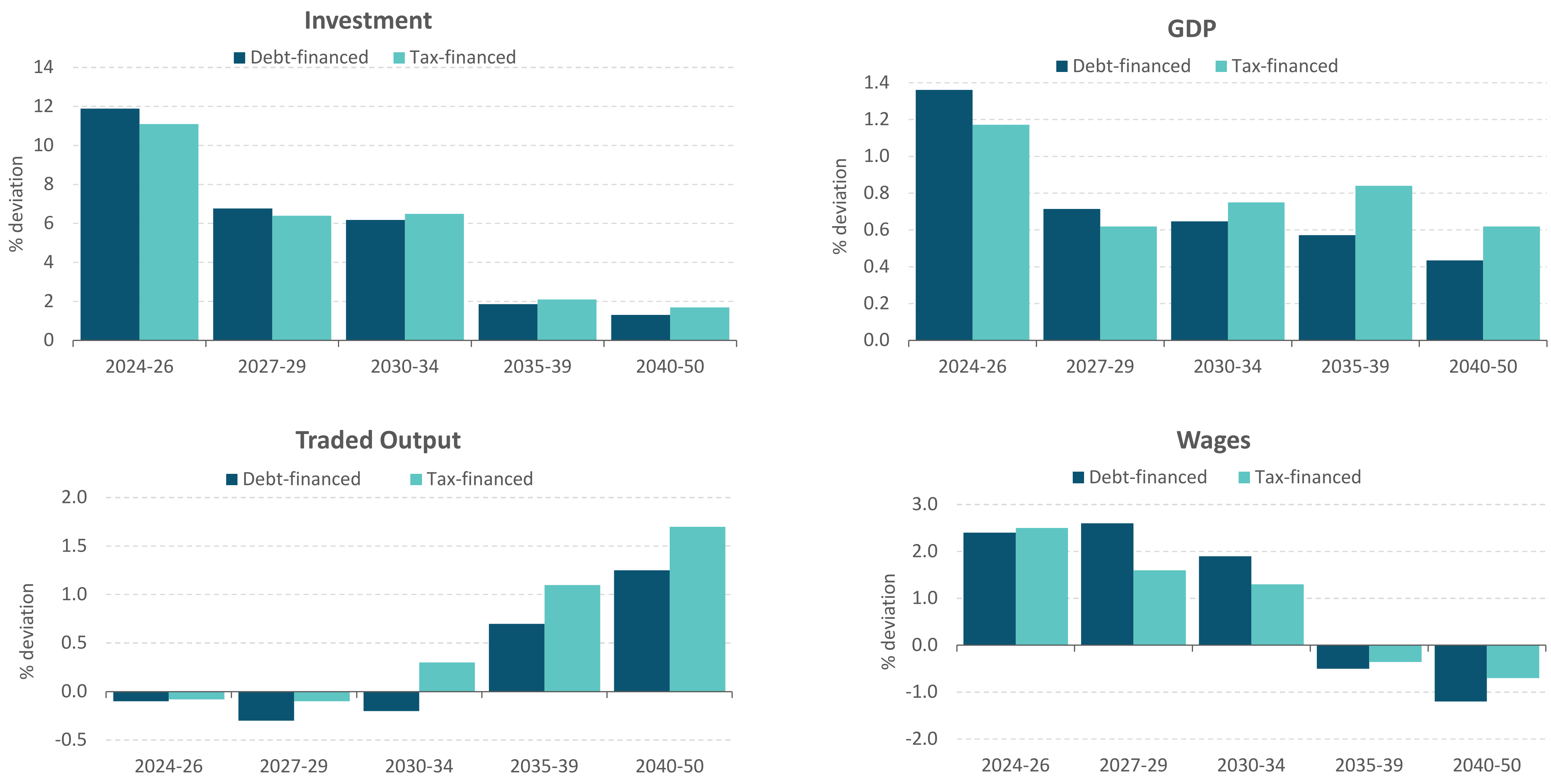




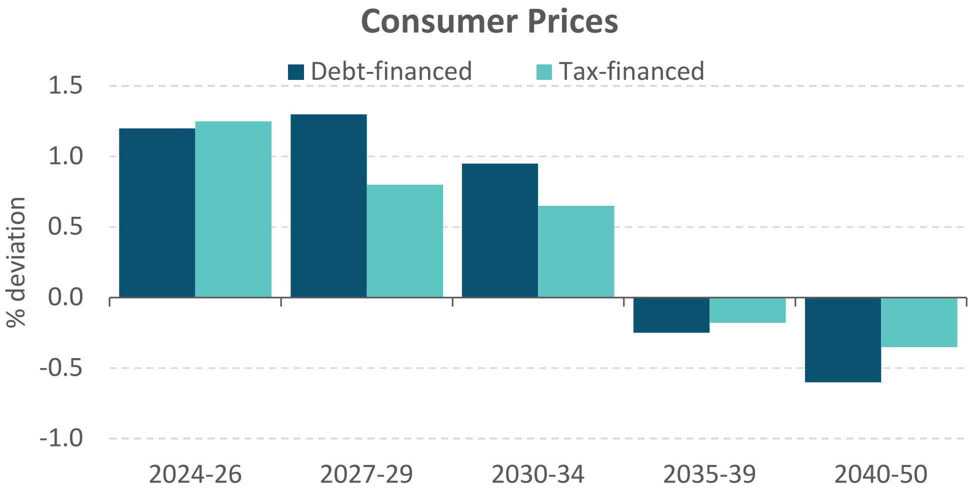
Financing public share of Investment

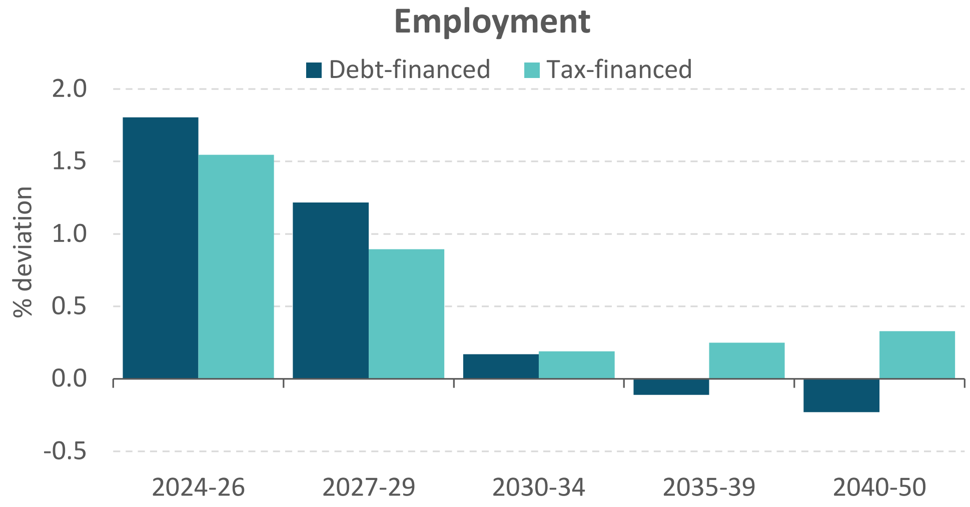
- **Tax** vs **Debt** financing
  - Financing through debt raises issues of intergenerational **equity** (De Mooij and Gaspar, 2023)
  - Exemption of green investment from new **fiscal rules** unlikely so adds to debt
  - Some studies suggest public **debt ratios** could rise by 10-25 percentage pp (OBR, 2023; Pisani-Ferry, 2023)
  - Financing gap may have to be by lower government **consumption** or higher labour/capital **taxes**
- We consider a scenario in which the **public share** of investment is financed through **personal income** taxes
  - In each period, personal **income tax rate** rises to cover additional government investment
  - Scenario highly stylised as raising **distortionary** taxes is a particularly inefficient way of raising financing
  - Capital, labour and indirect taxes will have different effects on output ('multipliers')

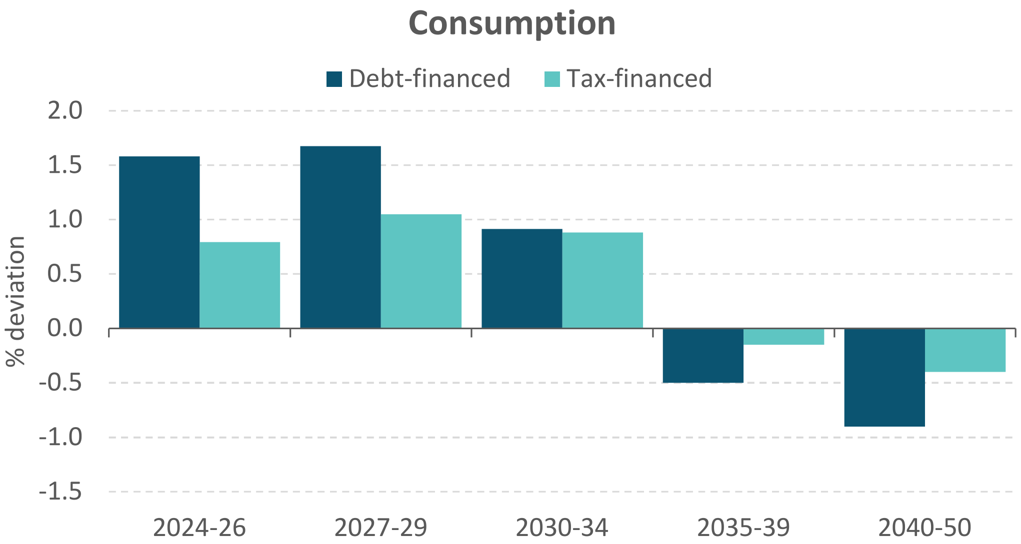
Tax- vs Debt-Financing of Government Component

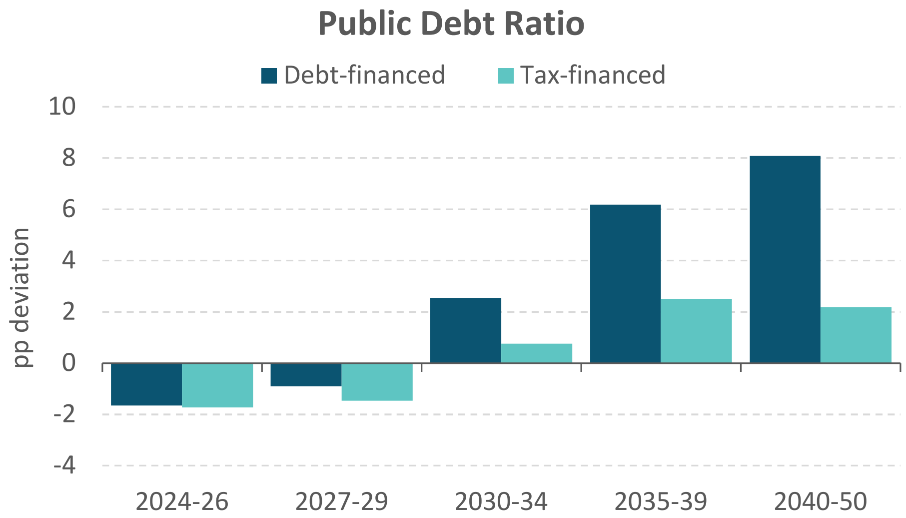


Tax- vs Debt-financing of Government Component



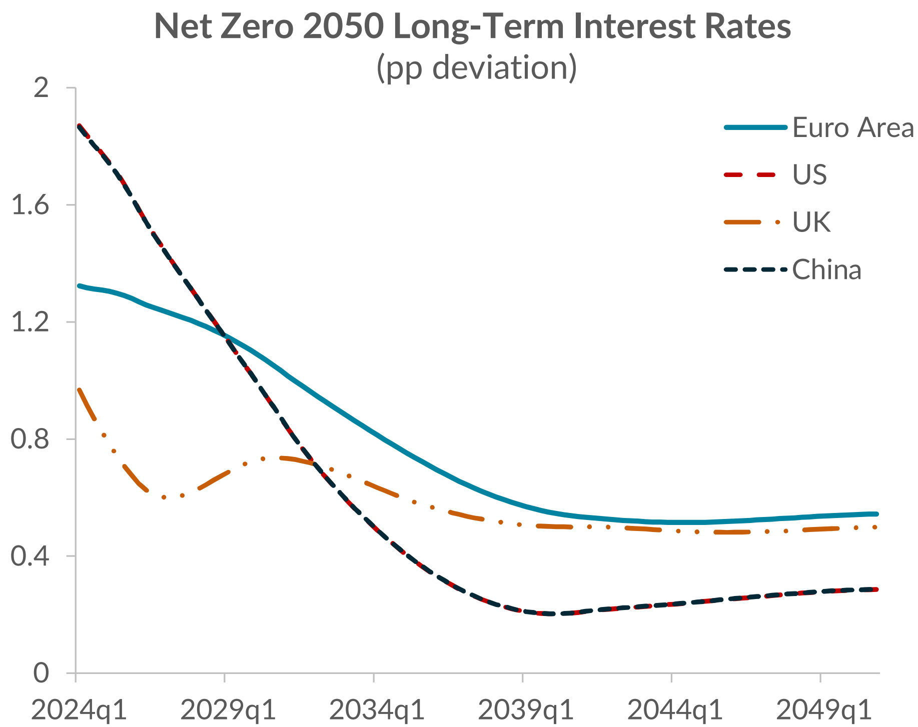






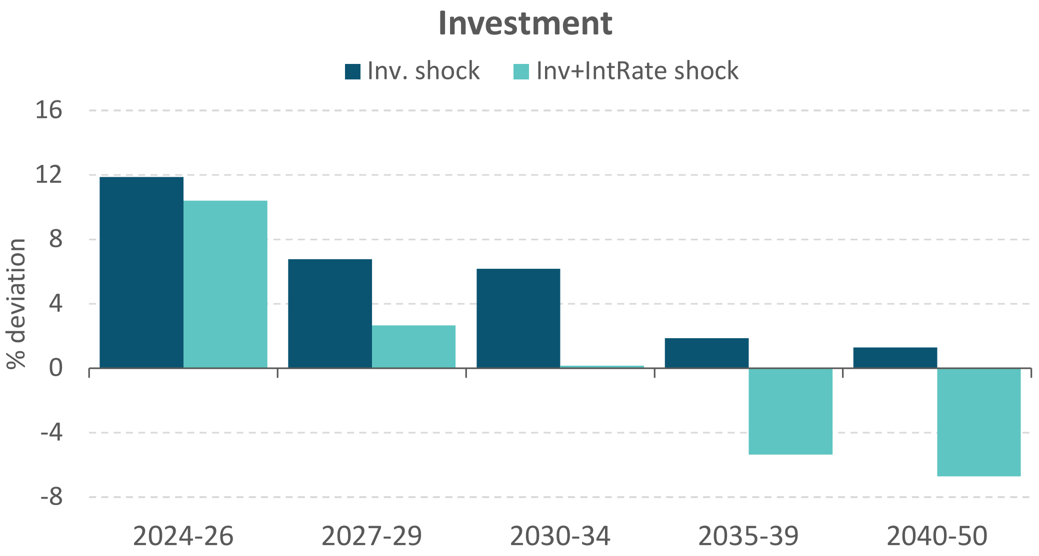
Higher Funding Costs for Public and Private Investment

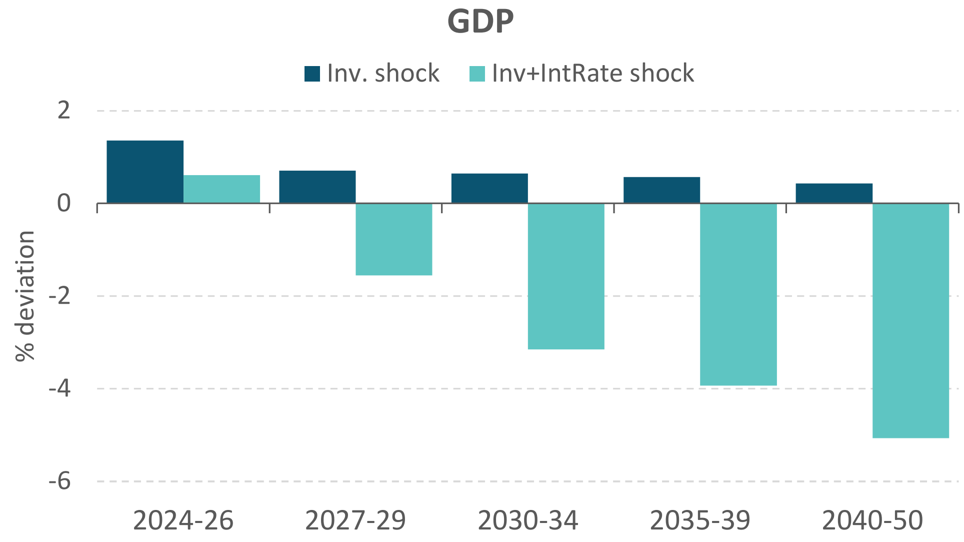
- **International** transition policies could generate significant *spillovers*
  - 'Green' investment requirements of 2-3% GDP (Pisani-Ferry, 2021)
  - Investment could push up **interest rates** if global saving fixed (FitzGerald, 2021)
- First simulate rise in international policy rates in NiGEM consistent with **rise in long rates** under NGFS Net Zero 2050 scenario
  - Impact on external demand for Irish goods, competitor prices, interest rates and equity prices
- Then simulate impact of **investment shock** in COSMO given paths of **external** variables and **domestic** interest rate shocks

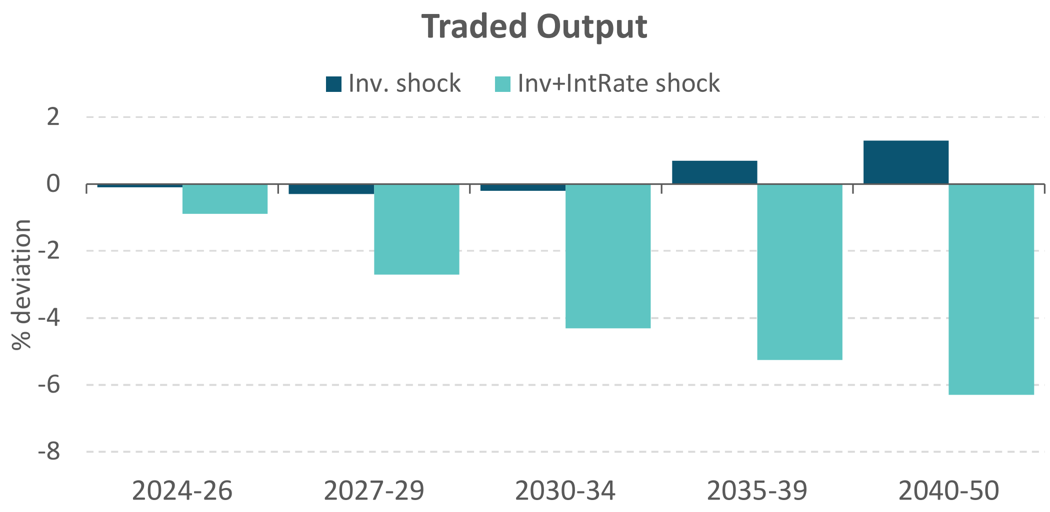


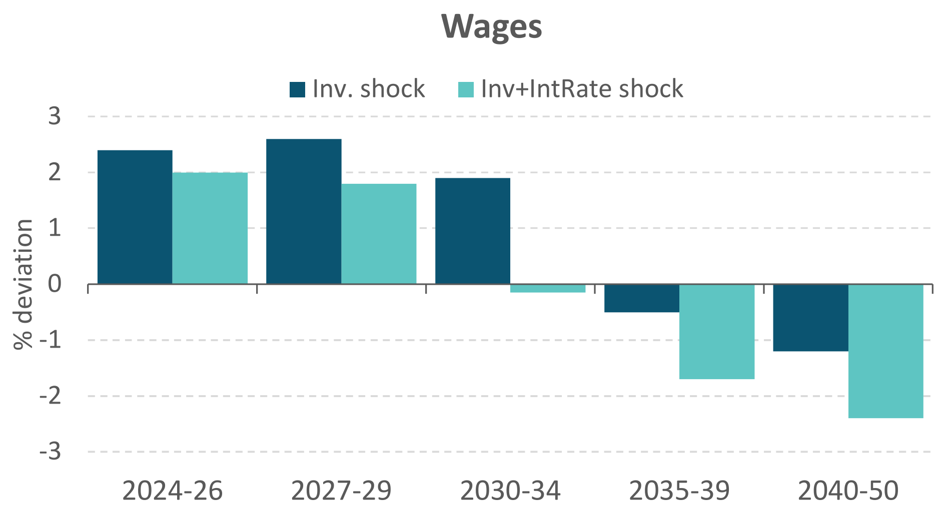
Source: NGFS (2023) and NiGEM model

Investment and Interest Rate Shock

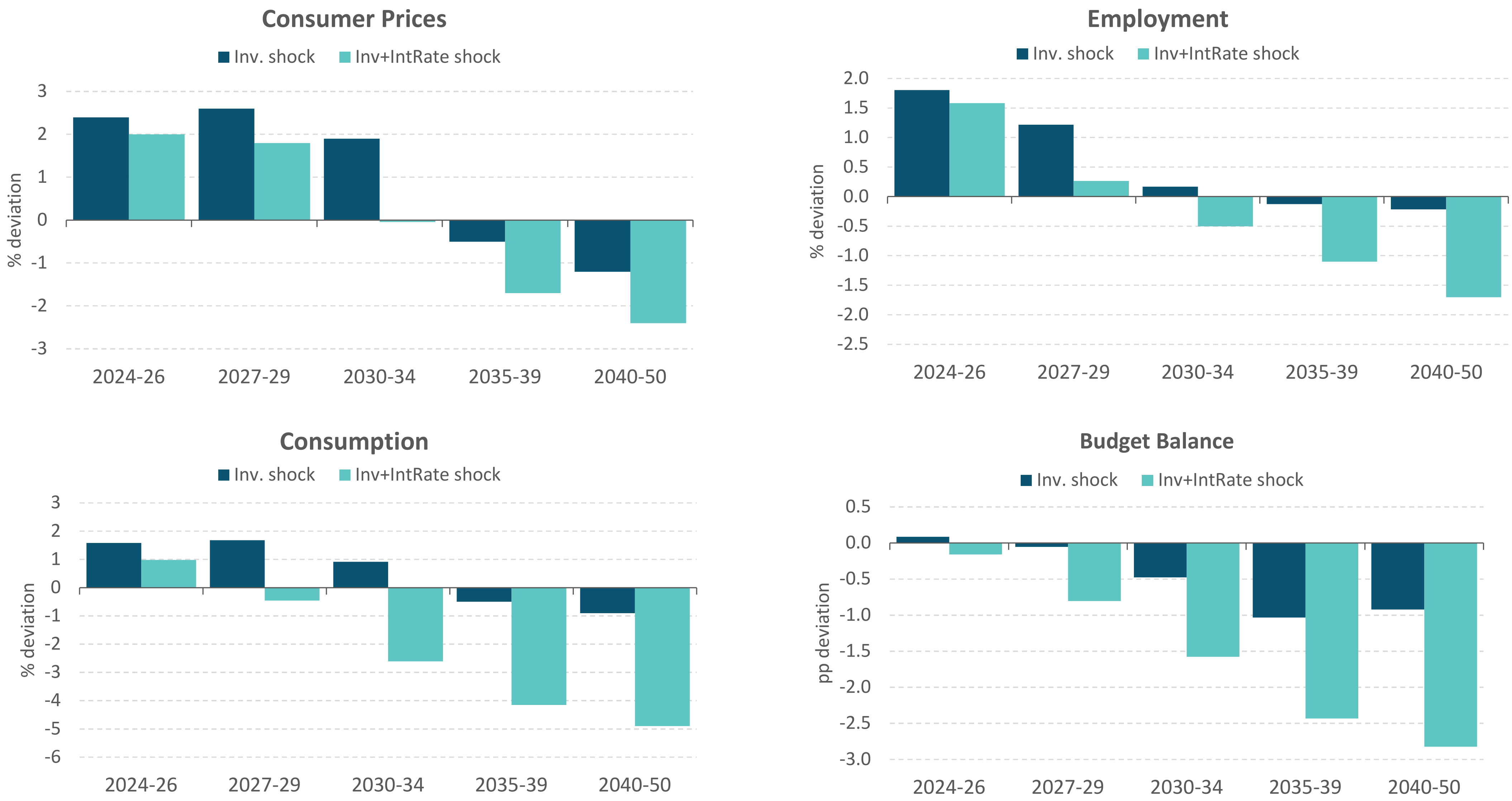








Investment and Interest Rate Shock



Caveats to Simulations

- Analysis is at the **aggregate** level and so cannot provide detail on how shocks transmit through sectors
- Abstract from other transition shocks such as carbon pricing or **investment frictions**
- **Overheating** simulations only consider two 'regimes'
  - Several are possible if wage- and price-setting **non-linear**
  - **Sample size** also relative small to estimate parameters across different regimes
- Impact on public finances focuses **on investment costs** only
  - Expenditure on adaptation (e.g. flood defences) and Just Transition not considered

Expert elicitation on plausible deployment rates of generation technologies in Ireland 2024 – 2040

CARBON BUDGETS WORKING GROUP – 28 JUNE 2024

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Structure of presentation

- Study objectives
- Method
- Results: Expert Pooled Opinion
  - Offshore wind
  - Onshore wind
  - Solar PV
  - Thermal plant utilising green/blue hydrogen or ammonia fuel
  - Carbon capture and storage
- Key messages

Study objectives

Deliverable:

Provide DECC information relevant to "validating critical assumptions that underlie model solutions informing the setting of the 3rd and 4th carbon budgets."

Critical assumptions prioritised:

Availability and deployment rates of onshore wind, offshore wind, solar PV, thermal plant utilising green/blue hydrogen (or ammonia), and power generation with Carbon Capture and Storage (CCS) up to 2040

Working group:

Representation from CRU, ESB Networks, Eirgrid, DECC and SEAI. Prioritized topics of expert elicitation, reviewed method, selected experts, reviewing results.

Method

- Expert elicitation: pooling probability distributions from experts for use in E3 modelling
  - O'Hagan et al. 2006, Durbash et al 2017
- Interviews, in-person and online (1.5 – 2.5hrs), questions and intro brief shared in advance
- Most participants prepared forecasts beforehand, drew on institutional analysis, or followed up with data

Provide a probabilistic forecast of the cumulative installed capacity of [ONW / OFW / SPV] in IRL at 2030, 2035, 2040

1. **Low deployment scenarios**: For [tech X] in [2030, 2035, 2040] what is a plausible ***low*** estimate for cumulative installed capacity (MW) such that *there is only a 5% probability it could be lower? You are almost certain it couldn't be lower.*

2. **Median (best guess) deployment scenario**: For [tech X] in [2030, 2035, 2040], what is a plausible ***median*** estimate for cumulative installed capacity (MW) such that *it is equally likely that the actual value will be higher or lower?*

3. **High deployment scenarios**: For [tech X] in [2030, 2035, 2040] what is a plausible ***high*** estimate for cumulative installed capacity (MW) such that *there is only a 5% probability it could be higher? You are almost certain it couldn't be higher.*

Method

- Expert elicitation: pooling probability distributions from experts for use in E3 modelling
  - O'Hagan et al. 2006, Durbash et al 2017
- Interviews, in-person and online (1.5 – 2.5hrs), questions and intro brief shared in advance
- Most participants prepared forecasts beforehand, drew on institutional analysis, or followed up with data

Identify the conditions that are associated with the *low* and *high* deployment of [ONW / OFW / SPV]
QUESTIONS (in general form): 1. What conditions drive or constrain the deployment of [tech X] up to 2030, 2035, and 2040 in a [low / high] scenario? 2. What are the assumptions that underpin a low and high deployment scenario?
OUTPUT: Qualitative data on conditions that cause lowest plausible or highest plausible technology deployment rates

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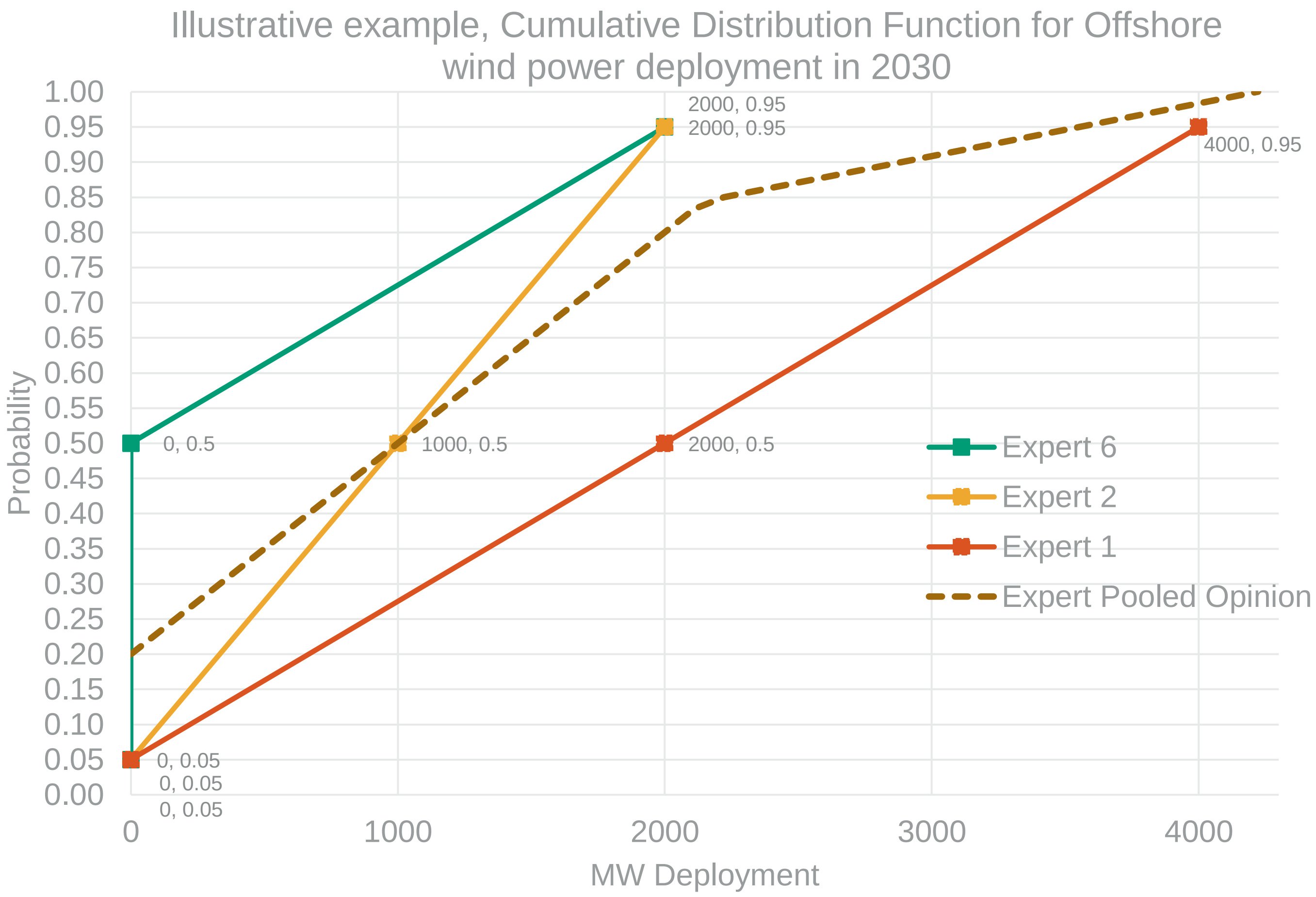
Method

- Create a linear Cumulative Distribution Function (CDF) for each expert from 3 forecast data points for each of 2030, 2035, 2040
- Expert pooled opinion ('wisdom of the crowd') = weighted average of individual CDFs
- Each expert's forecast is weighted equally
- Approach: O'Hagan et al (2006)



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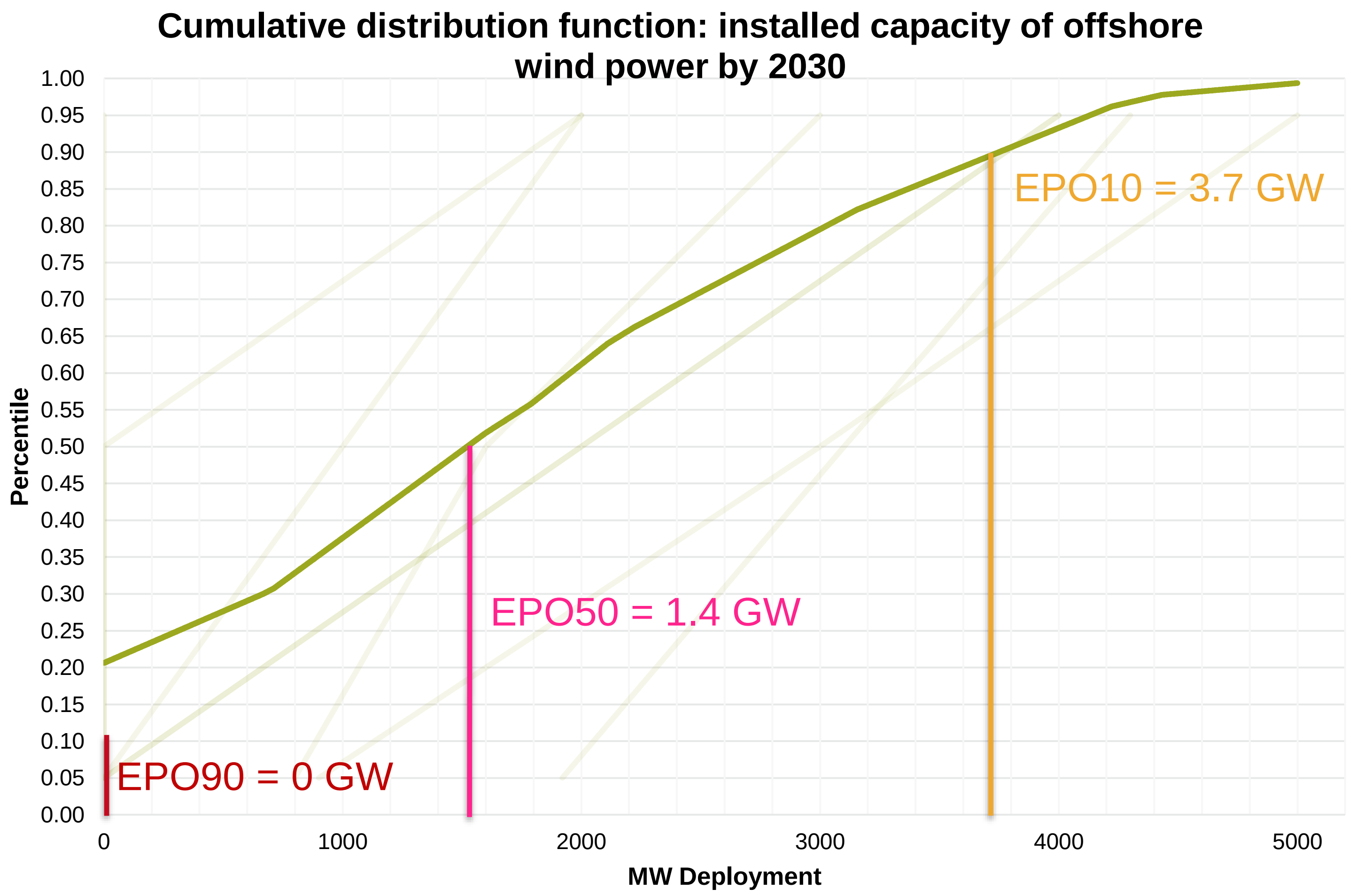
Method

- From expert pooled opinion, draw three forecasts to capture a plausible or credible interval

Forecast	Description
EPO90 (9 in 10 chance)	CDF of expert pooled opinion @ p = 0.1 *The lowest plausible bound for future deployment that captures the idea of being 'certain' or 'almost certain' that deployment would in fact be higher. Anything below this could be considered unbelievable, far-fetched, or unimaginable.*
EPO50 (1 in 2 chance)	CDF of expert pooled opinion @ p = 0.5 *A median or 'best estimate' deployment scenario*
EPO10 (1 in 10 chance)	CDF of expert pooled opinion @ p = 0.9 *The highest plausible bound for future deployment that captures the idea of a very unlikely but not impossible rate of deployment. Anything above this could be considered unbelievable, far-fetched, or unimaginable.*

Method

- Example of drawing EPO forecasts from pooled CDF:

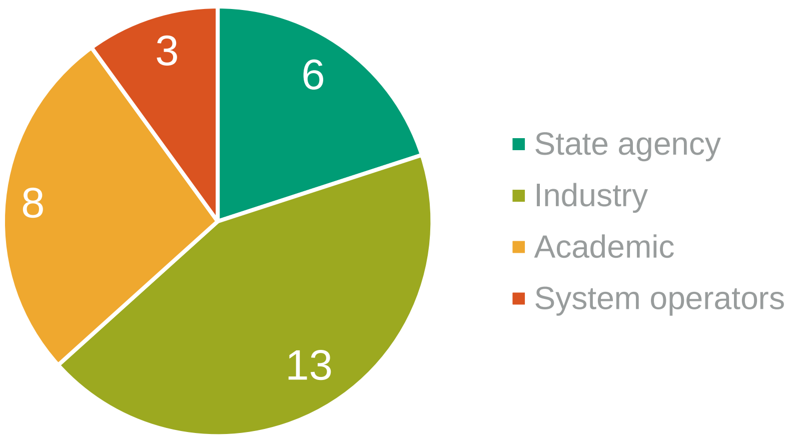


Method

- Participants nominated by study Working Group (DECC, CRU, TSO, DSO, SEAI)
- Highly regarded experts with deep knowledge of Irish power sector
- Interviews were confidential and not representative of institutional positions
- In some interviews, more than one individual contributed to a single forecast (group counted as 'one expert')
- 'Industry' includes wind and solar associations, generators (thermal, wind and solar), grid development and connection, and engineering, economic and legal services

	Organisation	OFW	ONW	SPV		Organisation	H2/NH3	CCS
Expert 1	State agency	Y	Y	Y	Expert 16	Industry	Y	N
Expert 2	Industry	Y	Y	Y	Expert 17	Academic	Y	N
Expert 3	Academic	Y	Y	N	Expert 18	Academic	Y	N
Expert 4	Industry	N	N	Y	Expert 19	Industry	Y	N
Expert 5	State agency	Y	N	N	Expert 20	Academic	Y	Y
Expert 6	Academic	Y	N	N	Expert 21	State Agency	Y	N
Expert 7	Industry	N	Y	Y	Expert 22	Industry	Y	N
Expert 8	Academic	Y	Y	Y	Expert 23	Academic	(Y)	(Y)
Expert 9	Industry	Y	Y	N	Expert 24	Industry	Y	Y
Expert 10	System Operator	N	Y	Y	Expert 25	Industry	Y	Y
Expert 11	State agency	Y	N	N	Expert 26	System Operator	Y	Y
Expert 12	Industry	N	Y	N	Expert 27	Academic	N	Y
Expert 13	State agency	N	Y	Y	Expert 28	State Agency	(Y)	(Y)
Expert 14	Industry	Y	Y	Y	Expert 29	Industry	Y	N
Expert 15	System Operator	(Y)	(Y)	(Y)	Expert 30	Industry	Y	Y
		9 (10)	10 (11)	8 (9)			12 (14)	6 (8)

Sectorial breakdown of participants



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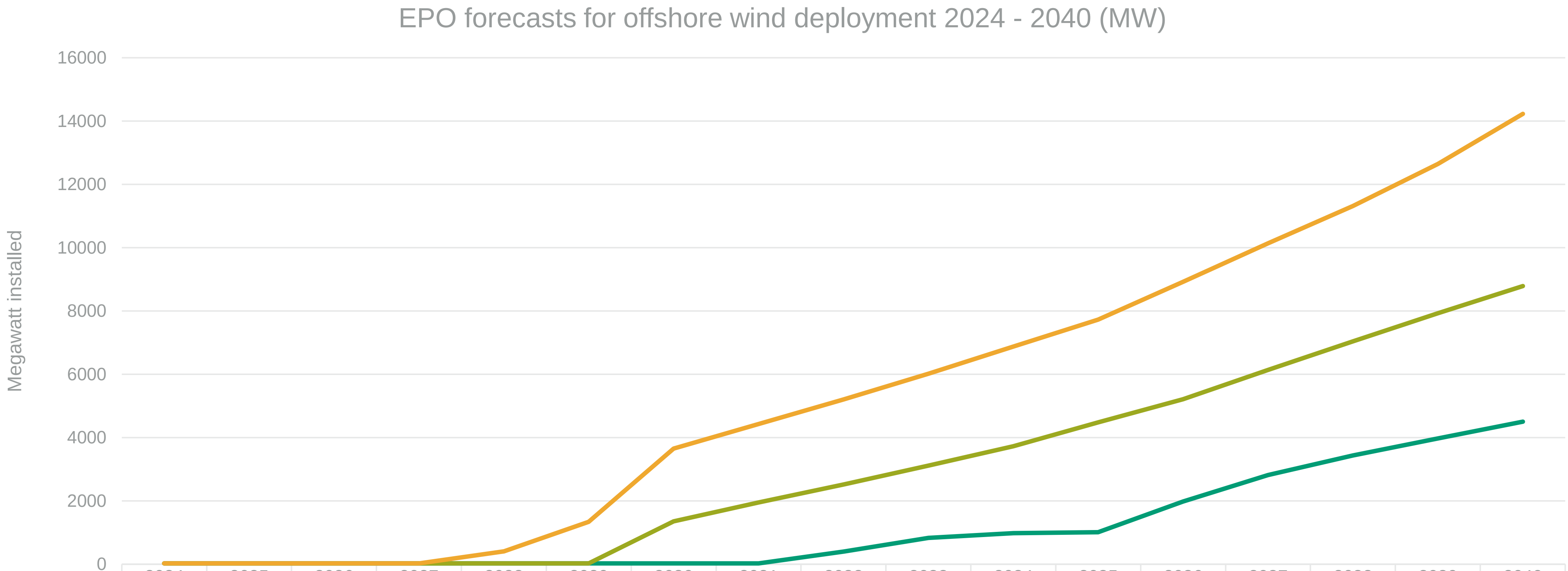
Results: Expert Pooled Opinion 2024 - 2040



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
EPO90	25	25	25	25	25	25	25	25	400	834	980	1008	1978	2815	3433	3977	4500
EPO50	25	25	25	25	25	25	1354	1952	2516	3118	3727	4481	5215	6140	7039	7928	8790
EPO10	25	25	25	25	407	1338	3654	4428	5204	6020	6873	7730	8922	10142	11318	12648	14226

EPO90 EPO50 EPO10

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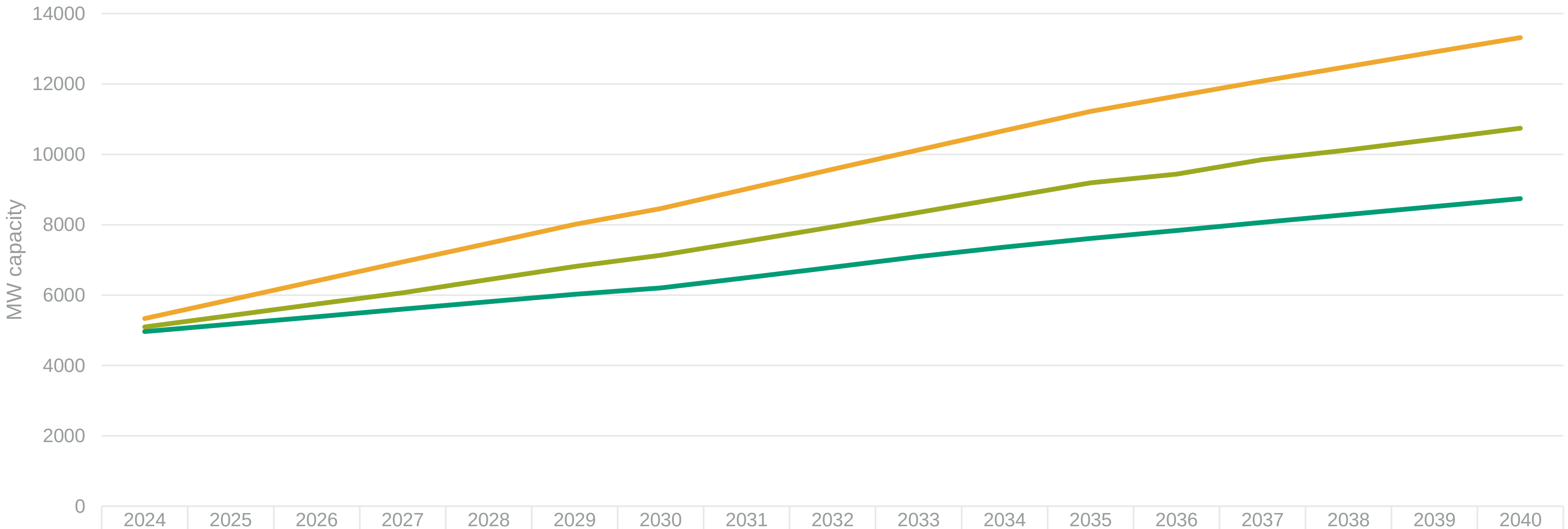
Results: Expert Pooled Opinion 2024 - 2040

EPO forecasts for onshore wind deployment 2024 - 2040 (MW)

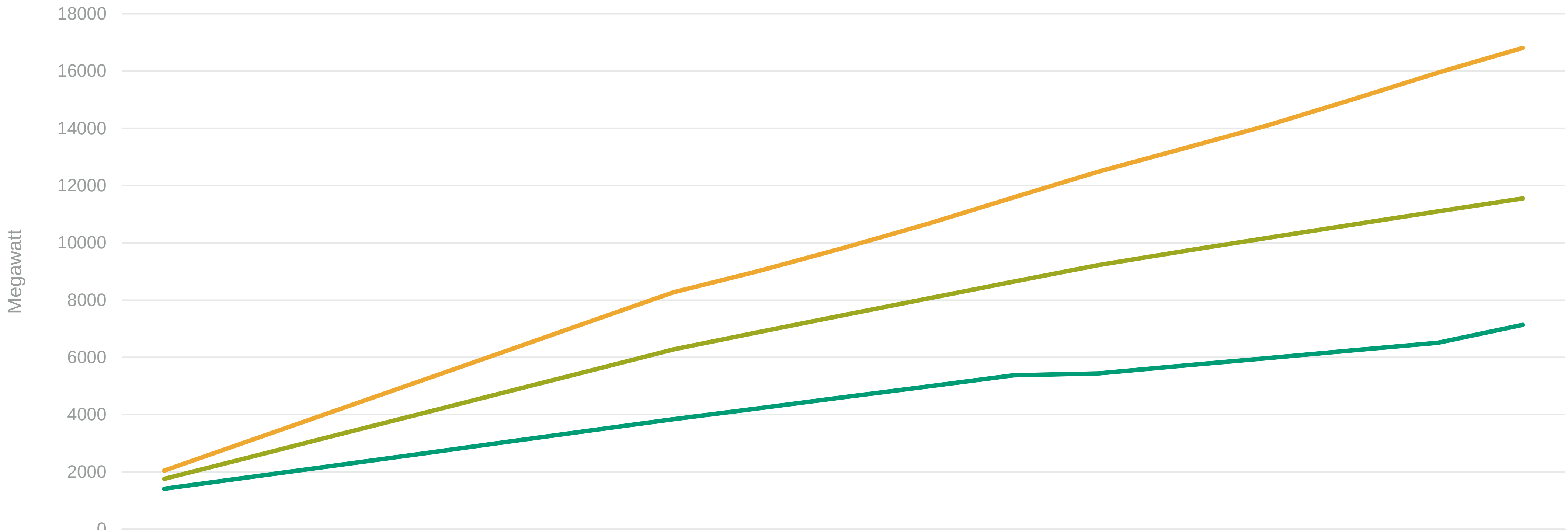


	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
ONW EPO90	4961	5174	5386	5599	5811	6023	6201	6492	6790	7098	7361	7612	7836	8065	8293	8518	8741
ONW EPO50	5093	5418	5744	6068	6441	6811	7130	7533	7939	8350	8770	9189	9437	9849	10127	10435	10743
ONW EPO10	5336	5870	6406	6941	7472	8010	8456	9021	9579	10130	10677	11220	11656	12082	12501	12913	13321

ONW EPO90 ONW EPO50 ONW EPO10

Results: Expert Pooled Opinion 2024 - 2040

EPO forecasts for solar PV deployment 2024 - 2040 (MW)



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
EPO90	1405	1811	2217	2622	3028	3433	3839	4221	4602	4984	5369	5439	5706	5974	6241	6508	7132
EPO50	1754	2507	3261	4014	4768	5521	6279	6883	7476	8061	8639	9222	9703	10175	10641	11099	11551
EPO10	2039	3078	4117	5156	6195	7234	8273	9010	9825	10667	11581	12487	13288	14103	15010	15942	16813

EPO90 EPO50 EPO10

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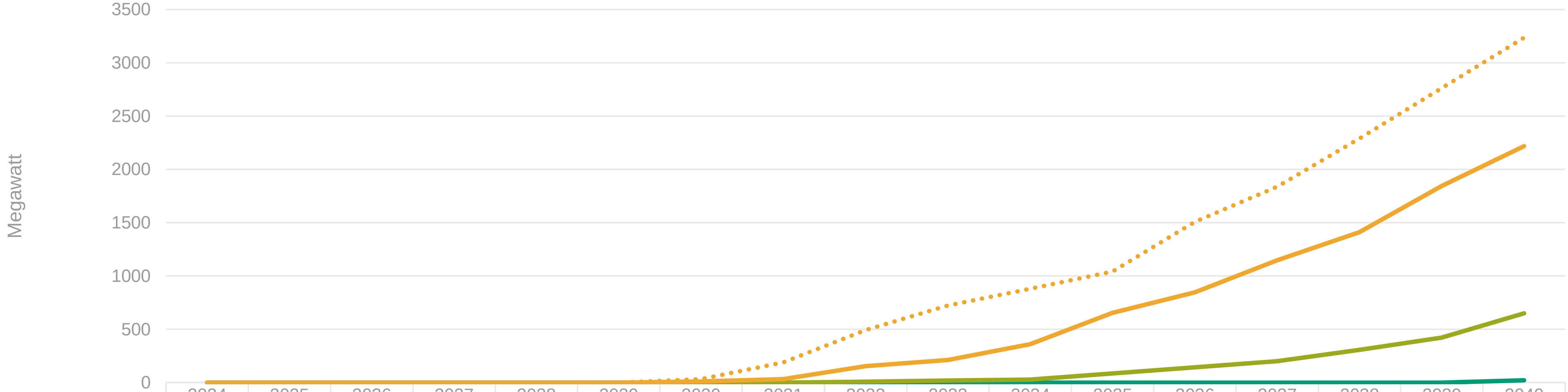
Results: Expert Pooled Opinion 2024 - 2040

EPO forecasts for thermal plant combusting 100% green/blue hydrogen or ammonia 2024 - 2040 (MW)



	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
EPO90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
EPO50	0	0	0	0	0	0	0	0	9	20	28	86	144	201	307	423	651
EPO10-adj	0	0	0	0	0	0	12	32	154	213	361	655	846	1148	1412	1845	2219
EPO10	0	0	0	0	0	0	34	190	493	722	881	1041	1509	1837	2288	2762	3236

EPO90 EPO50 EPO10-adj EPO10

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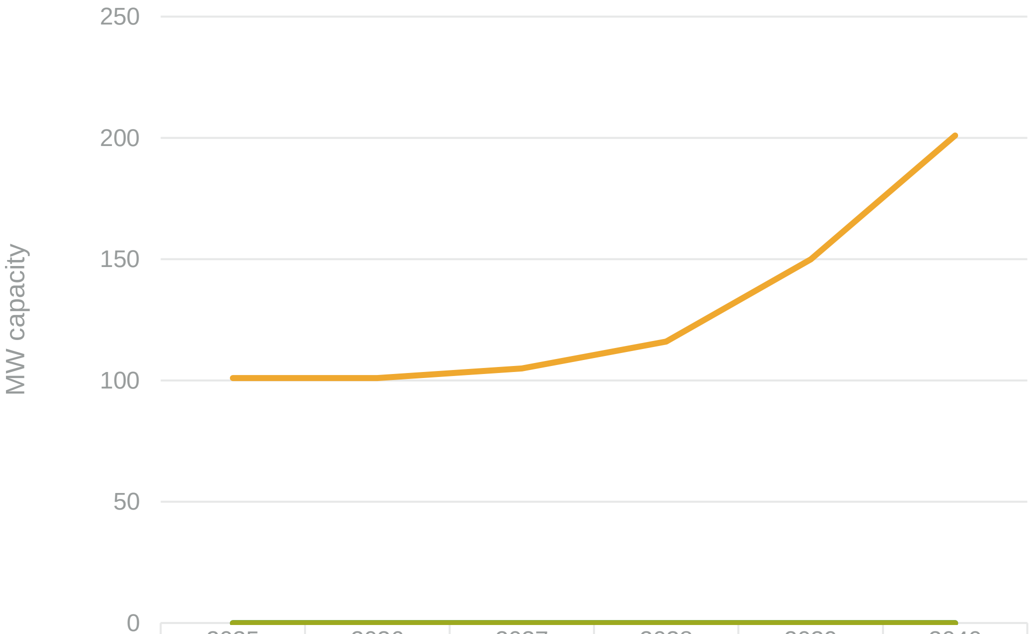
Results: Expert Pooled Opinion 2024 - 2040

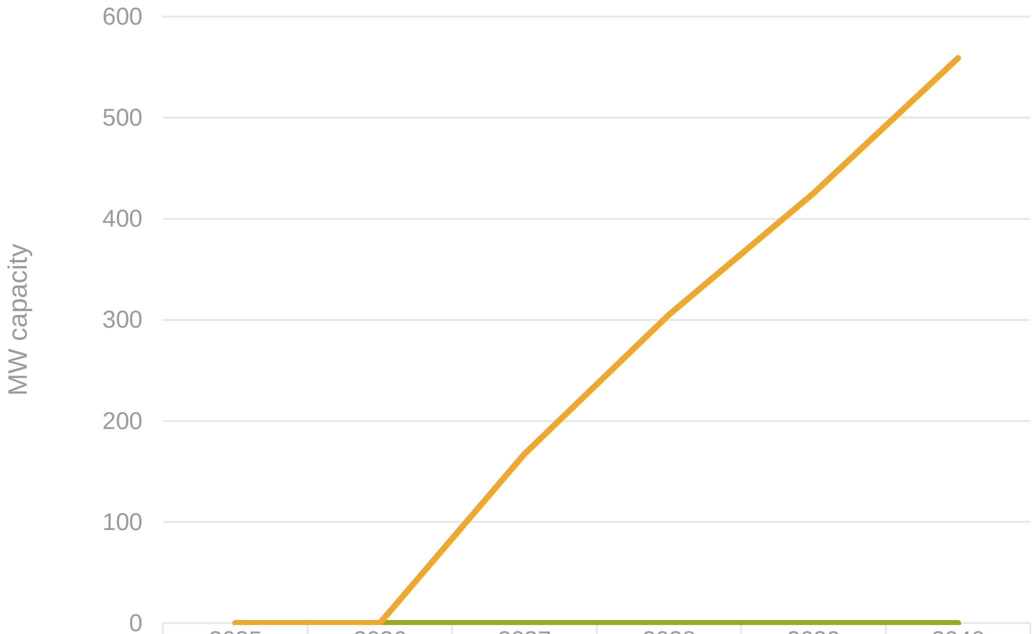
EPO forecasts for bio-energy and waste-to-energy plant with CCS 2024 - 2040 (MW)



	2035	2036	2037	2038	2039	2040
EPO90	0	0	0	0	0	0
EPO50	0	0	0	0	0	0
EPO10	101	101	105	116	150	201

EPO90 EPO50 EPO10

EPO forecasts for thermal gas power plant with CCS 2024 - 2040 (MW)



	2035	2036	2037	2038	2039	2040
EPO90	0	0	0	0	0	0
EPO50	0	0	0	0	0	0
EPO10	0	0	167	305	425	559

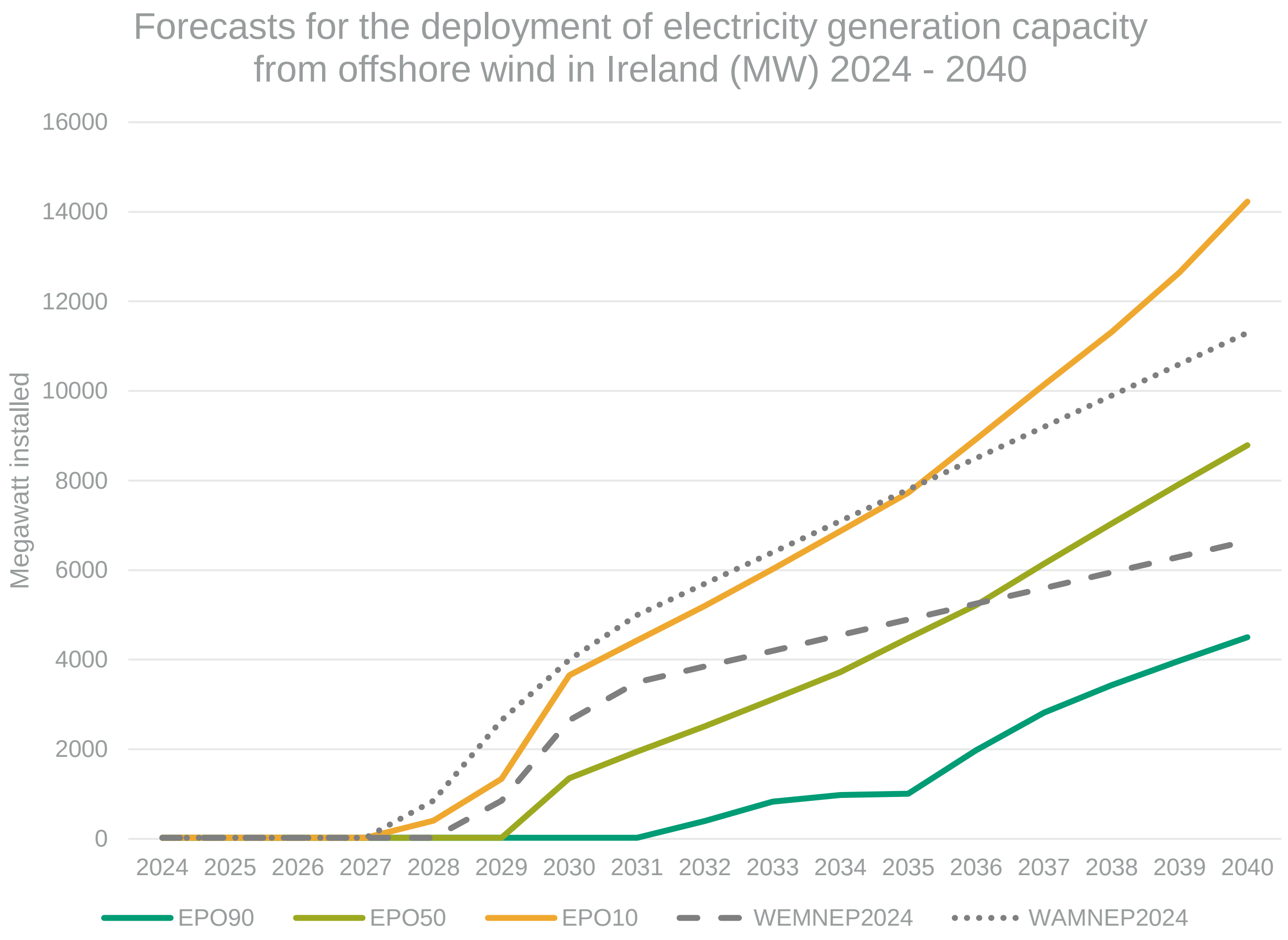
EPO90 EPO50 EPO10

SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Key messages

1. The pooled best guess is that about 0.7 GW of thermal power generation capacity could switch to an equivalent of 100% green/blue hydrogen or ammonia between 2035 – 2040. It is plausible that between 0.02 GW and 2.2 GW of thermal dispatchable power capacity could switch to green/blue hydrogen by 2040.
2. Almost all participants agree that dependence on fuel switching to hydrogen is a high-risk strategy for power sector decarbonisation before 2040, dependent on immature technologies, delivering at least one mega-infrastructure project (such as geological storage or a dedicated hydrogen network), and political willingness to subsidize the aforementioned at significant cost to electricity consumers.
3. The pooled best guess is that no CCS will be deployed in the power sector before 2040. It is plausible (but unlikely) that 0.2 GW of BECCS and WtE-CCS (2035 – 2040), and 0.6 GW of gas-CCS (2037 – 2040) could be deployed.

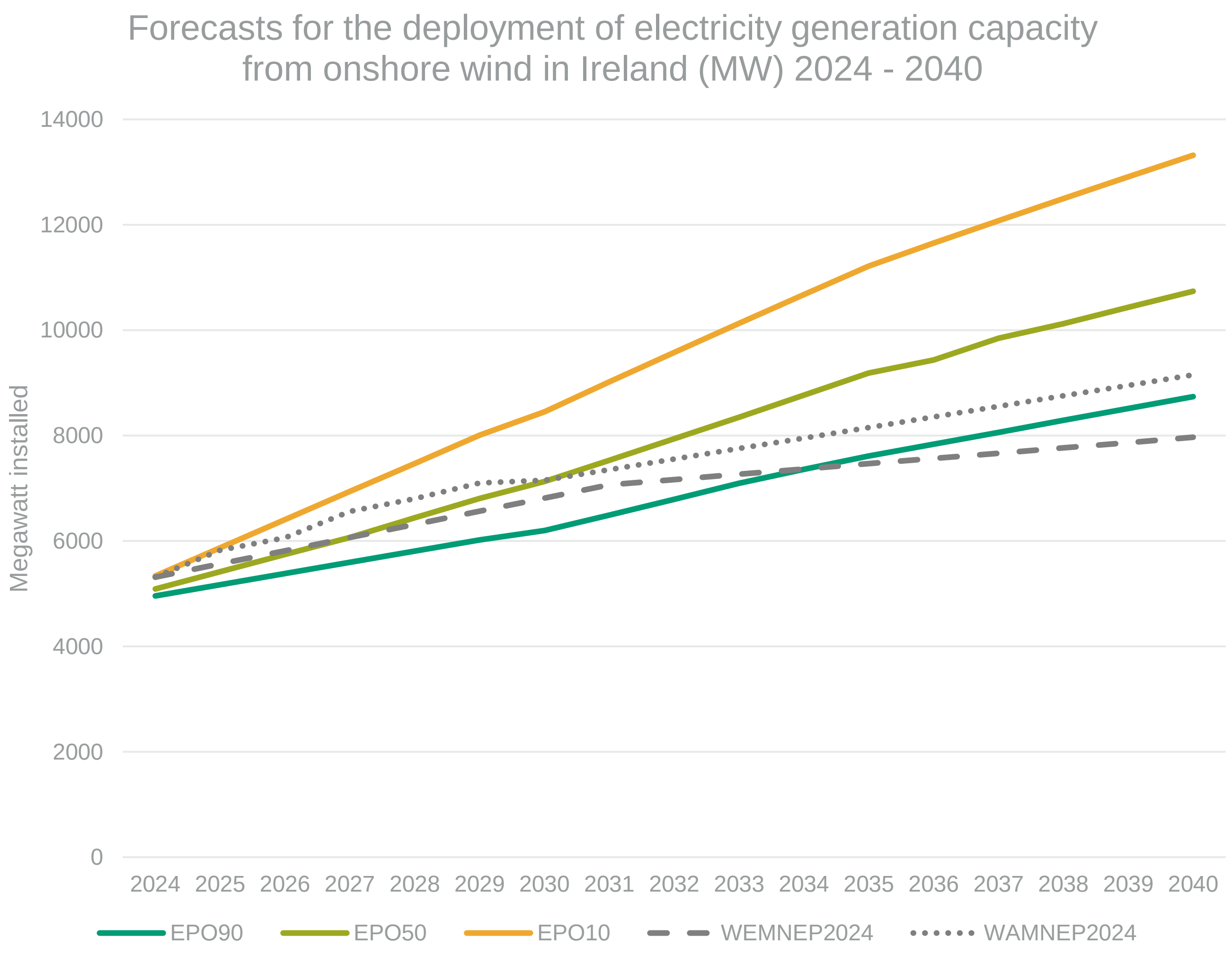
Key messages



For offshore wind:

- It is plausible that between zero and 3.7 GW will be installed by 2030, with a pooled best guess of 1.4 GW.
- Attaining the 5 GW target in 2030 (CAP24) is not deemed plausible
- The WAM policy assumption (4 GW by 2030) is at risk of being implausible
- Attainment of the WEM policy assumption (2.7 GW by 2030) is plausible but unlikely.

Key messages:



For onshore wind:

- It is plausible that between 6.2 and 8.5 GW of onshore wind capacity will be installed by 2030.
- Attaining the CAP24 target (9 GW) is not deemed implausible.
- The WEM (6.8 GW) and WAM (7.2 GW) policy scenario assumptions broadly align with the pooled median forecast of 7.1 GW for 2030.

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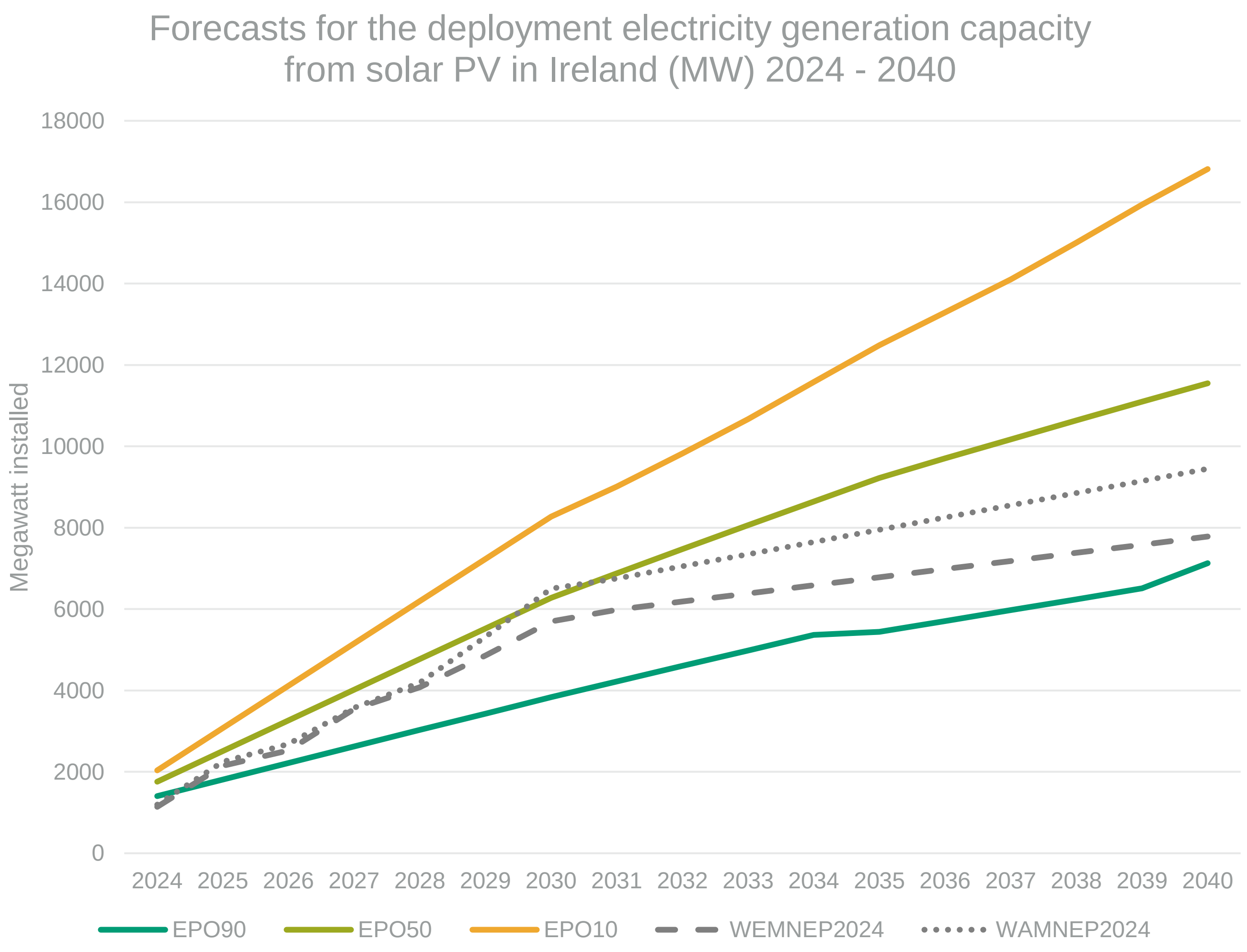
Key messages



For solar PV:

- It is plausible that between 3.8 GW and 8.3 GW will be installed by 2030
- It is plausible (but unlikely) that the 8 GW target (CAP24) can be attained in 2030.
- It is more likely than not that the WEM policy scenario forecast (5.7 GW) will be achieved in 2030
- The WAM policy assumption (6.5 GW) broadly aligns with the pooled median forecast of 6.3 GW for 2030.

Key messages

- Difference in GW between EPO50 forecasts (pooled ‘best guess’) Climate Action Plan 2023 (CAP23) targets and WEM and WAM policy scenarios.

	OFW	ONW	SPV
CAP23	-3.6	-1.9	-1.7
WAM	-2.6	0.0	-0.2
WEM	-1.3	0.3	0.6

- Negative figure indicates that EPO50 is less than target/ scenario
- WEM and WAM are policy scenarios used by the EPA and SEAI for European reporting and broadly align with 70% RES-E and 80% RES-E respectively.

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Key messages

1. Least-cost, ‘technically feasible’ scenarios exclude critical conditions for constraining technology deployment, e.g. planning system, labour market, and international supply chains
2. The expert elicitation internalises a larger set of risks that may constrain solution space, offering a more accurate and probabilistic account of *plausible* and *likely* solutions.
3. If implausible rates of technology deployment (or any other form of optimism bias) are assumed in models, the true requirement to decarbonise other areas is missed.
4. We recommend a comparison between current carbon budget solutions and the results of the expert elicitation to quantify the gap between what is required by (or proposed for) budgets and what is deemed plausible or likely.
5. Alternative pathways to power sector decarbonisation ought to be considered. It is very unlikely that the current set of power generation solutions (variable renewables, green/blue hydrogen/ammonia, and carbon capture and storage) will deliver the desired emissions reductions by 2040. A more comprehensive assessment of technology and policy options is merited; both in power generation and the increasingly coupled electrified heat and transport systems.
6. Secondary iterations of decarbonisation modelling should incorporate feedback or constraints from sector-specific, muti-faceted feasibility assessments of technologies that account for (amongst other things) availability, costs, and performance-related risks of immature technologies.

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Any questions?

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