Climate Change Advisory Council Secretariat

CB WG Meeting 9

15th December 2023

Agenda

Time	Agenda Item
13:30	1. Opening of Meeting
13:35	2. COP28 – Global Stocktake
14:05	3. Presentation of the 1st Iteration of Core Modelling Results
15:50	4. Irish Carbon budgets: Some Moral Considerations
16:20	5. Carbon Budgets Work Plan
16:25	6. Next Steps and Agenda for next meeting
16:30	7. AOB
16:30	Meeting Close

1. Opening of Meeting

Action Number	Date Raised	Description	Owner	Due	Status
9	19/10/23	CBWG members to provide feedback and/or suggestions on the proposed topics for consideration in 2024 as outlined in the Meeting No. 7 presentation	CB WG Members	Nov 2023	*Closed* *CB WG Members still welcome to provide suggestions for additional thematic topics on ad hoc basis.*
10	19/10/23	Secretariat to share a note on the inputs required for macroeconomic analysis and a template regarding the temperature impact analysis with the core modelling teams for review and feedback	CCAC Secretariat/ CB WG Members	Nov 2023	*Propose to Close* *Feedback on the inputs required for macroeconomic analysis to be discussed at the January 2024 CBWG meeting*

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16:30	Meeting Close

5. Carbon Budgets Work Plan: Topics for Meetings

CB WG Meeting No.	Proposed Date and Time	Topic(s) for Consideration
1	Thursday 9th March 2023 10:00 – 13:00	Carbon Budgets Methodology
2	Thursday 20th April 2023 13:30 – 16:30	Carbon Budgets Methodology / Scoping of modelling work
3	Wednesday 31st May 2023 10:30 – 13:30	Vision for 2050 and Beyond/ Scoping of modelling work/
4	Thursday 29th June 2023 13:30 – 16:30	Climate Justice and 'Paris Test'/ Scoping of modelling work/ Macroeconomic Impacts of carbon budgets/
5	Thursday 27th July 2023 13:30 – 16:30	Focused discussion on methane/ Scoping of modelling work/
6	Friday 8th September 2023 13:30 – 16:30	Populations Projections/ Socioeconomic considerations
CB WG Workshop 1	Wednesday 13th September 2023 13:30 – 16:30	Input model parameters for 2030 starting points, scenario development and assumptions
7	Thursday 19th October 2023 13:30 – 16:30	2024 Projections Process (EPA, SEAI & ESRI)/ International approaches to carbon budgets
8	Thursday 23rd November 2023 10:30 – 13:30	Role of Negative Emissions/ Biodiversity Considerations/ Agriculture and Land Use Review
9	Friday 15th December 2023 13:30 – 16:30	*COP28 – Global Stocktake /* *1st Iteration of Core Modelling Results* *Moral Considerations for Irish Carbon Budgets*

5. 2024 Meeting Schedule and Proposed Topics for Consideration

CB WG Meeting No.	Proposed Date and Time	Topic(s) for Consideration
10	Thursday 18th January 2024, 13:30 – 16:30	IEA Net Zero Roadmap 2023 Update/ Analysis of warming impact of selected core scenarios (1st iteration)/ Update on economic & macroeconomic analysis
11	Thursday 29th February 2024, 9:30 – 13:30	Quantitative approaches to carbon budgeting for Parties to the Paris Agreement (Victorian Government Report)/ Energy and Power systems modelling (Paul Deane)/ Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050 (ESAB)
12	Friday 22nd March 2024, 13:30 – 16:30	Agree inputs, parameters and assumptions for 2nd Iteration of Modelling/ Teagasc Research and implications for Carbon Budgets (Teagasc)
13	Friday 19th April 2024, 13:30 – 16:30	Just Transition principles and considerations in the Carbon Budget Process (NESC)
14	Thursday 23rd May 2024, 13:30 – 16:30	*2nd Iteration of Core Modelling Results/*
15	Friday 28th June 2024, 13:30 – 16:30	Analysis of warming impact of selected core scenarios (2nd iteration)/ *Macroeconomic and Economic Modelling Results (based on 1st and 2nd iteration)*
16	Thursday 25th July 2024, 13:30 – 16:30	Agree inputs, parameters and assumptions for 3rd Iteration of Modelling/
17	Thursday 29th August 2024, 13:30 – 16:30	*3rd Iteration of Core Modelling Results/*
18	Wednesday 18th September 2024, 13:30 – 16:30	*Macroeconomic and Economic Modelling Results (based on the 3rd iteration)* Analysis of warming impact of selected core scenarios (3rd iteration)

5. Other Proposed Topics for Consideration in 2024

- Follow on discussion on biodiversity considerations (Yvonne Buckley/ Secretariat)
- Discussion on various aspects of aviation and maritime (Secretariat)
- Greenhouse gas - air pollution interactions and synergies (Andrew Kelly)
- Economic assessment of climate change impacts and adaptation options in Ireland (ESRI)
- Follow on discussion on methane and climate neutrality (potential invited speakers TBC)
- Follow on discussion on CDR and Carbon Budgets (Oliver Geden/ Secretariat)

5. Carbon Budgets Workplan

Item	Description	2023									2024												
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	**Modelling / Analysis Iteration 1**																						
1.1	Agree inputs, paramaters and assumptions																						
1.2	Core pathways development and modelling																						
1.3	Paris Test Assessment																						
1.4	Additional modelling and testing of results																						
1.5	Post-hoc analysis																						
2	**Modelling / Analysis Iteration 2**																						
2.1	Agree inputs, paramaters and assumptions																						
2.2	Core pathways development and modelling																						
2.3	Paris Test Assessment																						
2.4	Additional modelling and testing of results																						
2.5	Post-hoc analysis																						
3	**Modelling / Analysis Iteration 3**																						
3.1	Agree inputs, paramaters and assumptions																						
3.2	Core pathways development and modelling																						
3.3	Paris Test Assessment																						
3.4	Additional modelling and testing of results																						
3.5	Post-hoc analysis																						

- Core scenarios presented on 15/12/23 to be submitted in line with excel template shared via email on 31/10/23, by COB on 18/12/23
- Analysis of warming impact of selected core scenarios from the 1st iteration of modelling and additional testing of scenario results from SEAI (NEMF) to be presented to CBWG on 18/1/24
- Update on macroeconomic and economic analysis to be discussed at the CBWG on 18/1/24

6. Agenda for Meeting No. 10: 18th January 13:30 – 16:30

1. IEA Net Zero Roadmap 2023 Update

- Christophe McGlade (IEA) to present on the IEA's Net-Zero by 2050 report

2. Analysis of warming impact of selected core scenarios (1st iteration)

- Joe Wheatley to present an assessment of the warming Impact of indicative emissions scenarios selected from the 1st iteration of modelling and analysis

3. Additional testing of scenario results

- SEAI to present additional testing of scenario results from the 1st iteration of modelling with the NEMF

4. Update on economic & macroeconomic analysis

- The data requirements for the macroeconomic/economic analysis to be discussed in the context of the 2nd and 3rd iteration of modelling and analysis

6. Agenda for Meeting No. 11: 29th February 9:30 – 13:30

1. **Quantitative approaches to carbon budgeting for Parties to the Paris Agreement**
- Malte Meinshausen (University of Melbourne) to present on Victorian emissions budgets

2. Energy and Power systems modelling
- Paul Deane (UCC) to present on energy and power systems modelling

3. ESAB Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050
- ESAB Secretariat to present on the ESAB 2040 Advice

Note: extended meeting timing – meeting invite to be updated

7. AOB

- Carbon Budgeting in Selected Countries (Sadhbh O'Neill, December 2023)
- CCAC planned procurement for a study on 'Biodiversity Synergies and Conflicts' due in early 2024
- CCAC planned procurement for a Just Transition study 'Methodological approach to social dialogue at national and local level'
- Secretariat due to brief Council on CBWG outputs in January and February prior to the next CCAC meeting

Global Stocktake Outcomes

Focus on Mitigation elements

Frank McGovern

15th December 2023

2015 Paris Agreement Global Stocktake (GST)

Paris Agreement adopted 2015 entered in to force in 2020.

Global stocktake (GST) key ratchet/ambition mechanism for the Paris Agreement

- First GST in 2023: then every 5 years,
- Inform Parties on required updates to their NDCs as framed by their Long erm strategies LTS.
- Informed by the best available science IPCC and Parties Submissions NDCs etc
- Inputs from key actors, other UN and regional bodies and stakeholders NGOs

Key focus Paris Agreement Article 2 (goals)

a) Temperature goal limit warming well below 2C and efforts to limit it 1.5C
b) Resilience
c) Financial flows

Temperate goal is linked to articles, 4.1 **peaking GHG emissions asap** and **balancing of GHG emissions and removals 2nd half of this century**.

Resilience is linked **Global Goal on Adaptation (GGA)**

Points introduced include: Loss and Damage, Response measures, Pre-2020 and historic responsibility, remaining carbon budgets, equity

Global Stocktake: Two phase process

Phase 1: Technical information gathering

- Three-year process: complex, comprehensive, open and inclusive; **World café, Round tables, Synthesis meetings.**
- Included consideration of material in IPCC Reports provided in the 6th Assessment Cycle.
- Completed in June, **report provided in September** by the two co-facilitators (USA, RSA).
  - Balanced and reflected the range of views of the Parties and wider inputs
  - Not on track and more ambition is needed

Phase 2: Political phase and outcomes

- **COP28 meetings from 30th November to 14th December**
- **Outcome** successful completion of the First Global stocktake the "**UAE Consensus"**
- **Covers all areas;** Science, Mitigation, Adaptation, Means of Implementation, Finance etc
- Part of package of wider decisions

GST Outcomes - Overview

- Underlines that despite overall progress, Parties are collectively not on track to achieving the purpose of the Paris Agreement.
- Expresses serious concern that 2023 is set to be the warmest year on record and that climate change impacts are rapidly accelerating
- “Transition away from fossil fuels”
- Parties commit to accelerate action in this critical decade
- Identifies 1.5C as a “North Star” of climate ambition

ADVANCE VERSION

United Nations

Framework Convention on Climate Change

FCCC/PA/CMA/2023/L.17

Distr.: Limited
13 December 2023

Original: English

Conference of the Parties serving as the meeting of the Parties to the Paris Agreement
Fifth session
United Arab Emirates, 30 November to 12 December 2023
Agenda item 4
First global stocktake

First global stocktake

Proposal by the President

Draft decision -/CMA.5

Outcome of the first global stocktake

The Conference of the Parties serving as the meeting of the Parties to the Paris Agreement,

Recalling Article 2, paragraph 1, of the Paris Agreement, which provides that the Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty,

Also recalling Article 2, paragraph 2, of the Paris Agreement, which provides that the Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances,

Further recalling, as provided in Article 14, paragraph 1, of the Paris Agreement, that the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement shall periodically take stock of the implementation of the Paris Agreement to assess the collective progress towards achieving the purpose of the Agreement and its long-term goals, and that it shall do so in a comprehensive and facilitative manner, considering mitigation, adaptation and the means of implementation and support, and in the light of equity and the best available science,

Recalling, as provided in Article 14, paragraph 3, of the Paris Agreement, that the outcome of the global stocktake shall inform Parties in updating and enhancing, in a nationally determined manner, their actions and support in accordance with the relevant provisions of the Agreement, as well as in enhancing international cooperation for climate action,

Also recalling decisions 19/CMA.1, 1/CMA.2, 1/CMA.3 and 1/CMA.4,

Underlining the critical role of multilateralism based on United Nations values and principles, including in the context of the implementation of the Convention and the Paris Agreement, and the importance of international cooperation for addressing global issues,

GST Outcomes – Mitigation (1) Para 28

Recognizes the need for deep, rapid and sustained reductions in greenhouse gas emissions in line with 1.5 °C pathways and calls on Parties to contribute to the following global efforts:

- **Tripling renewable energy** capacity globally and doubling the global average annual rate of energy efficiency improvements by 2030;
- Accelerating efforts towards the **phase-down of unabated coal power**;
- Accelerating efforts globally towards **net zero emission energy systems**, utilizing zero- and low-carbon fuels well before or by around mid-century;
- **Transitioning away from fossil fuels** in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050 in keeping with the science;

GST Outcomes – Mitigation (2) Para 28

- **Accelerating zero- and low-emission technologies**, including, inter alia, renewables, nuclear, abatement and removal technologies such as carbon capture and utilization and storage, particularly in hard-to-abate sectors, and low-carbon hydrogen production;

- Accelerating and substantially reducing non-carbon-dioxide emissions globally, including **in particular methane emissions by 2030**;

- Accelerating the **reduction of emissions from road transport** on a range of pathways, including through development of infrastructure and rapid deployment of zero-and low-emission vehicles;

- **Phasing out inefficient fossil fuel subsidies** that do not address energy poverty or just transitions, as soon as possible;

GST Outcomes

- **Para 20**. Commends the **68 Parties that have communicated long-term low greenhouse gas emission development strategies** and notes that **87 per cent of the global economy in terms of share of gross domestic product is covered by targets for climate neutrality, carbon neutrality, greenhouse gas neutrality or net zero emissions,"**

- **Para 40**: **Notes the importance of aligning nationally determined contributions with long-term low greenhouse gas emission development strategies**, and encourages Parties to align their next nationally determined contributions with long-term low greenhouse gas emission development strategies;

GST the Way Forward ()

- **Para 166**: Parties shall submit to the secretariat their next nationally determined contributions at least **9 to 12 months in advance of the seventh session of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (November 2025**) with a view to facilitating the clarity, transparency and understanding of these contributions;

- **Para 192**: Decides to launch, under the guidance of the Presidencies of the fifth, sixth and seventh sessions of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement, a set of activities **("Road map to Mission 1.5")** to significantly enhance international cooperation and the international enabling environment to stimulate ambition in the next round of nationally determined contributions, **with a view to enhancing action and implementation over this critical decade and keeping 1.5 °C within reach**

Thank you!

GOBLIN Scenarios for carbon budgets towards 2050

David Styles, Colm Duffy, Kevin Black, Daniel Henn, Andres Martinez

An Roinn Comhshaoil, Aeráide agus Cumarsáide
Department of the Environment, Climate and Communications

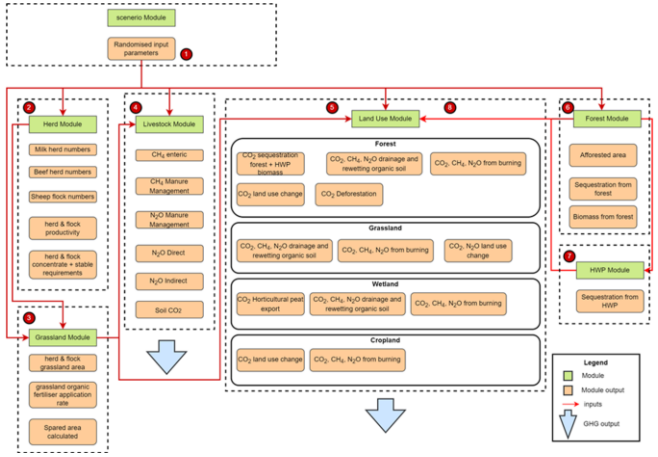
Modelling Approach

OLLSCOIL NA GAILLIMHE
UNIVERSITY OF GALWAY

1. Scenarios

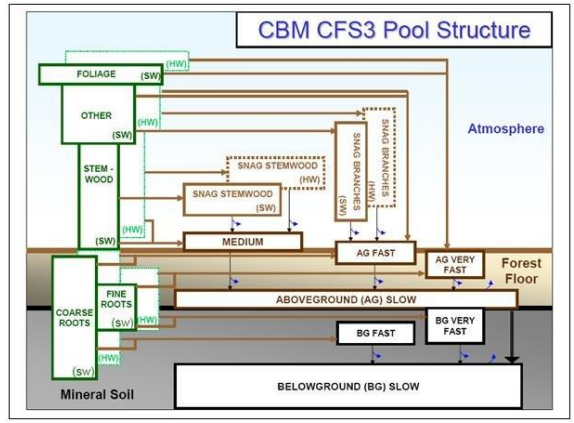
- Current data (baseline)
- MACC assumptions (2030)
- Animal number/productivity scenarios
- Land use choices

2. GOBLIN



3. FERS-CBM

Areas
Soils
Forest types

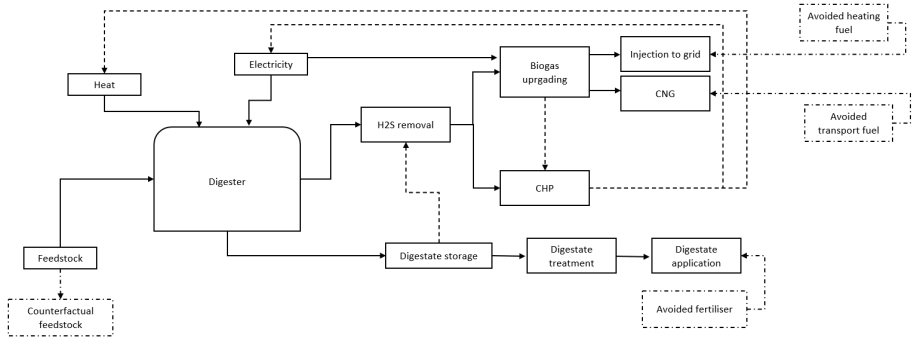


4. LCAD 2.0

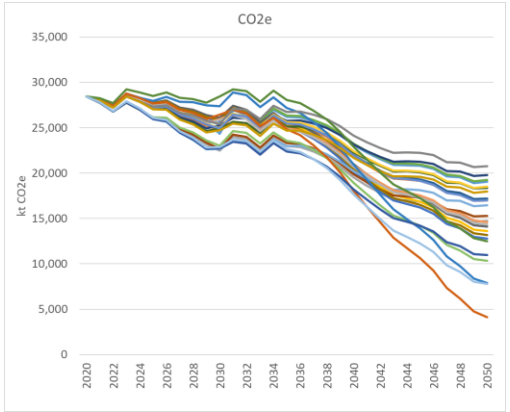
Areas
Grass yields
Manure

5. Aggregation

- Time series 2020-2050
- Fixed 2030 waypoints
- Progressive technical abatement (ag)
- Deployment (AD)
- GWP_{100} (w/wo CH_4)



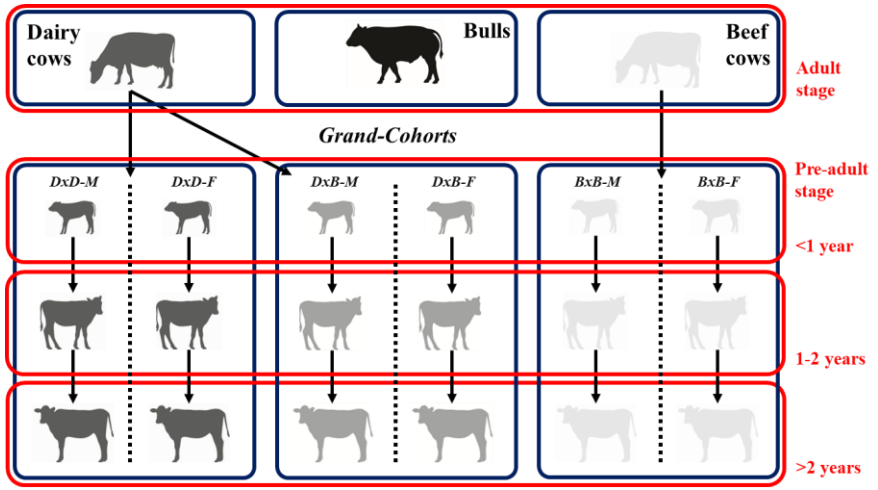
6. Results



CO_2
CH_4
N_2O

Agriculture

- Dairy, beef & sheep
  - Current animal numbers and productivity (19% GHG decoupling by 2030; 30% by 2050)
  - MACC+ (19% GHG decoupling by 2030; 30% by 2050)
  - MACC- (19% GHG decoupling by 2030; 30% by 2050)
  - Dairy specialisation for constant protein to 2050 (MACC + 15% milk productivity) (30% GHG decoupling by 2050)
  - 30% reduction dairy & beef (current productivity) (30% GHG decoupling by 2050)
- Grass utilisation rate
  - Increase aggregate GUE from c.60% to 65% (spares land)
- Crop production
  - Hold area constant



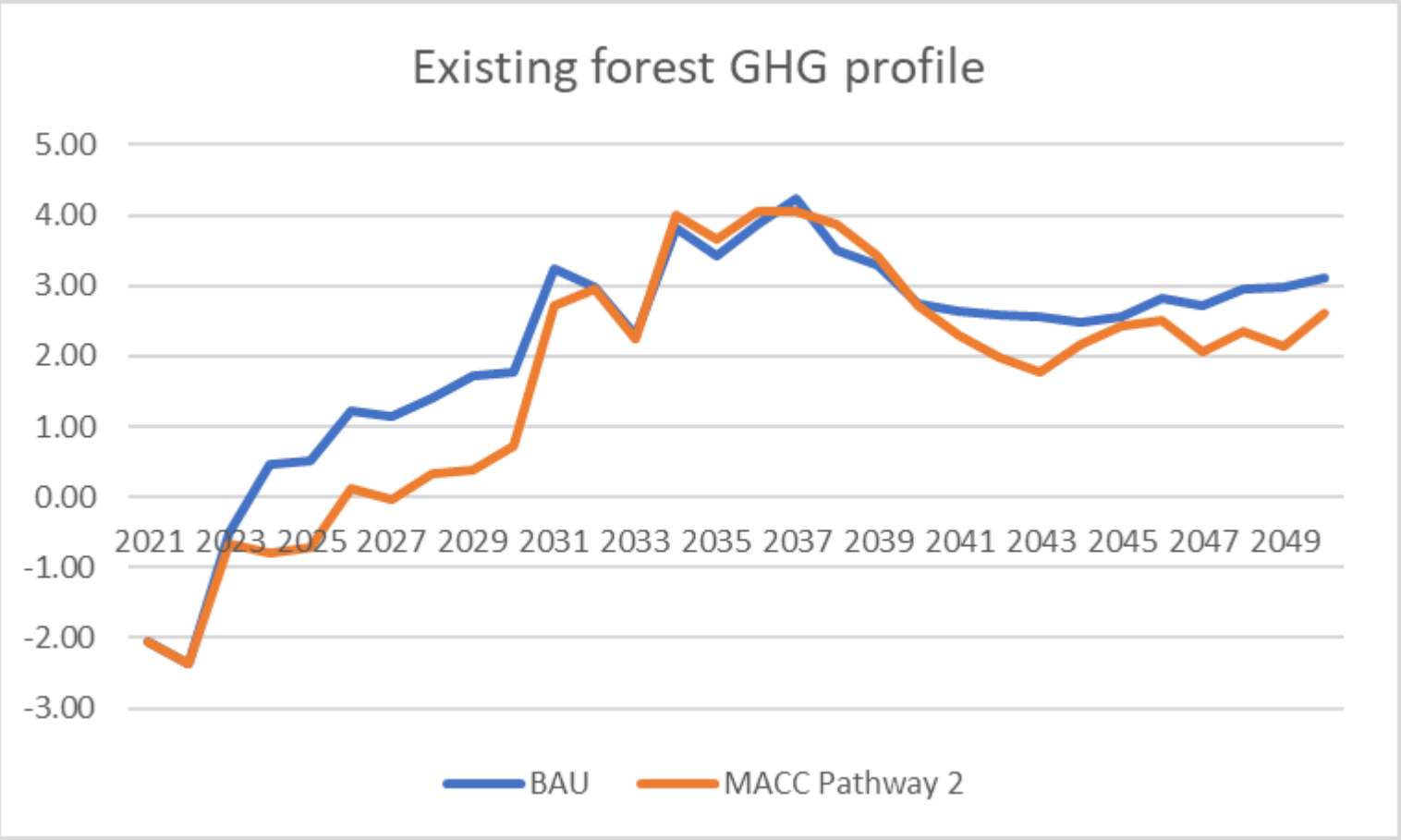
Land use

- Spared land areas assigned to:

Scenario	Rewetting	AD	Forestry
1	90% of spared organic soils minus new forest area	c.200kha (mineral soils), 5.7 TWh target	BAU mix, inc. 25% on organic-organo-mineral (200 kha 2025-2050, 8 kha per year planting)
2	90% of spared organic soils	0	70:30 conifer:broadleaf mix on mineral soils (200 kha)
3	90% of spared organic soils	c.200kha (mineral soils), 5.7 TWh target	BAU mix, inc. 25% on organic-organo-mineral (residual spared area)
4	90% of spared organic soils	c.200kha (mineral soils), 5.7 TWh target	70:30 conifer:broadleaf mix on mineral soils (residual spared area)
5…?			

NB: Residual area permutations depending on Step 1 combinations

Forestry



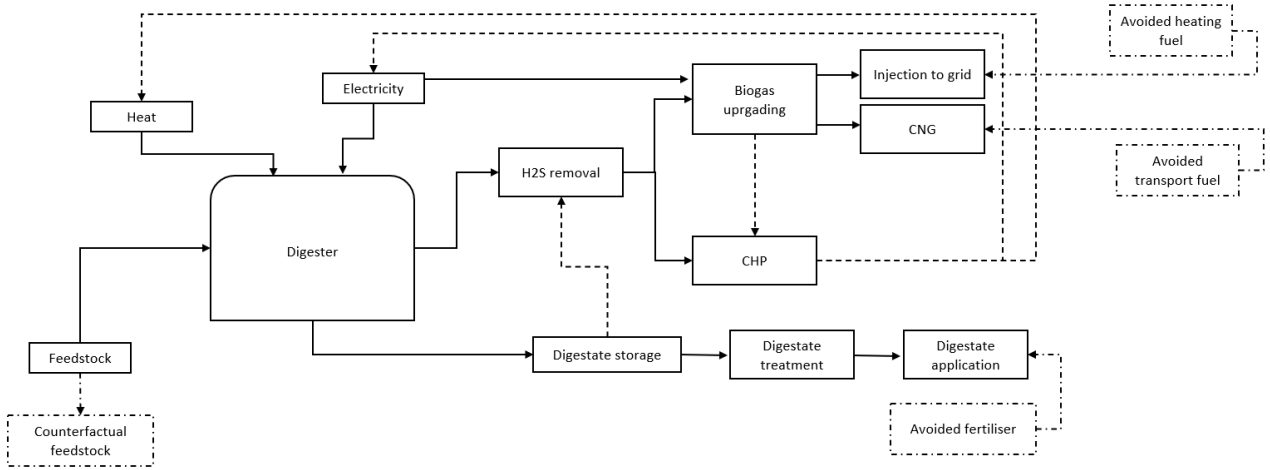
- FERS-CBM model
- Includes organic soil under forest EFs
- Includes HWP C storage (1st use only – no cascades or CCS)
- MACC P2 scenario selected
  - Aff. 2kha/yr to 2025, 8 kha/yr 2025-2030, variable thereafter by scenario
  - reduced deforestation (0.25 Mt CO_2e yr^{-1})
  - delayed harvest (longer rotations)
- Legacy forest c. 2.6 Mt CO_2e by 2050
- Afforestation generates varying gross sink

Anaerobic digestion

Digester temperature	Mesophilic (35 - 37°C)
Digester size	Large (≥1000 kWe)
Type of digester	Double membrane dome
CHP electric efficiency	42%
CHP thermal efficiency	41%
Biogas boiler efficiency	80%
CH4 content in biogas (%)	61%
CO2 content in biogas (%)	33%
Digester CH4 loss (%)	0.2%
CHP CH4 loss (%)	2.4%
Biogas upgrading CH4 loss (%)	2.1%
Boiler CH4 loss (%)	0.1%
Biomethane compression loss (%)	2.1%
Biogas upgrading technology	Water scrubbing
Digestate storage	Closed tank
Digestate application method	shallow injection

No CCS for now…

Outside temperature	9.8°C
Feedstock temperature	9.8°C
Electricity displaced by CHP	Combined cycle (NG)
Grid fuel being displaced	Heat from oil
Transport fuel being displaced	Diesel



Parasitic heat demand

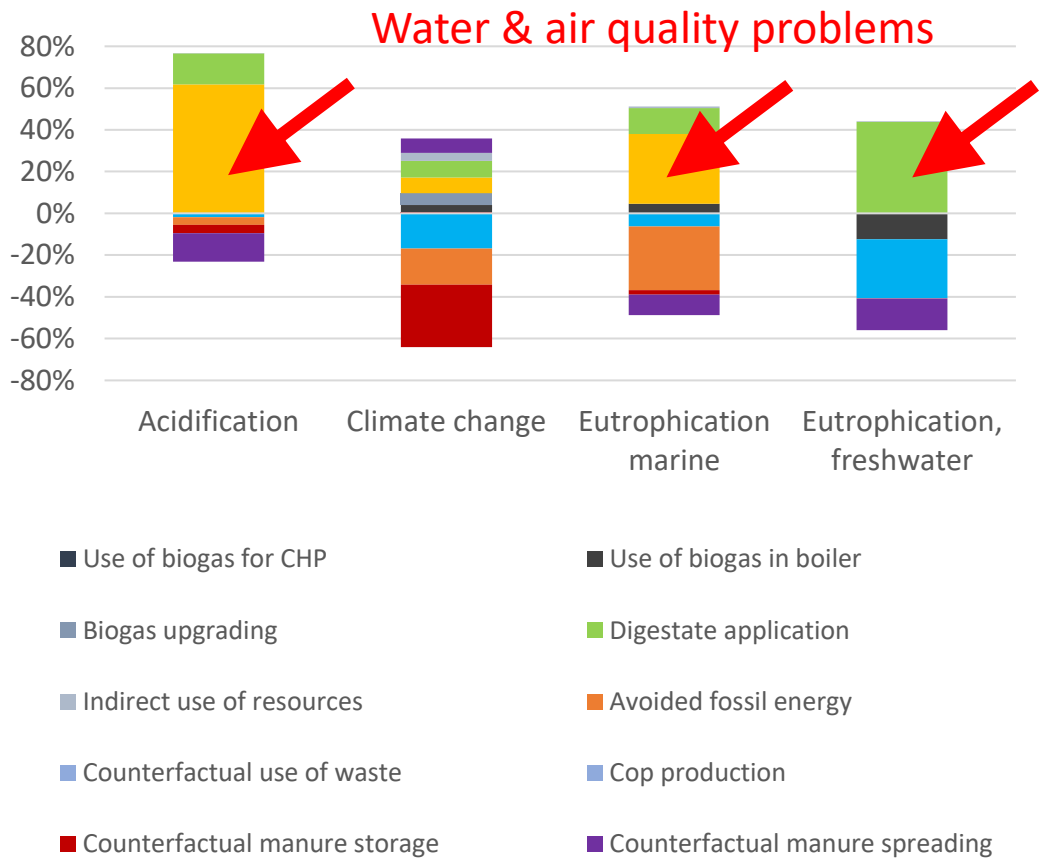
Feedstock	CHP	Boiler
Cattle slurry	54%	28%
Grass	10%	5%

6.6 TWh bio-CH_4 gross, 4 TWh net…

Cattle slurry - Biogas 28% boiler + transport fuel substitution (average digestate management)

Sector	Element	Value	Unit	Climate change (kg CO2-Eq)	Freshwater eutrophication (kg P-Eq)	Acidification (mol H+-Eq)	Marine eutrophication (kg N-Eq)
Agricultural	Digester operation	0.26	kgCH4	7.2E+00	0.0E+00	0.0E+00	0.0E+00
		68.15	kWh	3.2E+01	4.7E-05	2.3E-02	7.2E-03
	Digestate storage and application	1.67	kgCH4	4.7E+01	0.0E+00	0.0E+00	0.0E+00
		0.77	kgN2O	2.0E+02	0.0E+00	0.0E+00	0.0E+00
		23.69	kgNH3	0.0E+00	0.0E+00	7.2E+01	2.2E+00
		8.40	kgNO3	0.0E+00	0.0E+00	0.0E+00	2.4E-01
		0.08	kg P	0.0E+00	7.9E-02	0.0E+00	0.0E+00
	Avoided manure storage and application	-14.08	kgCH4	-3.9E+02	0.0E+00	0.0E+00	0.0E+00
		-6.17	kgNH3	0.0E+00	0.0E+00	-1.9E+01	-5.7E-01
		-1.09	kgN2O	-2.9E+02	0.0E+00	0.0E+00	0.0E+00
		-17.16	kgNO3	0.0E+00	0.0E+00	0.0E+00	-4.8E-01
		-0.08	kgP	0.0E+00	-7.9E-02	0.0E+00	0.0E+00
Subtotal agricultural sector				-3.9E+02	4.7E-05	5.3E+01	1.4E+00
Energy	Biogas handling and use	3.31	kgCH4	9.3E+01	0.0E+00	0.0E+00	0.0E+00
		430.35	kWh	5.5E+01	-2.2E-02	1.3E-01	2.4E-01
	Transport	150.00	tkm	2.9E+01	2.7E-04	8.8E-02	3.1E-02
	Avoided electricity	0.00	kWh	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Avoided heat	-9.55	kWh	-8.2E-01	-5.3E-06	-8.2E-04	-2.1E-04
	Avoided heat (grid)	0.00	kWh	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Avoided transport fuel	-2869.32	MJ	-2.8E+02	-4.2E-04	-3.4E+00	-1.6E+00
Subtotal energy sector				-1.0E+02	-2.2E-02	-3.2E+00	-1.3E+00
Total				**-5.0E+02**	**-2.2E-02**	**5.0E+01**	**4.8E-02**

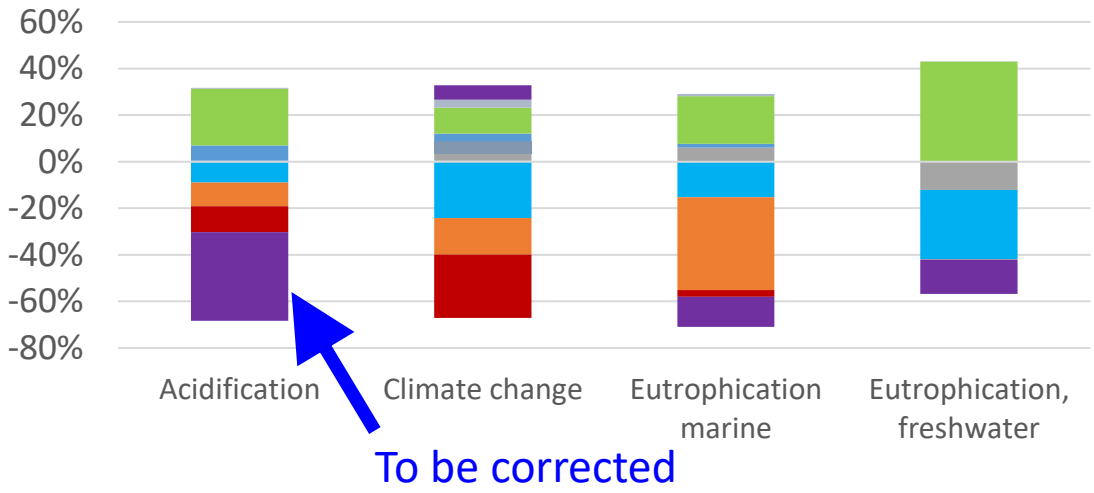
*Results per metric ton of DM



Cattle slurry - Biogas 28% boiler + transport fuel substitution (ideal digestate management)

Sector	Element	Value	Unit	Climate change (kg CO2-Eq)	Freshwater eutrophication (kg P-Eq)	Acidification (mol H+-Eq)	Marine eutrophication (kg N-Eq)
Agricultural	Digester operation	0.26	kgCH4	7.2E+00	0.0E+00	0.0E+00	0.0E+00
		68.15	kWh	3.2E+01	4.7E-05	2.3E-02	7.2E-03
	Digestate storage and application	1.67	kgCH4	4.7E+01	0.0E+00	0.0E+00	0.0E+00
		0.79	kgN2O	2.1E+02	0.0E+00	0.0E+00	0.0E+00
		3.45	kgNH3	0.0E+00	0.0E+00	1.0E+01	3.2E-01
		20.28	kgNO3	0.0E+00	0.0E+00	0.0E+00	5.7E-01
		0.08	kg P	0.0E+00	7.9E-02	0.0E+00	0.0E+00
	Avoided manure storage and application	-14.08	kgCH4	-3.9E+02	0.0E+00	0.0E+00	0.0E+00
		-6.17	kgNH3	0.0E+00	0.0E+00	-1.9E+01	-5.7E-01
		-1.09	kgN2O	-2.9E+02	0.0E+00	0.0E+00	0.0E+00
		-17.16	kgNO3	0.0E+00	0.0E+00	0.0E+00	-4.8E-01
		-0.08	kgP	0.0E+00	-7.9E-02	0.0E+00	0.0E+00
Subtotal agricultural sector				-3.9E+02	4.7E-05	-8.2E+00	-1.6E-01
Energy	Biogas handling and use	3.31	kgCH4	9.3E+01	0.0E+00	0.0E+00	0.0E+00
		430.35	kWh	5.5E+01	-2.2E-02	1.3E-01	2.4E-01
	Transport	150.00	tkm	2.9E+01	2.7E-04	8.8E-02	3.1E-02
	Avoided electricity	0.00	kWh	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Avoided heat	-9.55	kWh	-8.2E-01	-5.3E-06	-8.2E-04	-2.1E-04
	Avoided heat (grid)	0.00	kWh	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Avoided transport fuel	-2869.32	MJ	-2.8E+02	-4.2E-04	-3.4E+00	-1.6E+00
Subtotal energy sector				-1.0E+02	-2.2E-02	-3.2E+00	-1.3E+00
Total				**-4.9E+02**	**-2.2E-02**	**-1.1E+01**	**-1.5E+00**

*Results per metric ton of DM

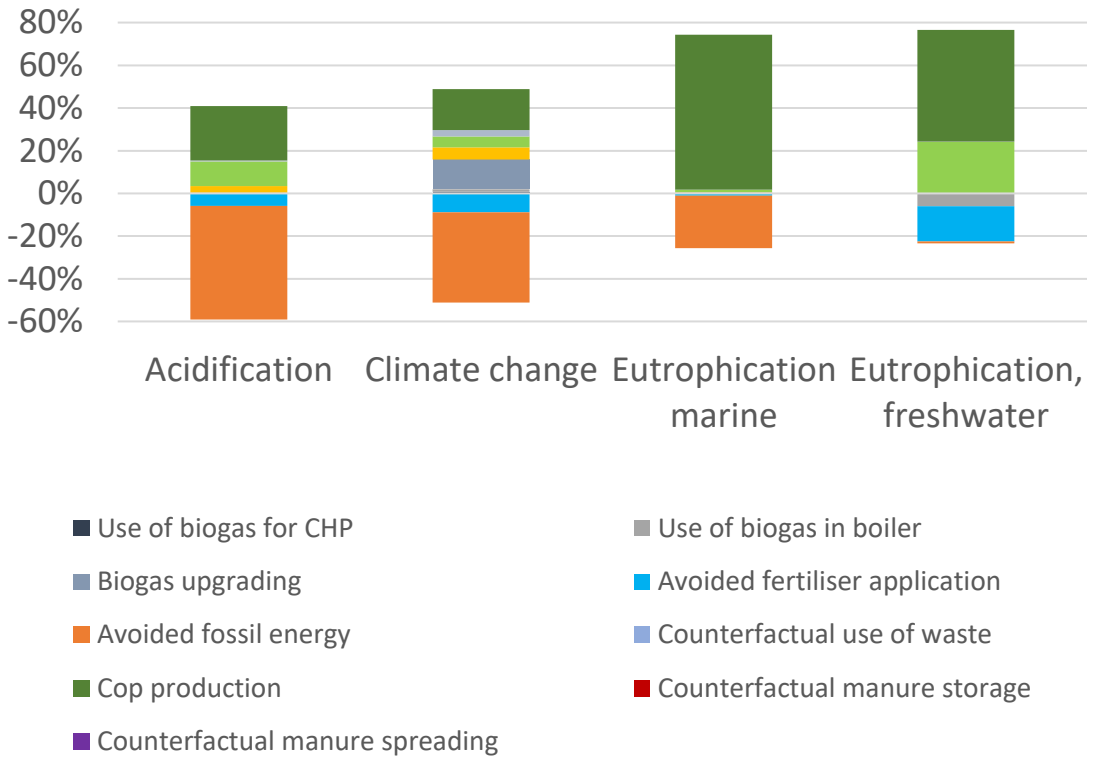


Ideal digestate management & current energy “credits” in scenarios – optimistic!

Grass – Biogas 5% boiler + transport fuel substitution (ideal digestate management)

Sector	Element	Value	Unit	Climate change (kg CO2-Eq)	Freshwater eutrophication (kg P-Eq)	Acidification (mol H+-Eq)	Marine eutrophication (kg N-Eq)
Agricultural	Digester operation	0.56	kgCH4	1.6E+01	0.0E+00	0.0E+00	0.0E+00
		98.20	kWh	4.6E+01	6.8E-05	3.3E-02	1.0E-02
	Digestate storage and application	3.64	kgCH4	1.0E+02	0.0E+00	0.0E+00	0.0E+00
		0.39	kgN2O	1.0E+02	0.0E+00	0.0E+00	0.0E+00
		0.90	kgNH3	0.0E+00	0.0E+00	2.7E+00	8.3E-02
		5.28	kgNO3	0.0E+00	0.0E+00	0.0E+00	1.5E-01
		0.03	kg P	0.0E+00	3.5E-02	0.0E+00	0.0E+00
	Avoided manure storage and application	0.00	kgCH4	0.0E+00	0.0E+00	0.0E+00	0.0E+00
		0.00	kgNH3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
		0.00	kgN2O	0.0E+00	0.0E+00	0.0E+00	0.0E+00
		0.00	kgNO3	0.0E+00	0.0E+00	0.0E+00	0.0E+00
		0.00	kgP	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Subtotal agricultural sector				2.7E+02	3.5E-02	2.7E+00	2.4E-01
Energy	Biogas handling and use	9.44	kgCH4	2.6E+02	0.0E+00	0.0E+00	0.0E+00
		167.97	kWh	2.1E+01	-8.7E-03	5.0E-02	9.5E-02
	Transport	60.00	tkm	1.2E+01	1.1E-04	3.5E-02	1.3E-02
	Avoided electricity	0.00	kWh	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Avoided heat	-8.88	kWh	-7.6E-01	-5.0E-06	-7.6E-04	-2.0E-04
	Avoided heat (grid)	0.00	kWh	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Avoided transport fuel	-8274.92	MJ	-8.0E+02	-1.2E-03	-9.8E+00	-4.6E+00
Subtotal energy sector				-5.1E+02	-9.8E-03	-9.7E+00	-4.5E+00
Total				**-2.4E+02**	**2.5E-02**	**-7.0E+00**	**-4.3E+00**

*Results per metric ton of DM



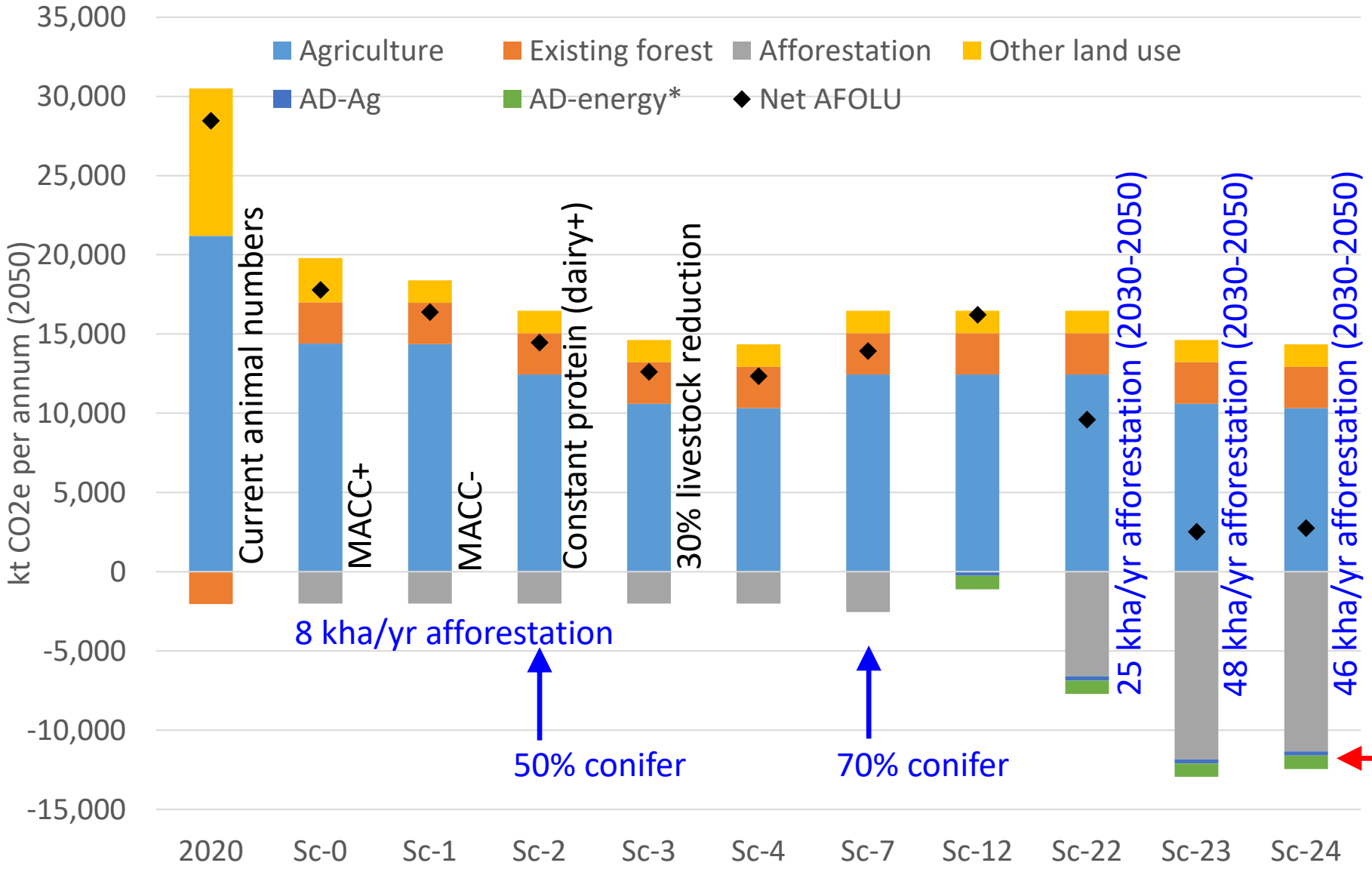
Ideal digestate management & current energy “credits” in scenarios – optimistic!

Ollscoil na Gaillimhe
University of Galway

Shortlisted scenarios

Scenario	Cattle	Rewetting (ha)	AD grassland (ha)	2025-2050 new forest (ha)	2030-2050 aff. Rate (ha/yr)	BL:SS	Aff. soils	Milk (kt/yr)	Beef (kt/yr)	Protein (% change vs 2020)
0	Current	227,222		200,000	8,000	50:50	25% O-M	8790	652	3%
1	MACC+	305,043		200,000	8,000	50:50	25% O-M	9940	643	12%
2	MACC-	305,043		200,000	8,000	50:50	25% O-M	9200	532	0%
3	Dairy - protein	305,043		200,000	8,000	50:50	25% O-M	9930	416	0%
4	30% reduction	305,043		200,000	8,000	50:50	25% O-M	6150	456	-28%
7	MACC-	305,043		200,000	8,000	30:70	Mineral	9200	532	0%
12	MACC-	305,043	200,000	0	0	NA	NA	9200	532	0%
22	MACC-	305,043	200,000	546,932	25,347	30:70	Mineral	9200	532	0%
23	Dairy - protein	305,043	200,000	992,825	47,641	30:70	Mineral	9930	416	0%
24	30% reduction	305,043	200,000	950,502	45,525	30:70	Mineral	6150	456	-28%

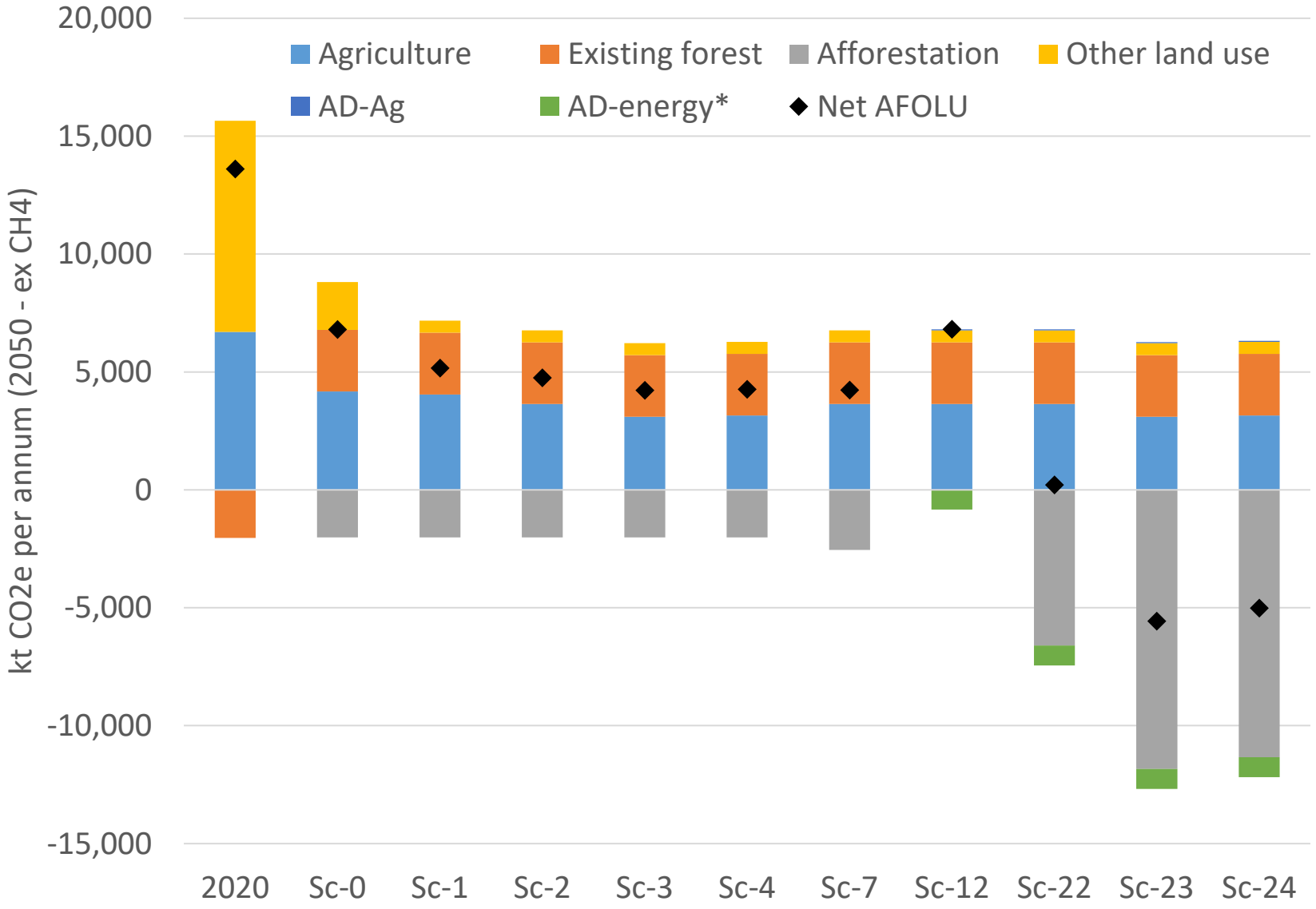
2050 snapshots



AFOLU Net Zero GWP_{100} unattainable without 50%+++ animal number reductions (even with optimistic assumptions all round)

200 kha AD energy "credit". Even with highly optimistic assumptions & truncated forest credits, 33% of forestry credit on 200 kha

2050 snapshots (ex. CH_4)



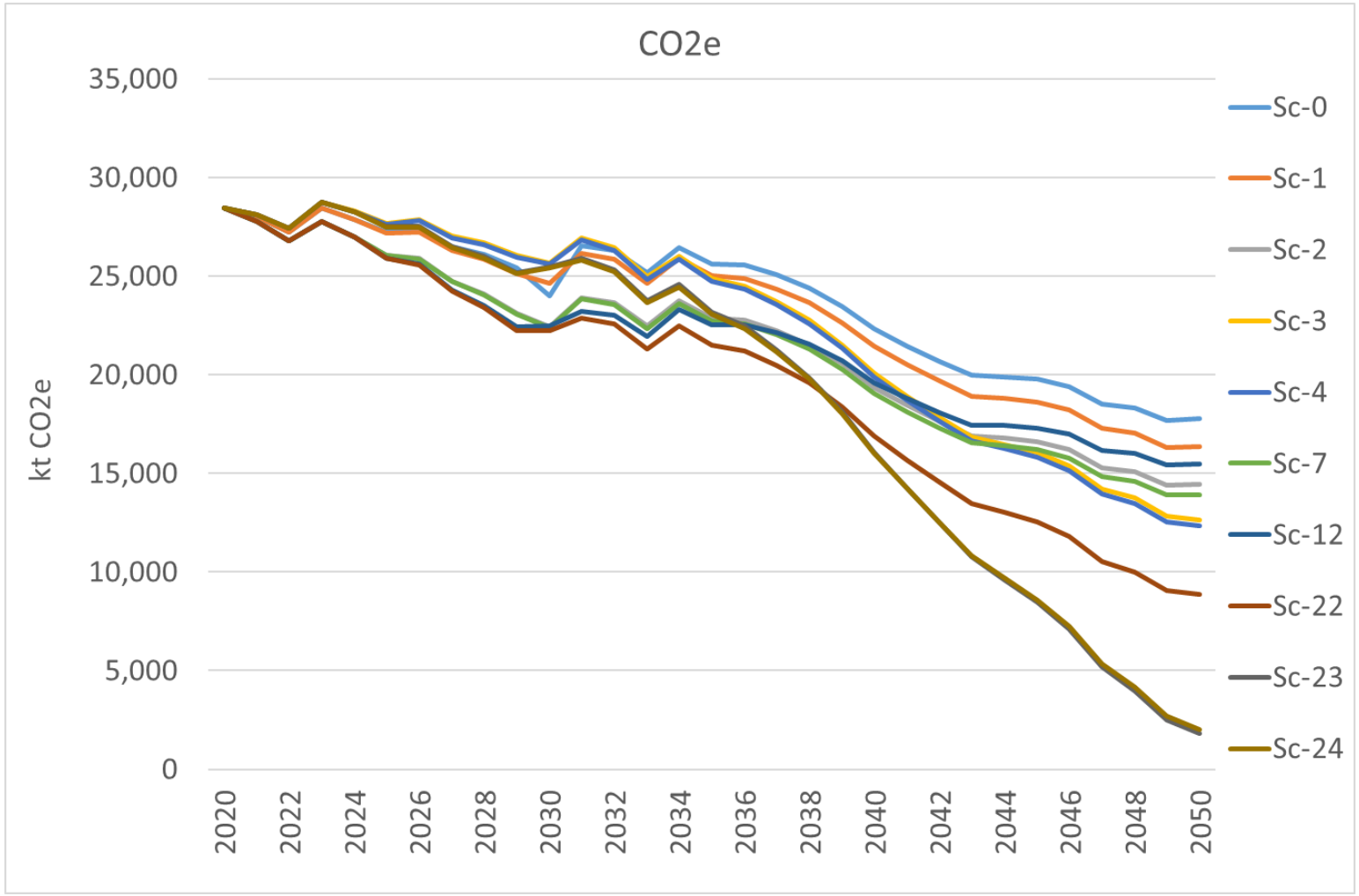
IF separate target set for CH_4 (as a SLCP)…

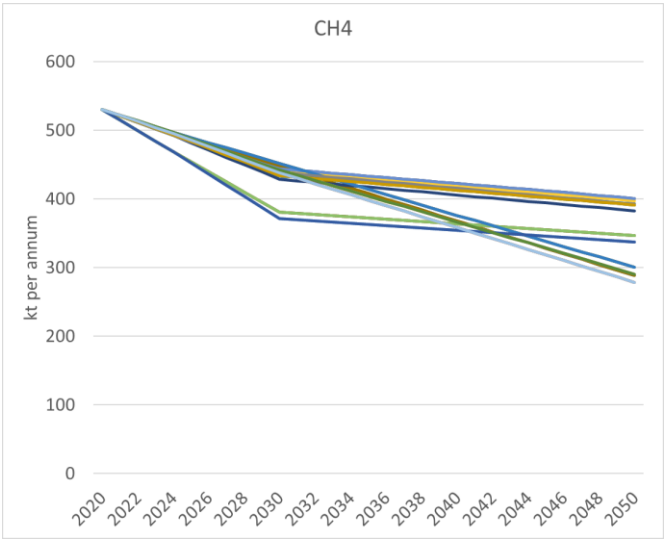
AFOLU climate neutrality *just about* attainable with:

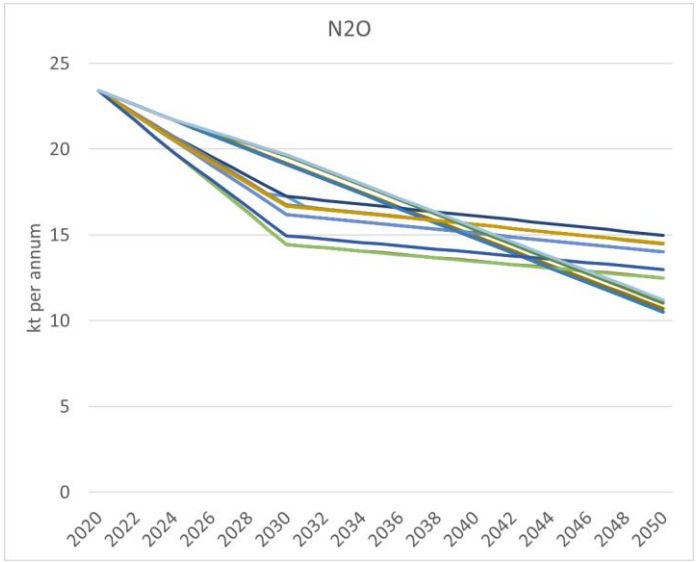
MACC- animals (or fewer)

- 30% technical emission abatement
- 90% organic soil rewetting
- 25kha/yr afforestation from 2030

Time series







Need to extend beyond 2050 for AFOLU!

Conclusions

- Achieving GWP_{100} NZ by 2050 extremely challenging
  - All scenarios assume very ambitious rewetting (90% of area drained) – uncertain residual emissions
  - Large herd reduction needed
  - Excluding CH_4 from GWP_{100} balance brings climate neutrality into play with modest herd reduction, maintaining protein output – but only IF super ambitious action across entire land sector realised
- Ag sector technical abatement of 30% by 2050 assumed
  - High end of proven abatement options
  - Land will also be a constraining factor
- Afforestation could generate a substantial net sink by 2050, but only if:
  - >>8 kha/yr
  - Ramped up soon
  - This sink could be enhanced by cascading wood use & CCS (not yet modelled)
  - 70% conifer mix on mineral soil = 26% bigger sink than 50% conifer mix on 25% organo-min soil
  - Climate solutions in land sector require longer time horizon of assessment – 2100+++
- AD may facilitate diversification out of livestock, but does not generate any CO_2 sink and limited GHG mitigation in energy sector - NH_3 pollution risks.

CAPACITY
CLIMATE ACTION PATHWAYS & ABSORPTIVE CAPACITY

Energy system pathways for carbon budgets: First iteration of TIM scenarios

CCAC Carbon Budgets Working Group
December 15th, 2023

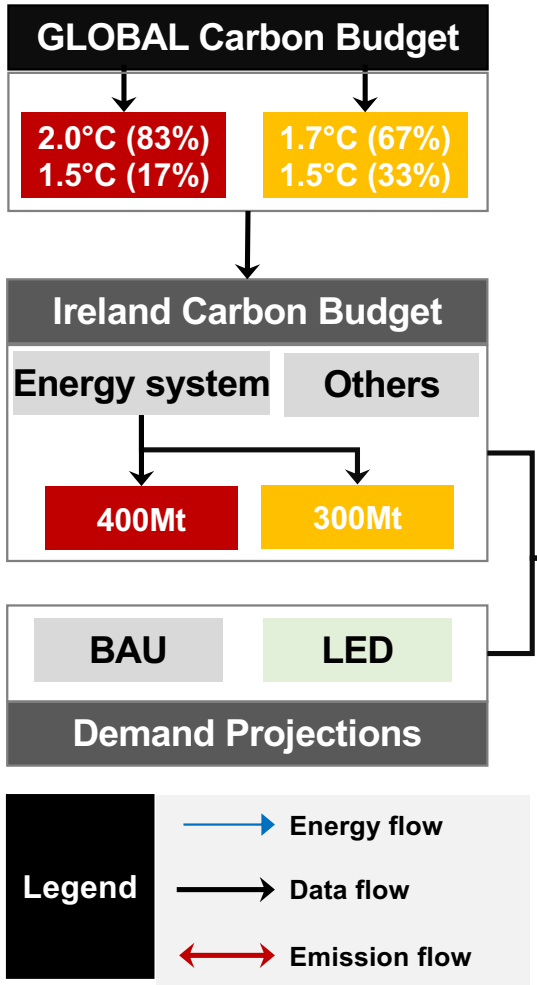
Hannah Daly, Vahid Aryanpur & Bakytzhan Suleimenov

MaREI Energy · Climate · Marine | Environmental Research Institute | UCC University College Cork, Ireland Coláiste na hOllscoile Corcaigh | Science Foundation Ireland sfi For what's next

Introduction

- Objectives:
  - Assess consequences of adhering to CB aligned with global temperature outcomes
  - Identify gaps in current policies to meet legally-binding Sectoral Emissions Ceilings
  - Examine timing of mitigation efforts and novel technologies
  - Explore timing of fossil-fuel phase-out & implications for investment & demands
- Context
  - Energy system (including industrial processes, excluding international aviation & shipping) 53% of Ireland's GHG emissions in 2022; 82% of CO2
  - 86% of Ireland's primary energy is from fossil fuels
  - Remaining Global Carbon Budget (GCB) for 50% chance of 1.5C is 500 $GtCO_2$ from 2020, currently as low as 250 $GtCO_2$, potentially zero without significant methane reduction

Carbon budget & scenario definition



Main Scenarios

- 400MT_BAU
- 400MT_LED
- 300MT_BAU
- 300MT_LED

TIMES-Ireland Model (TIM)

Supply-side

- **Resources and Potentials**: Fossil fuel; Renewable
- **Power Generation**: Fossil-based; Renewables; CCS (Gas/Biomass)
- **Fuel production**: Oil products; Biofuels; Natural gas; Hydrogen
- **Energy Trades**: Electricity; Oil products; Biofuels; Natural gas
- **Transportation & Distribution**

Demand-side

- **End-use Technologies**: Cars & Trucks; Buses & Trains; Heaters; Boilers; Appliances; Dryers; Dishwashers; Fans & Pumps; Refrigerators; Stoves & Ovens; Agr. Equipment; Ind. Machineries; Others
- **Energy Service Demands**: Passenger; Freight; Space heating; Hot water; Lighting; Electricity; Cooking; Refrigeration; Industries; Data Centre; Others

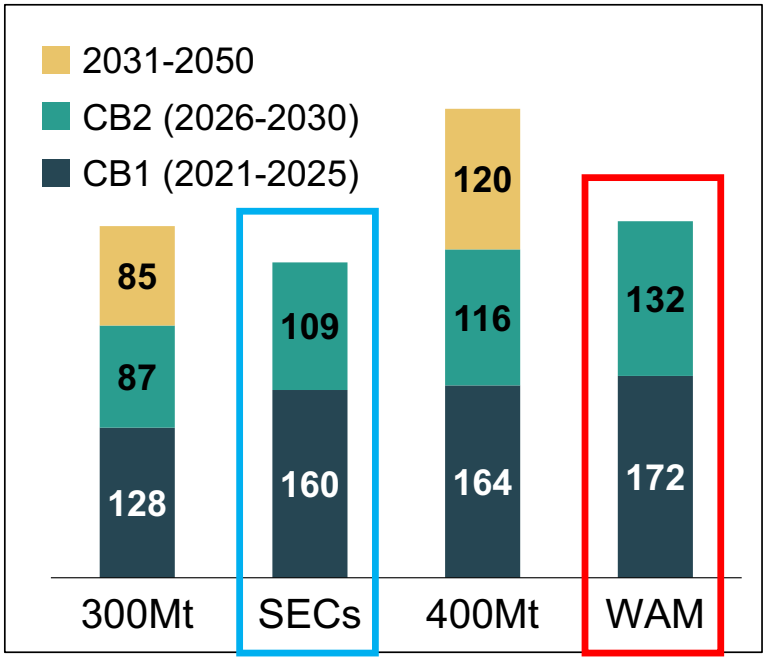
Emission Control

- **CO_2 Constraint**: Carbon Budget
- **CO_2 Removal**: Capture & Storage

See Notes & Assumptions

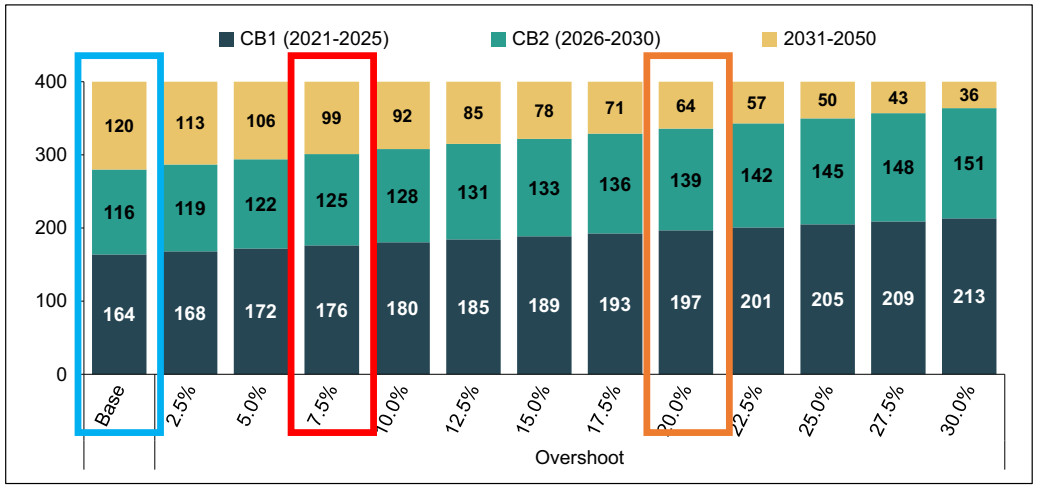
Main Scenarios & Overshoot

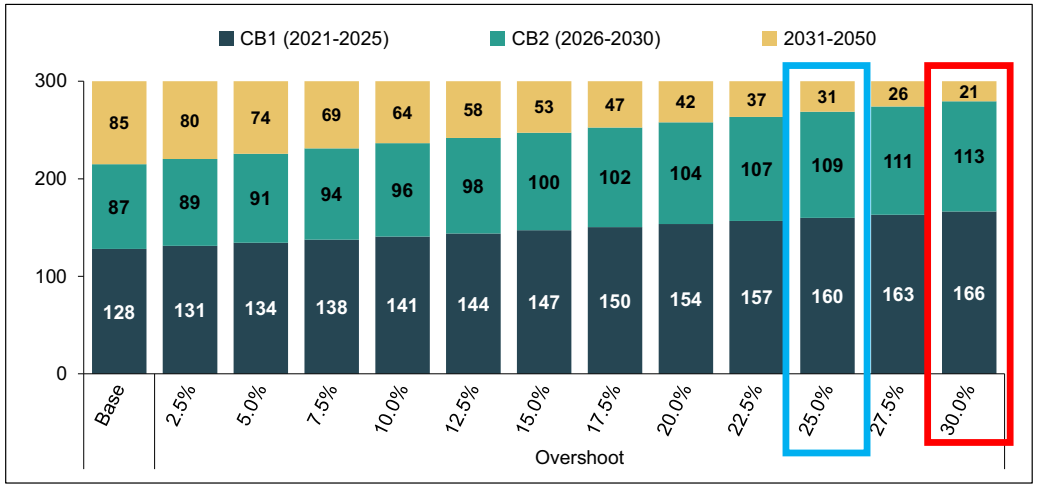
- Overall alignment with Sectoral Emissions Ceilings for CB1 & CB2
- Scenarios examine implication of overshoot



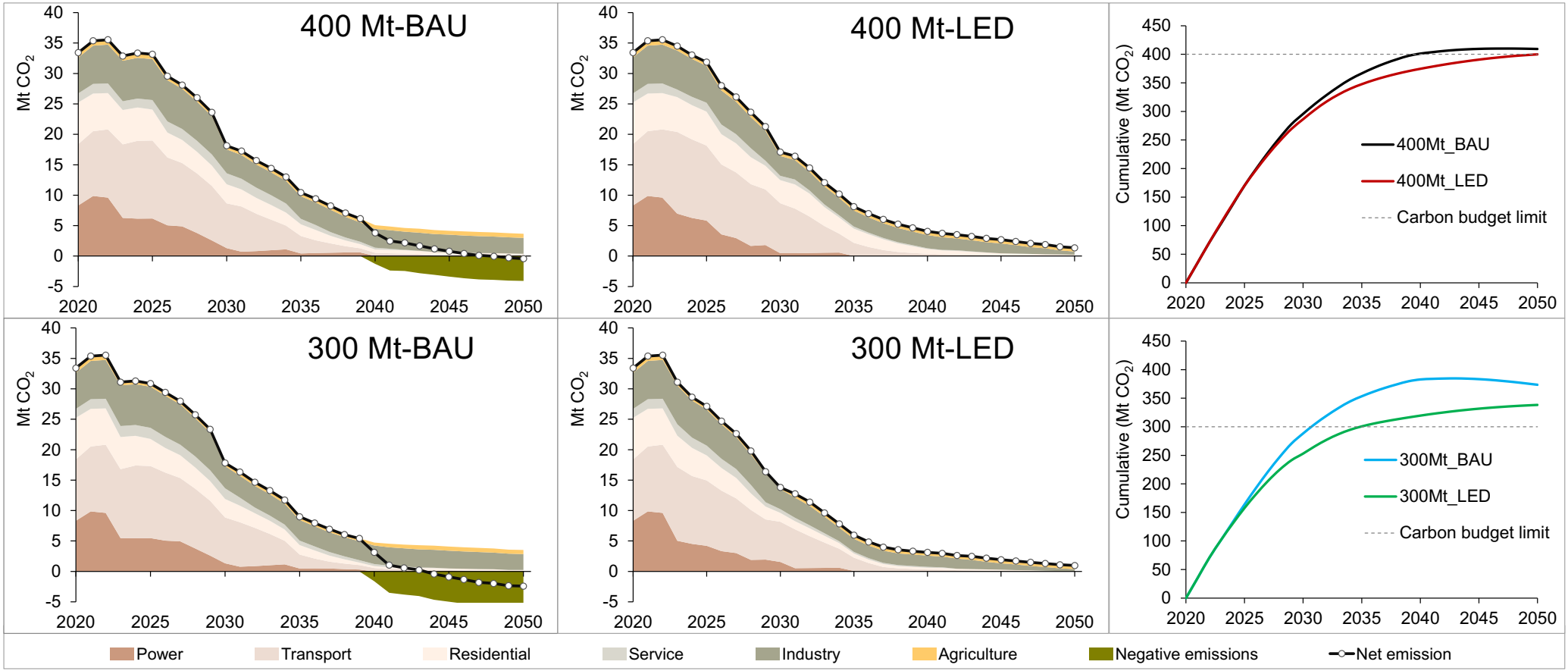
See Notes & Assumptions

Overshoot scenarios

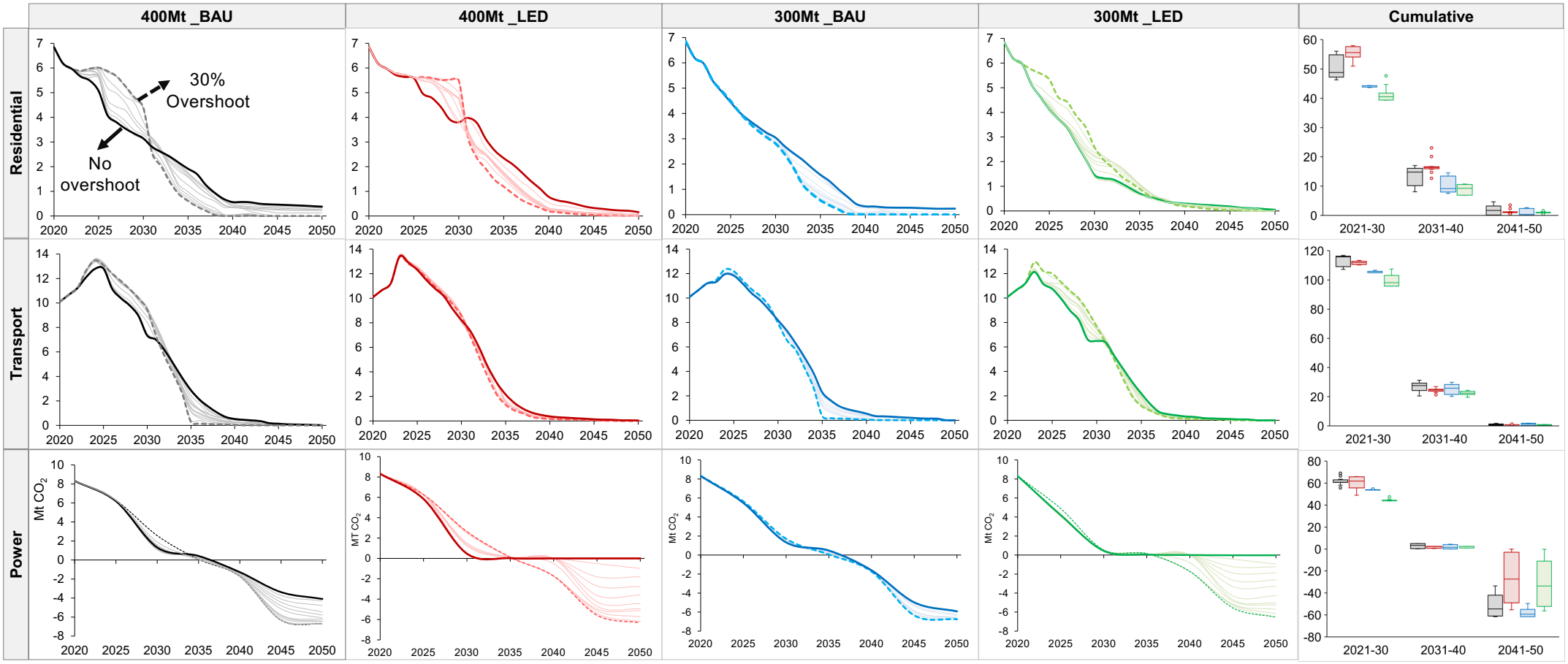




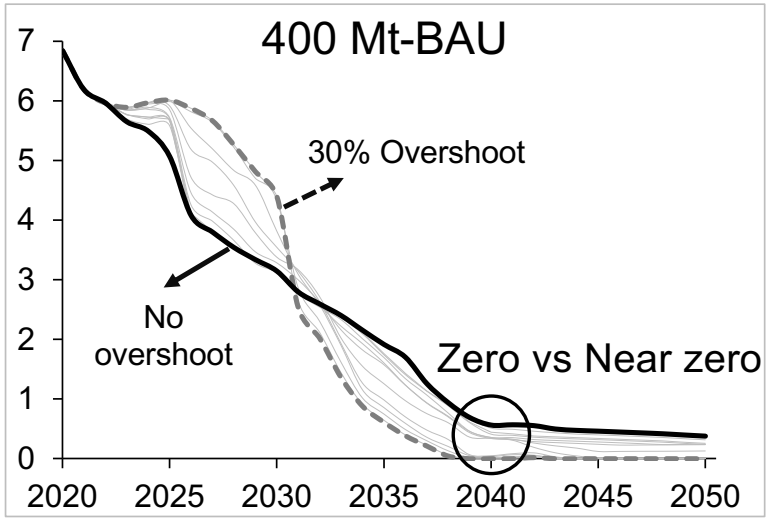
Results: Total emissions

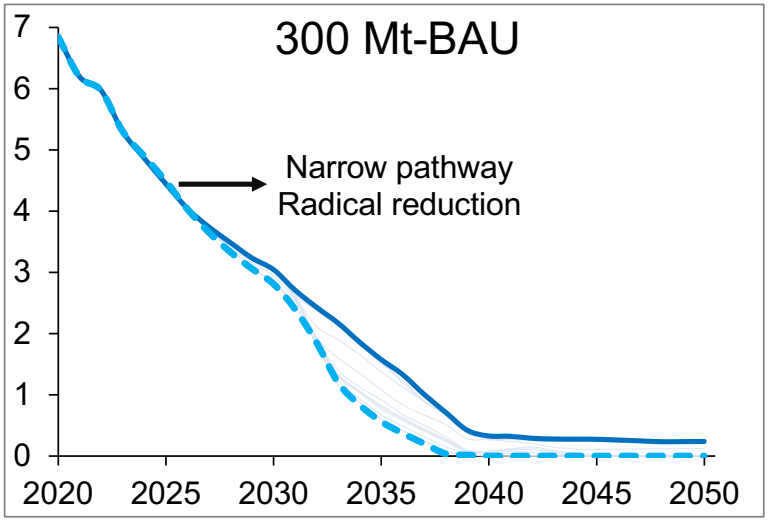


Results: Sectoral emissions

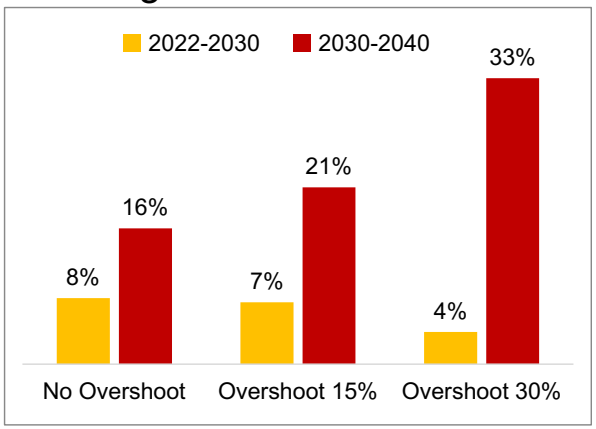


Results: Residential sector

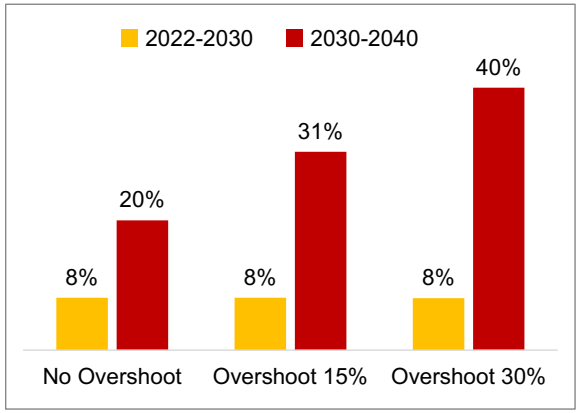




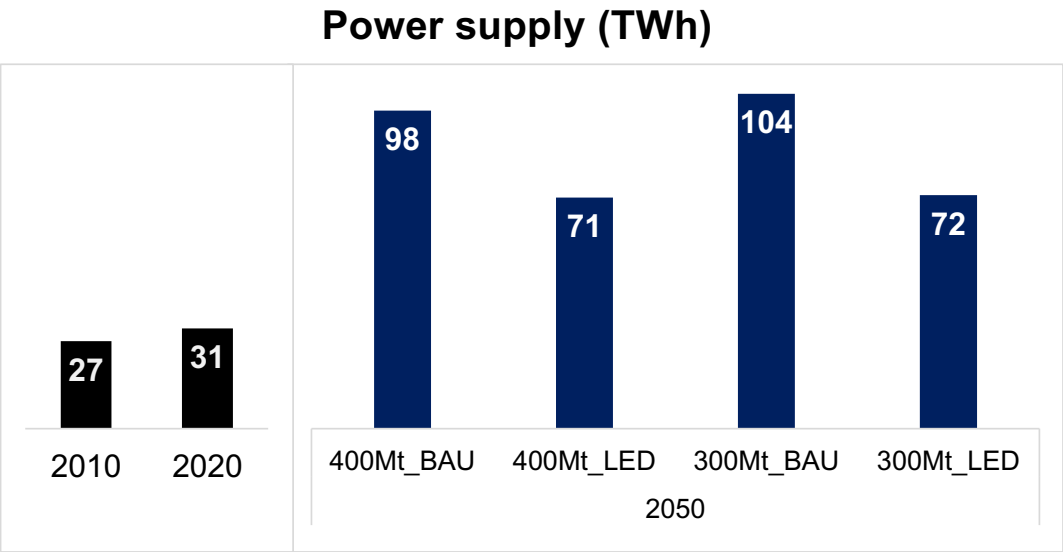
Average annual reduction rate

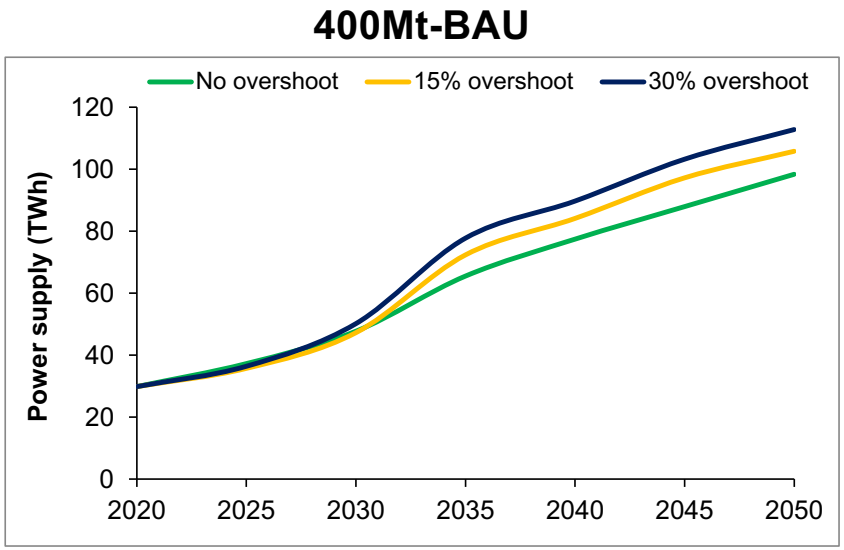


Average annual reduction rate



Results: Power Generation





Average annual growth rate

- 2010-20: ~1.5%
- 2020-2050: 3.0 - 4.2%

IEA net zero: Triple renewable by 2030

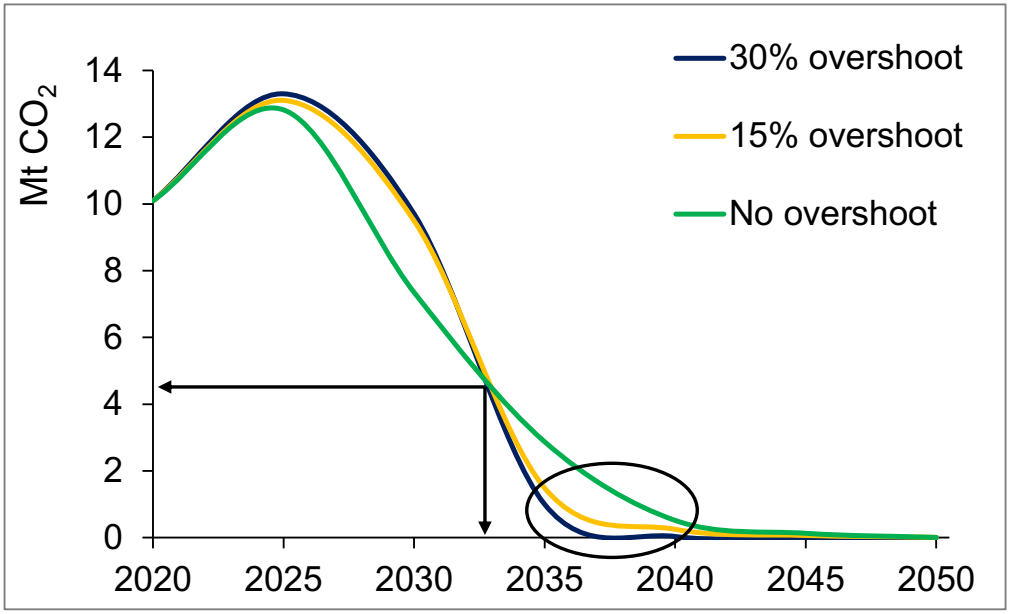
Ireland: 2022: 12 TWh (5.3 GW)
2030: 44 TWh (22.1 GW)

Overshoot would require more electricity:

- Residential: Hot water, Heating & Cooking
- Transport: Trucks, Bus

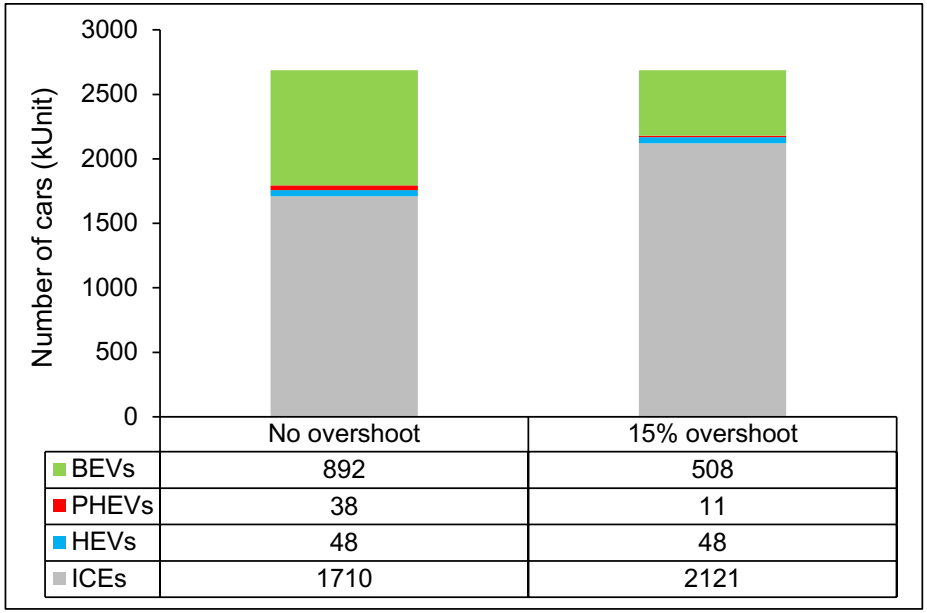
Results: Transport

Scenario: 400Mt-BAU



- Shared convergence point: 55% reduction by 2033 in all pathways
- Overshoot speeds up near-zero by 5 years

Private cars in 2030



	No overshoot	15% overshoot
BEVs	892	508
PHEVs	38	11
HEVs	48	48
ICEs	1710	2121

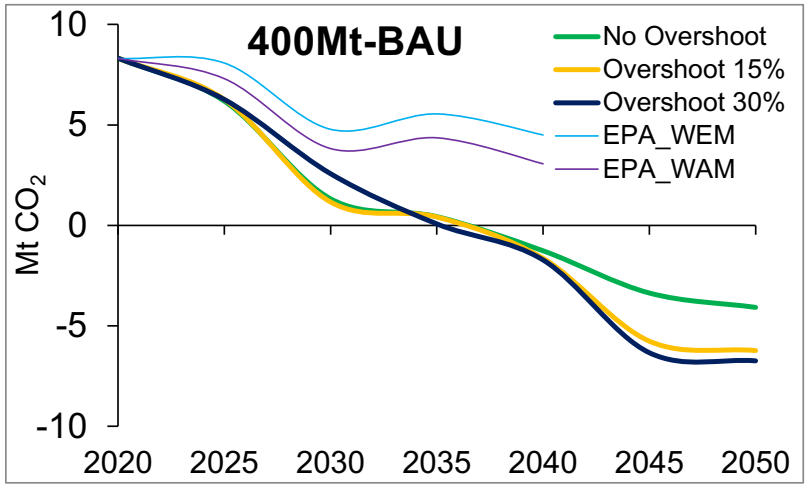
No overshoot scenario would require:

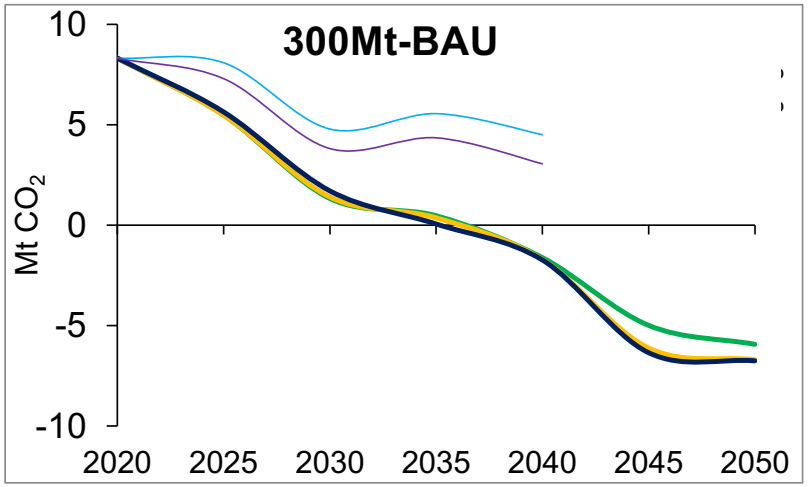
- 900k BEVs by 2030
- halt ICE sales from 2025

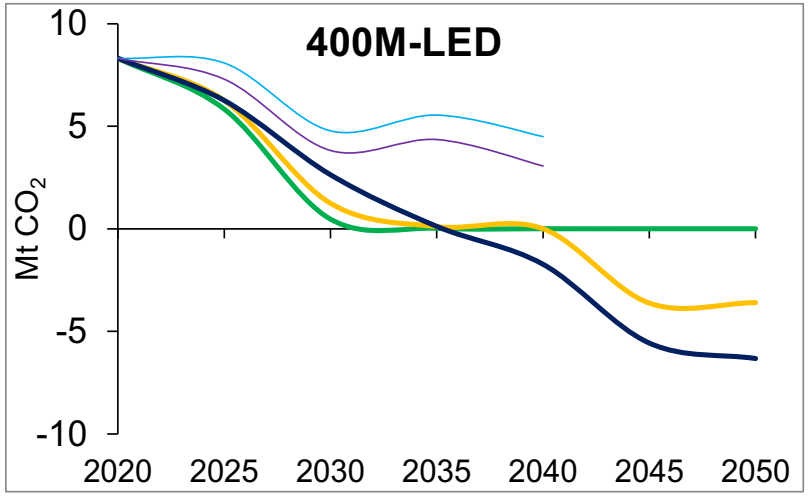
Overshoot scenario:

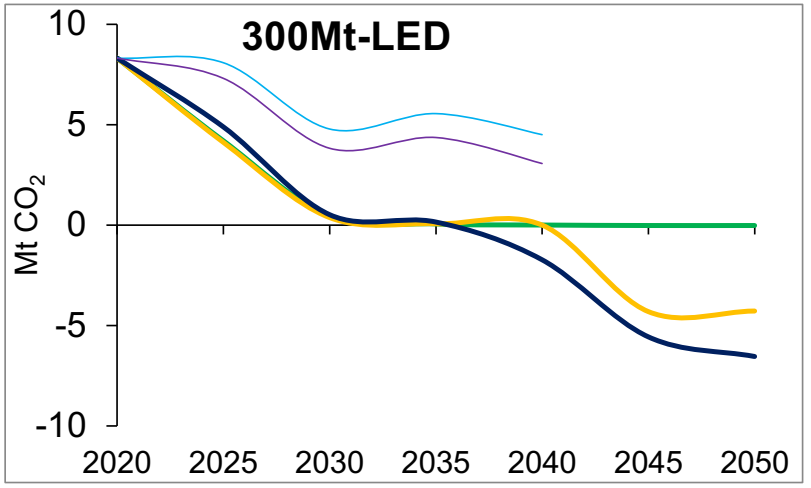
- 2.1M ICEs result in carbon lock-in

Identify the gap (power sector)



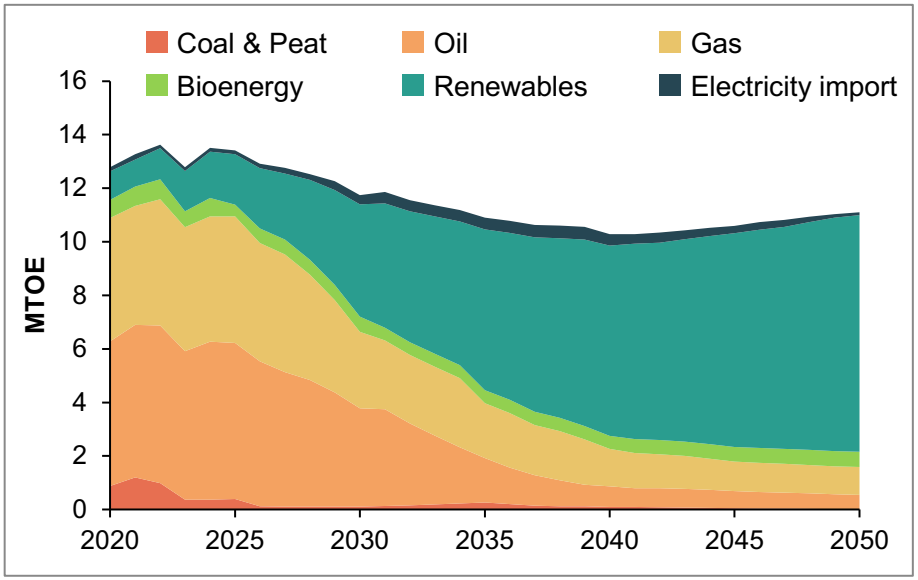




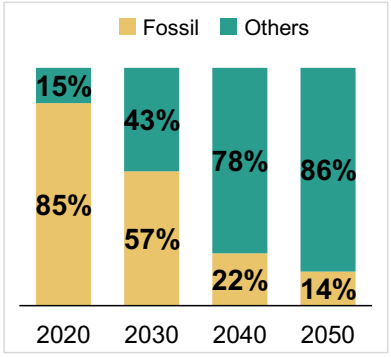


Primary energy

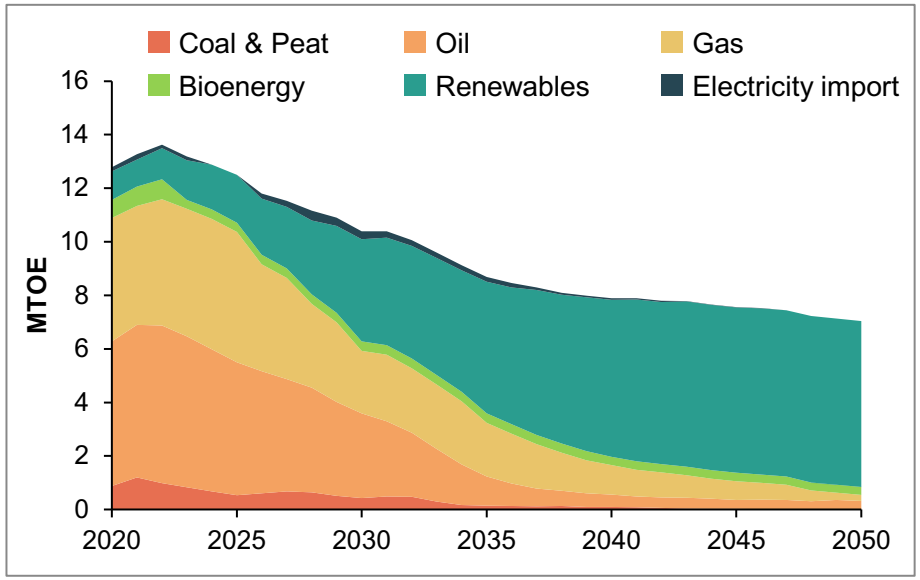
400Mt-BAU



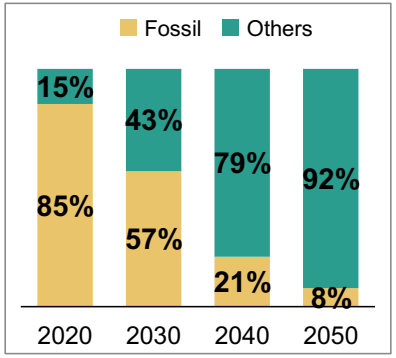
* Excluding jet fuel



400Mt-LED

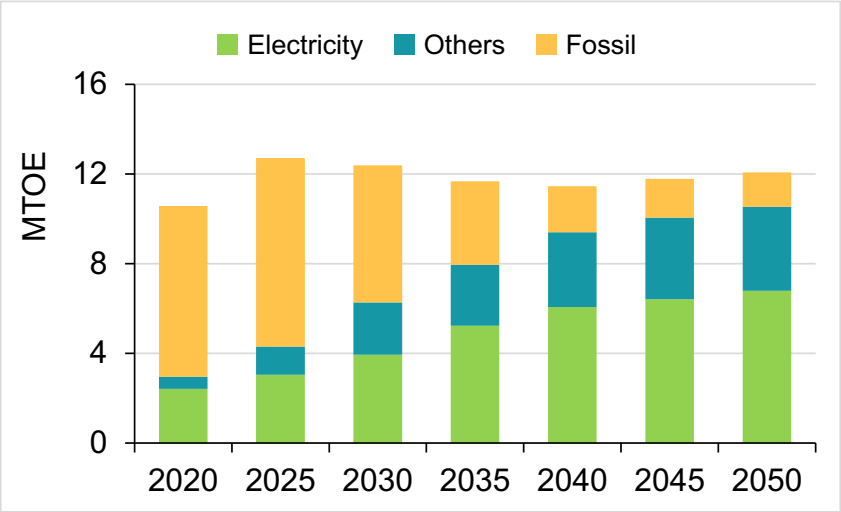


Total supply: about 45% lower than 2020



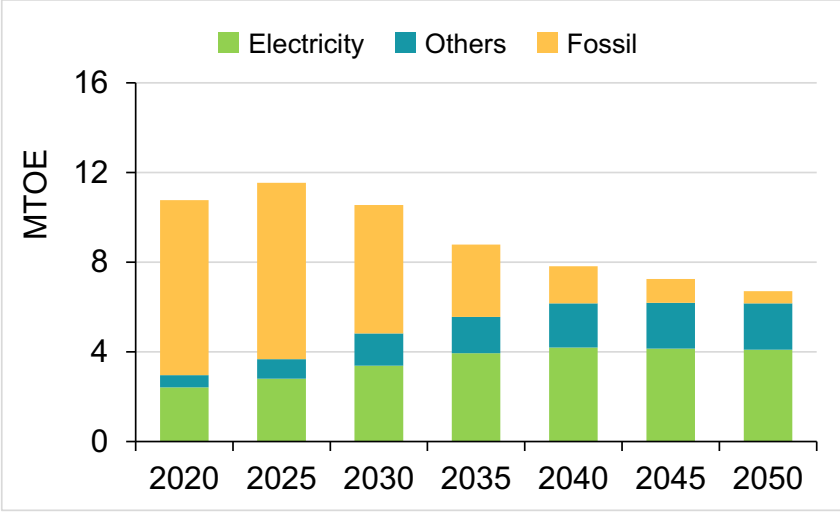
Final energy

400Mt-BAU



- Demand: +14%
- Electricity: from 23% to 56%
- Fossil: from 72% to 13%

400Mt-LED



- Demand: -38%
- Electricity: from 23% to 61%
- Fossil: from 72% to 8%

Others: Bioenergy, H2, Heat, Solar Heat. Note some includes additional electricity, indirectly

Scenario comparison

	1.7°C*	2.0°C	Impact of tighter CB
Carbon budget (Mt)	**300 BAU** (300) LED	**400** (400)	**-25%** (-25%)
System costs (B€)	**568** (422)	**475** (344)	**+20%** (+23)
Overshoot year	**2030** (2035)	**2040** (2050)	**-10 yrs** (-15)
Unmitigated (Mt)	**21** (3)	**9** (0)	**+12** (+3)
Power generation (Growth/yr)	**4.2%** (3.0%)	**4.1%** (3%)	**0.1%** (0%)
Wind & Solar in 2050 (GW)	**43** (34)	**42** (34)	**+1 GW** (0)
H2 for power (GW)	**2.4** (1.5)	**1.9** (1.3)	**+0.5 GW** (+0.2 GW)
BECCS (GW)	**1.4** (0)	**1.0** (0)	**+0.4 GW** (0)

* From 25% overshoot to be in line with CAP23 carbon budgets

A note on costs

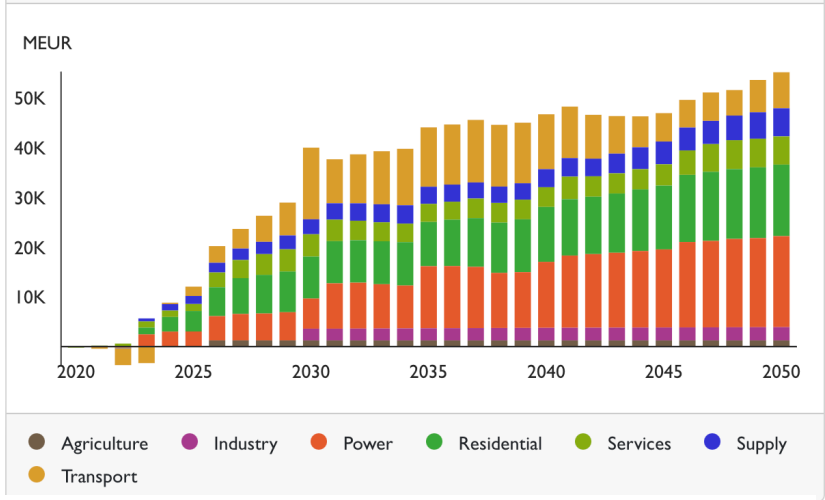
- 400MT-BAU scenario require additional **€55 bn investment** above "no mitigation" scenario,
  - ~€2bn/year, <1% annual GNI*
  - 300MT-BAU scenario ~34% greater
  - >70% of cumulative investment is required this decade

- Monetary & non-monetary benefits of energy transition accrue in later decades that recoup investment. Current energy system:
  - ~€9 bn annual fossil fuel imports (wholesale)
  - €1 bn cost of energy credits & financial support in 2022
  - Energy insecurity & inflation
  - Health & hardship: >1000 annual premature deaths from energy-related air pollution; high asthma & poor housing quality
  - Cost of fines to EU for exceeding GHG targets: €x bn?
  - Energy transition investment drives domestic economy

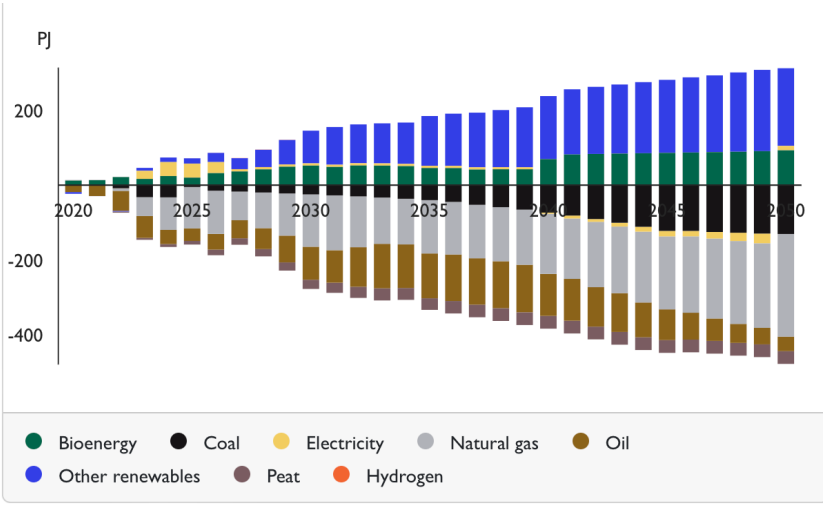
- LED scenario cuts costs significantly – sufficiency approach can bring broader benefits for wellbeing & nature

Difference between "No Mitigation" & 400MT-BAU

Cumulative lump-sum investment



Total Primary Energy Demand



Conclusions

- Nearly complete **phase-out of all fossil fuels** required in 2040s in all scenarios.
  - Phase out of coal & oil most urgent
  - No remaining carbon budget for additional fossil fuel equipment (e.g., ICE vehicles)
  - Planned decommissioning of natural gas infrastructure, with local heat plans required.
    - Gas still used for industrial heat in model, but new solutions are under development
  - Overshoot of SECs creates risks for stranded assets and/or carbon lock-in
- Depending on temperature outcome & early overshoot, some **negative emissions technology** (NETs) required. This brings **very significant risks & trade-offs:**
  - Technologies not proven at scale
  - Biomass with carbon capture and storage (BECCS) requires **significant land area**: up to 10% of Irish agricultural area in the 2040s for 6 $MtCO_2$ removal: conflict with nature, food, fibre and natural carbon sinks
  - Direct Air Capture and Storage (DACS) requires significant energy input (~2 $TWh/MtCO_2$) & cost projection >$800/t
  - NETs is mainly required to offset early overshoot of GHG emissions, not to allow ongoing fossil fuels in the long-term
- Approach to "sufficiency" – moderating final energy demands through structural change – is necessary

Next steps

- Which carbon budget scenario?
  - Decision for Council/CBWG
  - Scenario aligned with 50% 1.5C would be possible with LED, NETs & all mitigation options
- Planned model developments
  - Industrial heat
  - Bioenergy supply & land use interactions
  - Model DACS
  - Review key costs: renewables, EVs etc
  - International aviation & shipping
- CBWG reviews
  - Climate test (Joe Wheatley)
  - Assessment of deployment rates (SEAI)
  - Assessment of macroeconomic impacts (ESRI/Prof. John FitzGerald)
- Peer-review & expert consultation
  - Centralised process from CBWG or UCC-led?

Notes, assumptions & references

Carbon budget assumptions

- CB: downscaling remaining Global Carbon Budget from the beginning of 2020 on a **per-capita basis** to estimate Ireland's share
- **Global RCB:** from IPCC AR6 Table SPM.2, beginning from 2020 the global RCBs are 700 Gt (2C >83%, or 1.5C <17%) and 900 Gt 1.7C >67% or 1.5C 33%
- Two energy-related CBs for Ireland, each **rounded** to 300 and 400 Mt for the period of **2021-2050**
- Recent estimates indicate that GCB is reducing – from beginning of 2023, 250 Gt for 50% probability of 1.5C (Lamboli et. al., 2023). Inadequate non-CO2 mitigation exhausts this budget already (https://doi.org/10.21203/rs.3.rs-3326772/v1)
- This analytical framework **covers energy systems** CO2 emissions (excluding Int. Aviation and Shipping, excluding LULUCF),

TIM

- Energy system calibrated to 2022 energy balances
- Social discount rate: 2%
- Planning horizon: 2023-50
- "Unmitigated emissions": mitigation backstop technology €2000/tonne CO2
- Costs include fuel imports, energy technology investments

TIM Documentation Paper

- O. Balyk *et al.*, "TIM: Modelling pathways to meet Ireland's long-term energy system challenges with the TIMES-Ireland Model (v1.0)" *Geoscientific Model Development*, vol. 15, 2022 (Link)

TIM Application

- **Transport Sector:** V. Aryanpur *et al.*, "Decarbonisation of passenger light-duty vehicles using spatially resolved TIMES-Ireland Model" *Applied Energy*, vol. 316, 2022 (Link)
- **Low Energy Demand:** A. Gaur et al., "Low energy demand scenario for feasible deep decarbonisation: Whole energy systems modelling for Ireland" *Renewable Sustainable Energy Transition*, 2022 (Link)
- **Residential Sector:** J. Mc Guire *et al.*, "Developing decarbonisation pathways in changing TIMES for Irish homes" *Energy Strategy Reviews*, vol. 47, 2022 (Link)
- **Power Sector:** X. Yue *et al.*, "Least cost energy system pathways towards 100% renewable energy in Ireland by 2050" *Energy*, vol. 207, 2020 (Link)

Results Visualisation Website

- https://epmg.netlify.app/TIM-Carbon-Budget-2023/results/overview/emissions-and-cost

TIM Source Code on GitHub

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


MaREI
Energy · Climate · Marine


Environmental
Research
Institute


UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh


Science
Foundation
Ireland
sfi
For what's next

Teagasc FAPRI-Ireland Projections and MACC

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Athenry, Co. Galway

Agriculture and Food Development Authority

Teagasc FAPRI-Ireland Activity Projection

- Each year three model runs are provided
  - Base case (S1), Low Activity (S2) and High Activity (S3) scenarios
- The Low (S2) and High (S3) scenarios based on differing assumptions
  - About taxes/subsidies on beef and milk production that alter the beef and dairy cow breeding inventories
  - Core drivers of agricultural activity levels in Ireland and agricultural emissions
- Results of model runs provided to the EPA on annual basis
  - Used in the Agency's annual GHG inventory projections
- These activity projections also underpin the Teagasc MACC analyses

Teagasc FAPRI-Ireland Projections

- Activity levels as per the CRF tables
  - Animal inventories (Bovine/Ovine/Porcine/Poultry)
  - Chemical Fertiliser (N)
  - Lime application
  - Crops areas (Cereals/Beans/Root Crops)
  - Grassland (Pasture/Hay/Silage/Rough Grazing)
- Agricultural input and output prices
- Agricultural Commodity Supply and Use balances
- Economic Accounts for Agriculture (Output, Input and Income in Agriculture)
- Agricultural GHG emissions (absent MACC measure adoption)

Overview of 2023 activities: MACC

- 3rd Teagasc MACC published in July 2023 (Lanigan et al. 2023)
- Teagasc MACC is composed of 3 sub-MACCs
  - Agriculture / LULUCF / BioEnergy
- Teagasc Agriculture MACC analysis is based on
  - Detailed analysis of suite of technical measures
  - 3 Scenarios regarding agricultural activity levels (Base – S1, Low – S2, High – S3)
  - 2 alternative MACC measure adoption pathways (P1 and P2) at farm level (ambitious and very ambitious)
  - 2 sets (high and low) of measure costs
- The agricultural activity scenario projections used in the Teagasc MACC are based on FAPRI model runs provided to the EPA in late 2022/January 2023

Scenario Summary (including MACC measures)

- Medium term (2030) BAU projection indicate
  - established trends of contracting suckler cow inventories continues
  - continued though slowing growth in dairy cow numbers continues
- Without implementation of MACC measures the Carbon Budgets 1 and 2 are not adhered to
- **S1:** very ambitious adoption pathway (P2) required to adhere to budget
- **S3 (High):** budgets exceeded even under P2 pathway
- **S2 (Low)**: would require very ambitious measure adoption (P2)
- At P1 levels of measure adoption (or lower) budgets not met

S1 and Pathway 1 Agriculture MACC

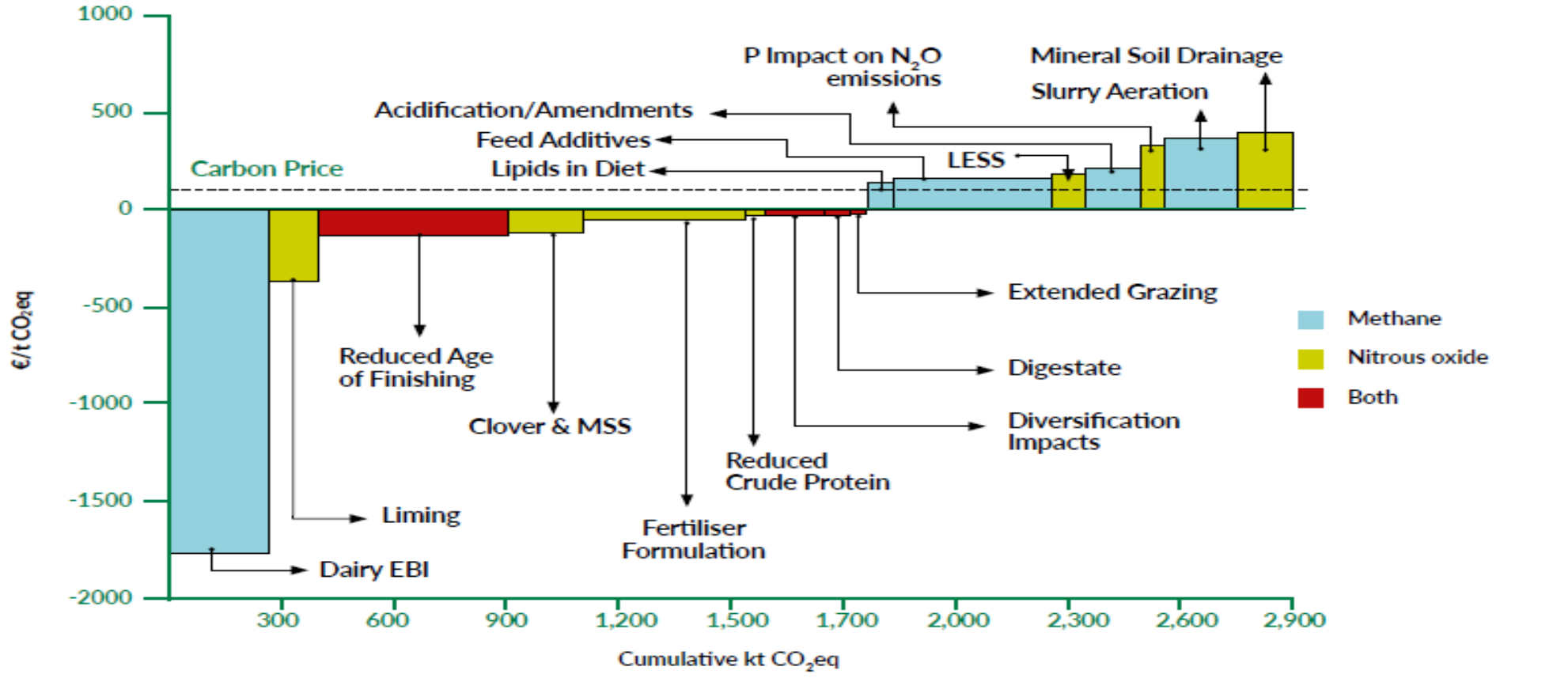


Figure 1: Agricultural MACC for the expected animal numbers (Scenario 1) with a similar level of measure adoption to that previously used (Pathway 1) for methane, nitrous oxide and both gases. The dashed line indicates a Carbon Price of €100 per tonne CO_2eq.

Scenario 1 Pathway 2 Agriculture MACC

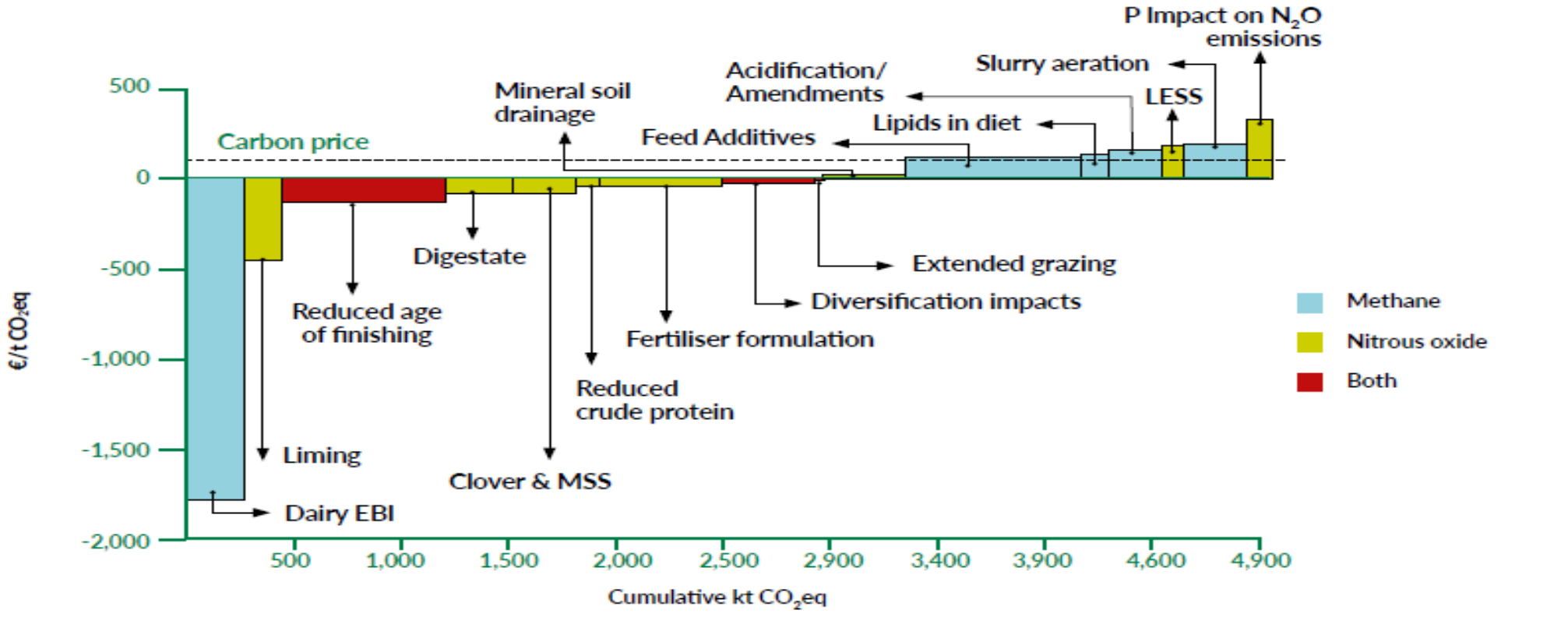
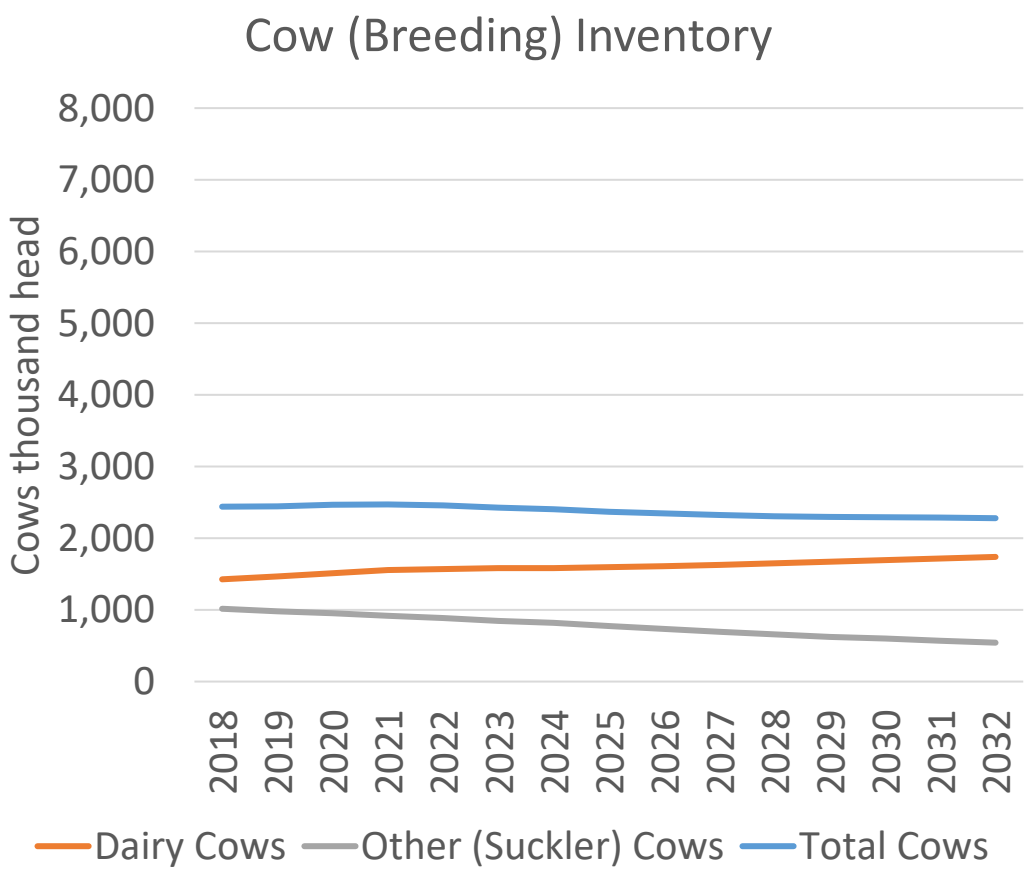
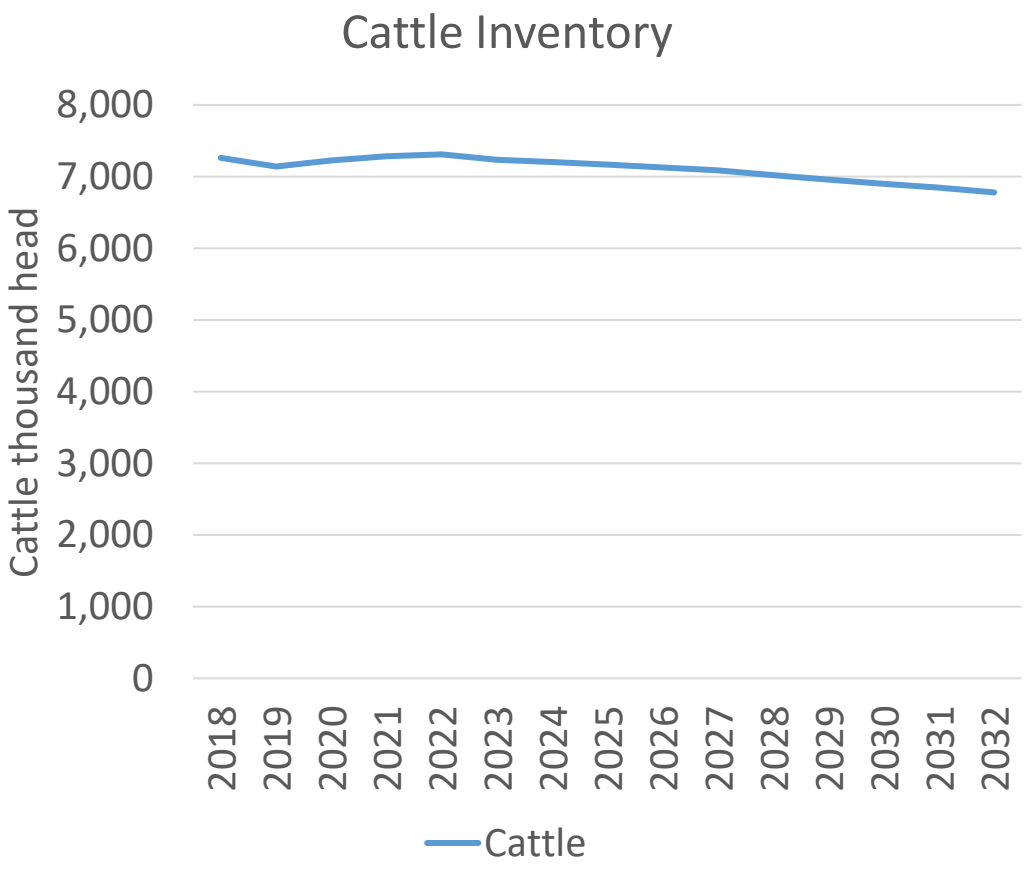


Figure 2: Agricultural MACC for the expected animal numbers (Scenario 1) with a high level of measure adoption (Pathway 2) for methane, nitrous oxide and both gases. The dashed line indicates a Carbon Price of €100 per tonne CO_2eq.

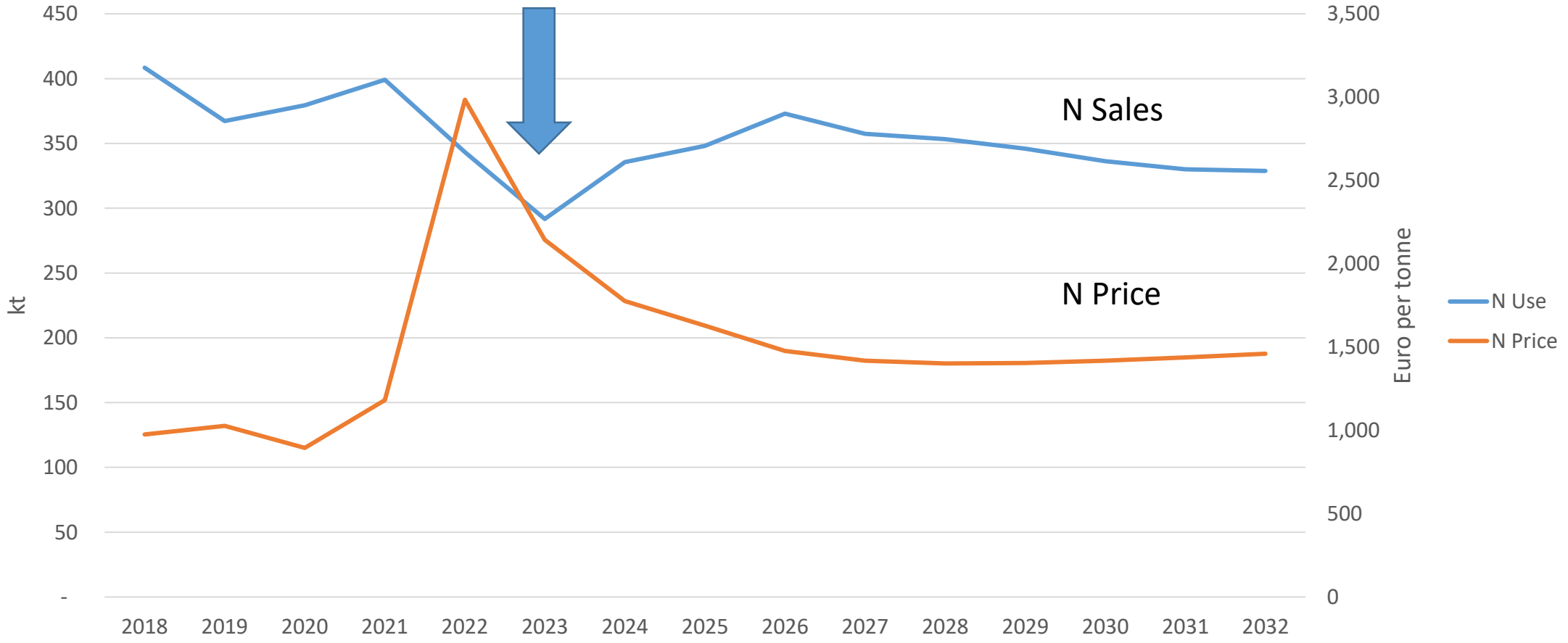
S1 Bovine activity projections





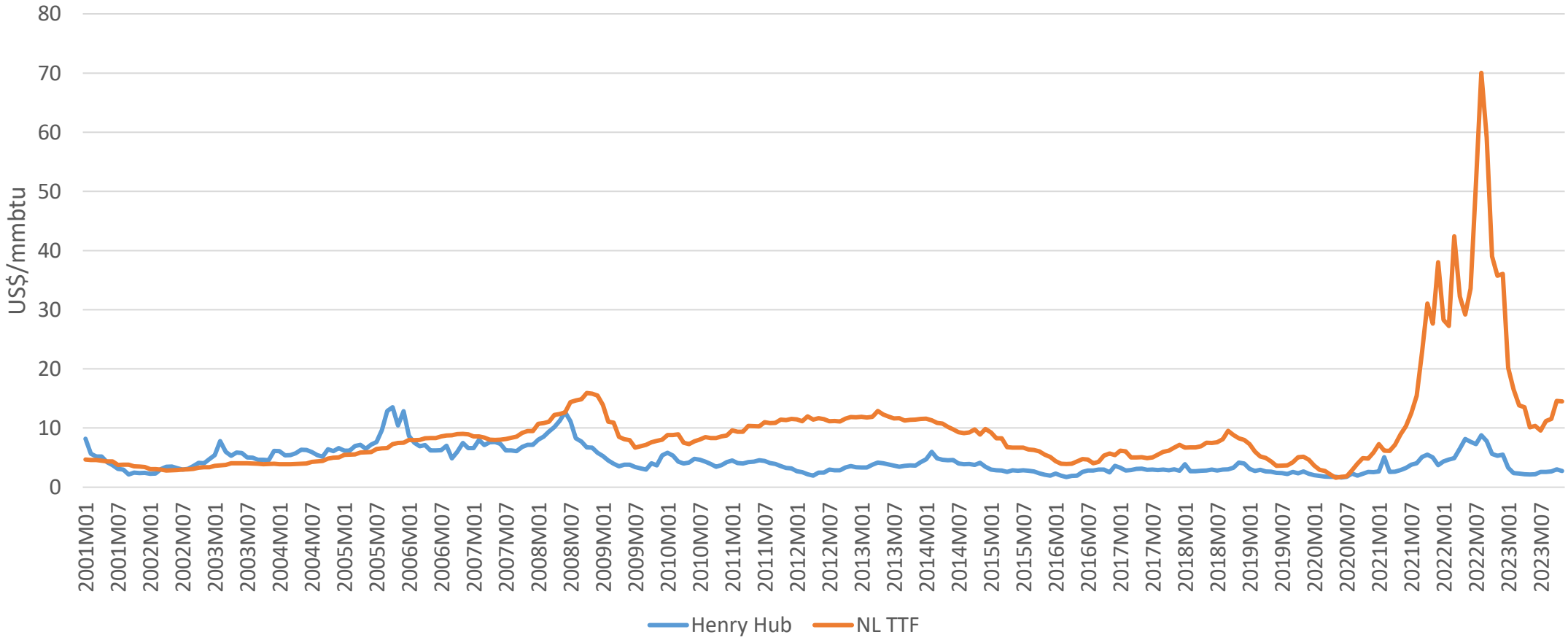
Teagasc FAPRI-Ireland Model.
Provisional: Not for quotation

S1 Chemical N Sales and N price



Teagasc FAPRI-Ireland Model.
Provisional: Not for quotation

Structural Break in Henry Hub and TTF price relationship ? Monthly 2001 - Present



Source: World Bank Pink Sheet https://www.worldbank.org/en/research/commodity-markets

Work in early 2024 & remaining uncertainties

- Teagasc MACC built on the FAPRI-Ireland projections from 12 months ago
- Provisional Base, Low and High Scenario projections provided to the EPA
  - Will require more work in January
- Projections subject to further revision in January to take account of
  - Macroeconomic projections from the ESRI COSMO model expected in early 2024
  - Updated European and Global Agricultural Commodity Market projections from colleagues at FAPRI at the University of Missouri
  - Reflection on assumptions relating to the relationship of Global reference prices for Natural Gas (Henry Hub) and Western European Gas Prices (NL TTF)
- Path of Irish fertiliser use – persistence of recent reductions in sales/use ?