Climate Change Advisory Council Secretariat

Carbon Budgets Working Group

Meeting No. 14
23rd May 2024

Agenda

Time	Agenda Item
13:30	1. Opening of Meeting
13:35	2. Presentation of the 2nd iteration of Core Modelling Results
15:25	3. Carbon Budgets Work Plan
15:30	4. Next Steps and Agenda for next meeting
15:35	5. AOB
15:45	Meeting Close

1. Opening of Meeting

Action Number	Date Raised	Description	Owner	Due	Status
15	29/02/24	Request for clarification on the role of the CBWG in terms of presenting a range of scenarios for Council consideration as opposed to proposing a particular feasible pathway.	CCAC Secretariat	April 2024	Proposed to close *Role of CBWG outlined in the ToR reiterated for clarity at the Council meeting on the 25th of April.*
16	29/02/24	Request for a more detailed discussion within the CBWG on the feasibility of various scenarios	CBWG Members	May 2024	Proposed to Close *(1) Accompanying descriptive narrative for each of the modelled scenarios requested from core modelling teams.* *(2) Scenario dialogue tool developed to facilitate a collective narrative on impacts of various scenarios based on feedback from all CBWG members.*
17	29/02/24	Core and additional modelling teams to confirm delivery timelines for the 2nd iteration of modelling and analysis in line with Carbon Budgets Workplan	CBWG Members	Mar 2024	Proposed to close *Core modelling teams confirmed delivery of 2nd iteration results on 23rd May (UCC, Teagasc and University of Galway).* *Additional modelling teams confirmed delivery of results on 28th June (Central Bank) & 25th July (SEAI).* *The Secretariat and CBWG economists (JF, ESRI, Central Bank) met on the 14th of May to discuss macroeconomic analysis*

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	Open Trilateral discussion with NTA, TIM and SEAI CBWG members scheduled for Monday the 27th of May
21	22/03/24	Secretariat to issue a poll to hold an in-person meeting in an alternative location	CCAC Secretariat	May 2024	*Proposed to Close* Poll in relation to July and August meetings issued on 23 April

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5. Carbon Budgets Workplan: 2nd Iteration of Modelling & Analysis

Item	Description	2024											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	**Modelling / Analysis Iteration 2**												
2.1	Agree inputs, parameters 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												

- **CBWG Meeting No. 14, Thursday 23rd May 2024, 13:30 – 16:30:**
  - 2nd Iteration of Core Modelling Results
- **CBWG Meeting No. 15, Friday 28th June 2024, 13:30 – 16:30:**
  - Analysis of warming impact of selected core scenarios (2nd iteration),
  - COSMO Macroeconomic Modelling Results (based on 1st and 2nd iteration)
- **Thursday 25th July 2024, 13:30 – 16:30**
  - Additional Testing of Scenario Results (SEAI & NTA)
  - Agree inputs, parameters and assumptions for 3rd Iteration of Modelling

5. Carbon Budgets Workplan: 2024 Meeting Schedule and Proposed Topics

CB WG Meeting No.	Proposed Date and Time	Topic(s) for Consideration
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)/ *COSMO Macroeconomic Modelling Results (based on 1st and 2nd iteration)* *Discussion on various aspects of aviation and maritime (Secretariat)* *Decarbonised Electricity System Study (SEAI)*
16	Thursday 25th July 2024, 13:30 – 16:30	Agree inputs, parameters and assumptions for 3rd Iteration of Modelling/ *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)
17	Thursday 29th August 2024, 13:30 – 16:30	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 in Ireland (ESRI)

Update on in person attendance at selected CBWG meetings:

- July meeting: Yes (4), No (3), Maybe (1)
- August meeting: Yes (4), No (2), Maybe (2)
- Locations: Dublin City Centre (5), Dublin EPA (3), Galway (3)

6. Next Steps

1. Core modeling teams to submit results in line with Joe Wheatley's template for subsequent warming analysis by 24th May
2. Core modelling teams to submit Accompanying Descriptive Narrative for Scenarios developed as part of the 2nd iteration of modelling and analysis
3. Secretariat to circulate updated scenario dialogue tool to be updated by all CBWG members in June and July

7. AOB

- Update on Carbon Budgets Working Group Membership

GOBLIN Scenarios for carbon budgets towards 2050

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

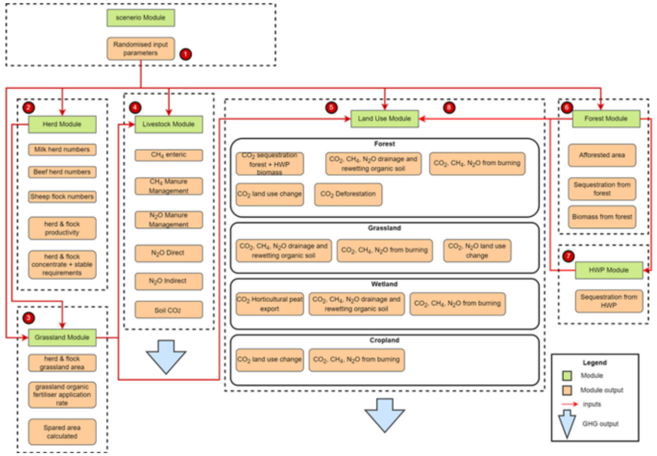
An Roinn Comhshaoil, Aeráide agus Cumarsáide
Department of the Environment, Climate and Communications

Modelling Approach

1. Scenarios

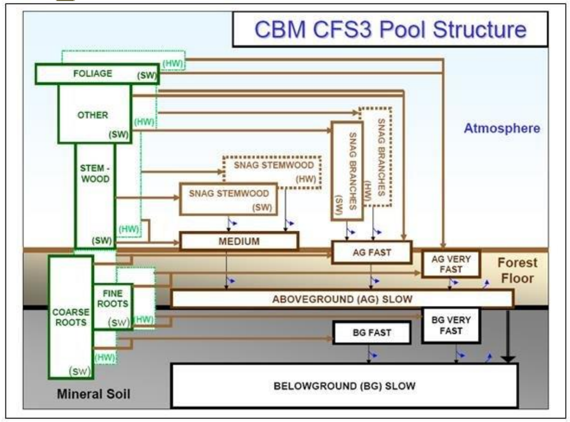
- Current data (baseline)
- MACC assumptions (2030)
- Animal number/productivity scenarios
- Land use choices

2. GOBLIN



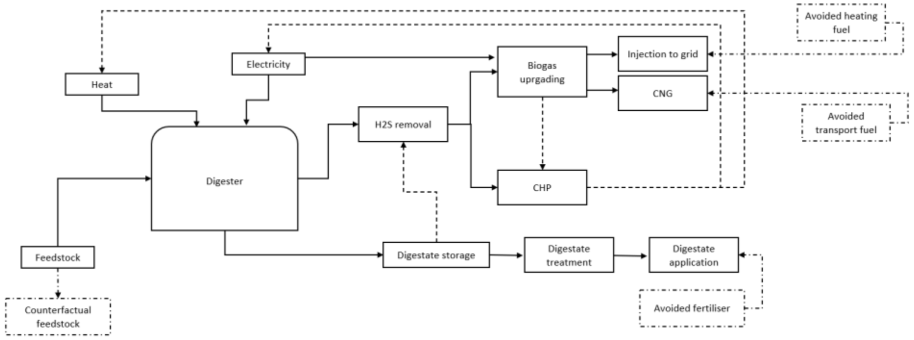
Areas
Soils
Forest types

3. FERS-CBM



Areas
Grass yields
Manure

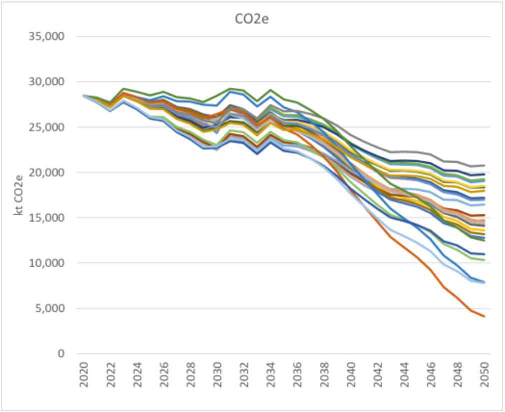
4. LCAD 2.0



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

Scenario rationale

- Emphasis on dairy specialisation
  - Profitability vs beef & sheep (NFS, 2022)
  - Maintain bovine protein output
  - Aligned with more sustainable diet dairy to beef ratio (Soteriades et al., 2020 https://doi.org/10.1016/j.jenvman.2020.111054; Mazzetto et al., 2020 https://doi.org/10.1016/j.jclepro.2020.124108; Porto-Costa et al., 2023 https://doi.org/10.1016/j.jclepro.2023.138826)
- Ambitious abatement
  - Build on MACC+ (extensive deployment of upper-end technical abatement)
  - AD: Future-oriented low-emission deployment (food waste > slurry > grass-clover) (Styles et al., 2022 https://doi.org/10.1016/j.jclepro.2022.130441; O'Donnell et al., 2021 https://www.sciencedirect.com/science/article/pii/S0048969721023226)
- Organic soil rewetting (90% of drained area)
- Forestry
  - Commercial afforestation plus future wood use = "carbon pump" (Forster et al., 2021 https://www.nature.com/articles/s41467-021-24084-x)
  - Long-term forest strategy (2100+) critical to avoid future carbon cliffs (Duffy et al., 2022 https://www.nature.com/articles/s41893-022-00946-0)
  - Doubling temperate forest area need to meet future wood demand (Forster et al., in review)
  - Current policy > post 2050, or max historic rate for 50 years, tailing off (30% forest cover by 2125)

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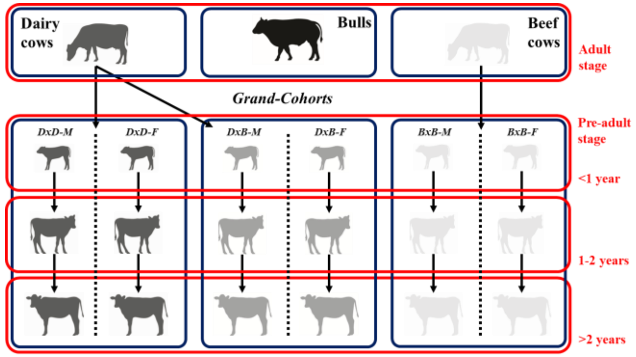
Agriculture



Aspect	2020 Baseline (Ambition 0)	Ambition 1	Ambition 2
Livestock protein output	• 2020 cattle herd • 2020 sheep flock • 2020 dairy cow productivity (14.85 L/day) AG-30%	• 2020 protein outputs (1.725m dairy cows and 150k beef cows) • 2020 sheep flock decreases by 20% • Increased dairy cow productivity (15.3 L/day) AG-45%	• 2020 protein outputs (1.418m dairy cows and 150k beef cows) • 2020 sheep flock decreases by 20% • Increasing dairy cow productivity strongly (19.2 L/day) AG-50% & AG-60%
Livestock management	• 2020 mean slaughter ages • 2020 mean slaughter weights	• Mean slaughter ages decrease by 50 days • 2020 mean slaughter weights	• Mean slaughter ages decrease by 100 days • 2020 mean slaughter weights
Grassland sward composition and management	• 0% white clover swards (WCS) • 100% perennial ryegrass swards (PRS) with 2020 inorganic N fertilisation rates	• 50% WCS without inorganic N fertilisation • 50% PRS with 2020 inorganic N fertilisation rates	• 75% WCS without inorganic N fertilisation • 25% PRS with 2020 inorganic N fertilisation rates
Fertiliser type	• 0% inorganic N fertiliser spread as protected urea	• 50% inorganic N fertiliser spread as protected urea	• 100% inorganic N fertiliser spread as protected urea
Grassland use efficiency	• 2020 dairy farm GUE (72%) • 2020 beef farm GUE (55%)	• Dairy farm GUE increase (75%) • Beef farm GUE increase (60%)	• Dairy farm GUE increase (75%) • Beef farm GUE increase (65%)
Afforestation	• 75% deciduous trees • 25% coniferous trees • 15% thinning	• 50% deciduous trees • 50% coniferous trees • 15% thinning	• 25% deciduous trees • 75% coniferous trees • 15% thinning
Methane inhibition	• 0%	• 15% enteric fermentation • 38.5% manure management	• 30% enteric fermentation • 75% manure management

- Ambitious deployment of proven technologies
- Conservative approach: maintain bovine protein output (but 18% reduction for AG-60% scenario)
- 2050 end-points, interpolated via a 25% Ag emission reduction by 2030

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Agriculture

Scenario climate targets	kt CO_2e	Dairy Cows	Suckler Cows	% change adult herd	Sheep	Bovine protein (kt yr^{-1})
Baseline	21,270	1,555,000	915,000		2,556,000	440
-30%	14,889	1,555,000	915,000	0	2,556,000	440
-40%	12,762	1,643,651	516,068	-13%	2,289,420	440
-45%	11,518	1,725,000	150,000	-24%	2,044,800	440
-50%	10,635	1,418,000	150,000	-37%	2,044,800	440
-60%	8,508	1,151,647	121,824	-48%	1,660,710	361

- Protein output can be maintained with smaller herd

Soils & biogenic C

- Numerous updates to organic soils & wetlands in NIR
  - Much higher CH_4 fluxes from rewetted soils
  - New wetland land use categories with new EFs
- Not yet embedded in GOBLIN (shift towards GeoGOBLIN)
  - Have proxied soil rewetting effects for now (caveats!)
  - Priority for coming months
- Emphasis placed on tracking biogenic C flows from AFOLU
  - IEA work on BECCUS
  - Aligns with IAMS climate models, future carbon pricing, land use diversification
  - Assume decadal progression of CCS deployment

Anaerobic digestion

Ollscoil na Gaillimhe
University of Galway

- Feedstock
  - 75% of national food waste
  - 75% pig & poultry slurry
  - Housed dairy slurry (equivalent)
  - Grass-clover @ 9 t DM ha^{-1} (134 kha)
  - 5.7 TWh bio-CH_4 gross

Indicative calculations of:

- Avoided energy sector emissions (progressive decarbonisation through time)
- Negative emissions potential via BECCS (progressive deployment through time)
- Avoided manure management emissions

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Anaerobic digestion cont…

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
Carbon capture	Progressive combustion (BE)CCS
Digestate storage	Closed tank
Digestate application method	shallow injection

Outside temperature	9.8°C
Feedstock temperature	9.8°C
Electricity displaced by CHP	Combined cycle (NG) (progressive CCS)
Grid fuel being displaced	Natural gas (progressive CCS)
Biomethane displacement to 2040	Diesel
Biomethane displacement 2040+	Natural gas with progressive CCS

Carbon capture

Period	(BE)CCS deployment
2025-2029	0%
2030-2039	20%
2040-2049	40%
2050-2059	60%
2060+	80%

Pertinent for 2050 Net Zero

Assume equal CCS deployment on stationary bio- & fossil- (substituted) energy sources…

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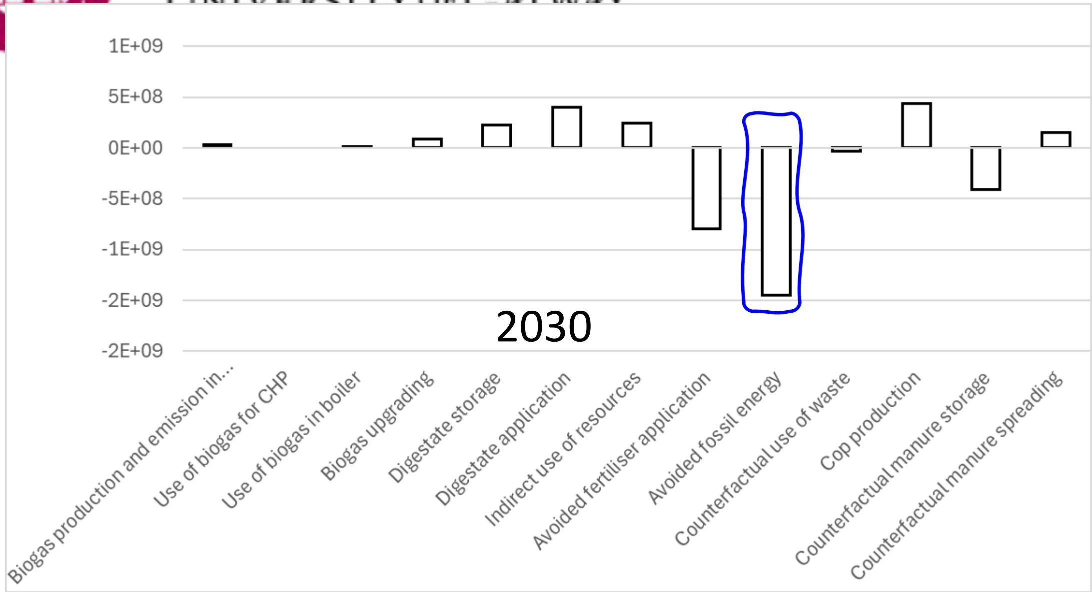
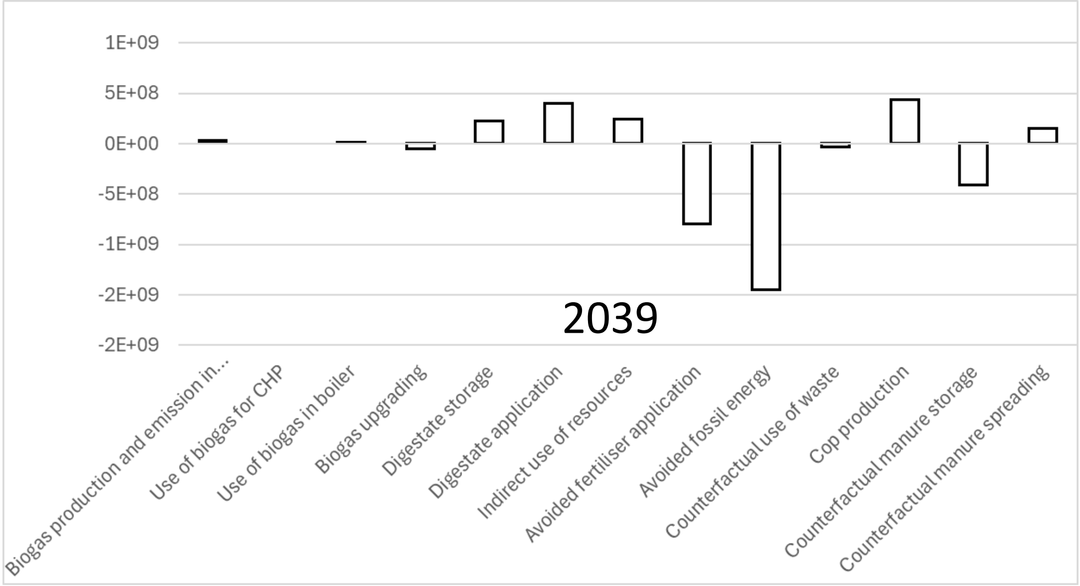
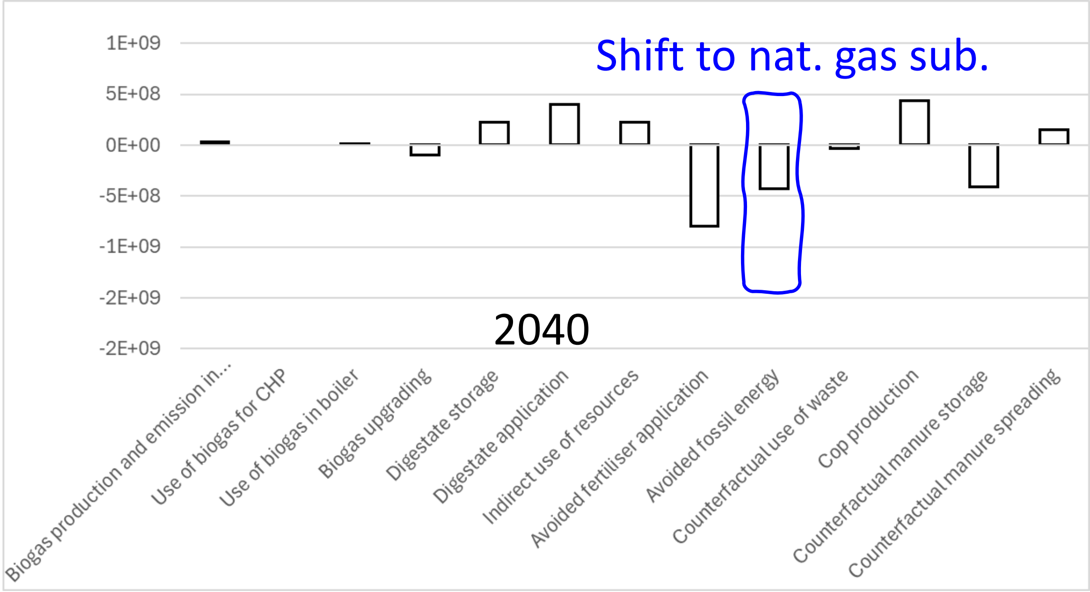
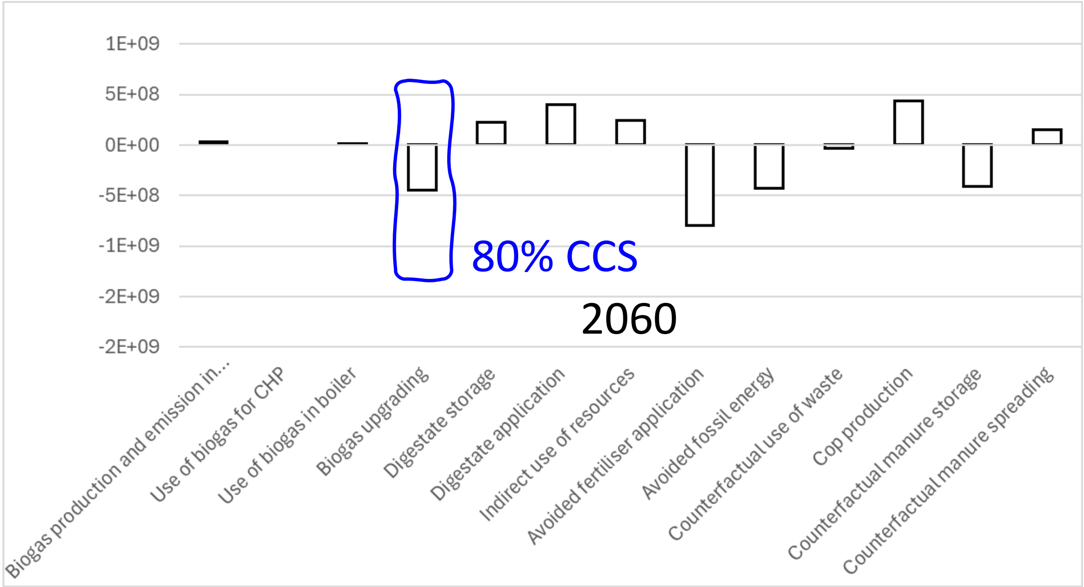
AD GHG balance

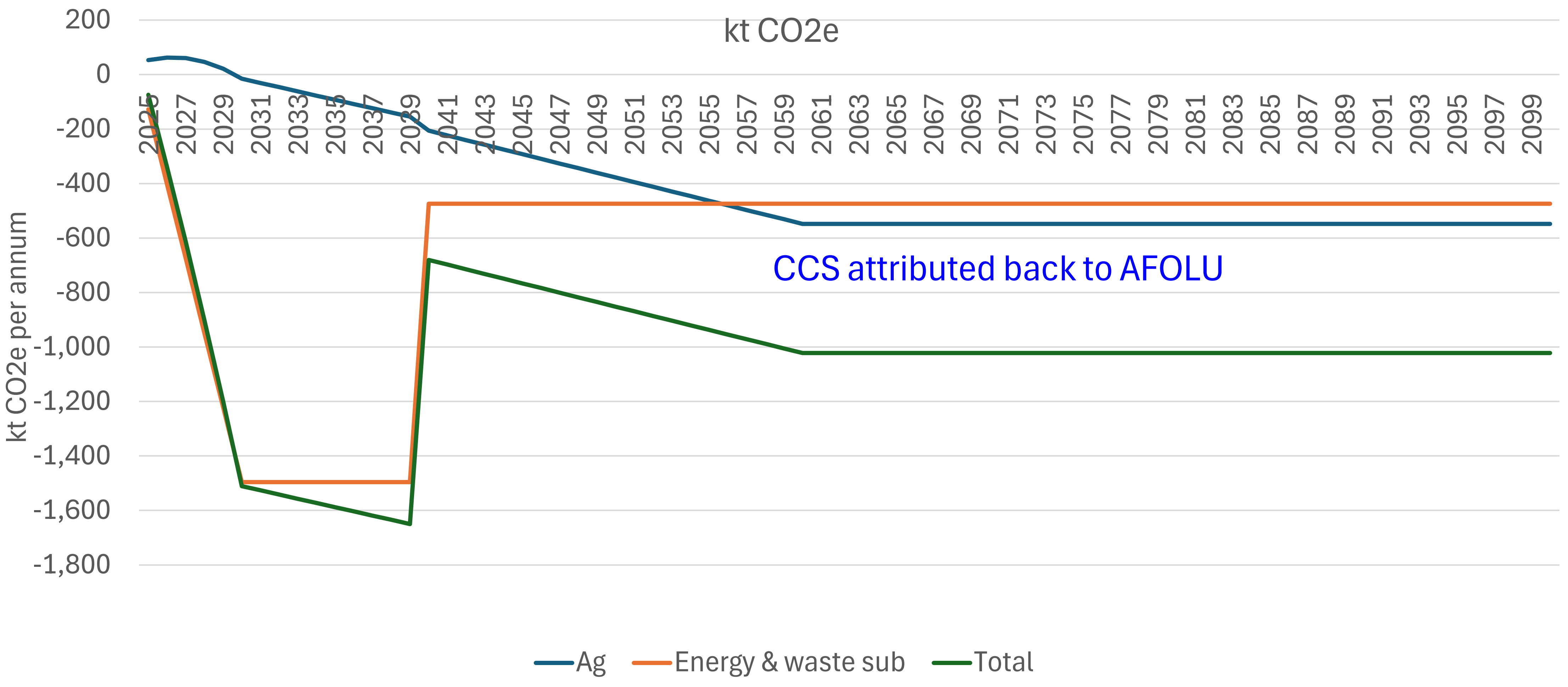








AD GHG time series



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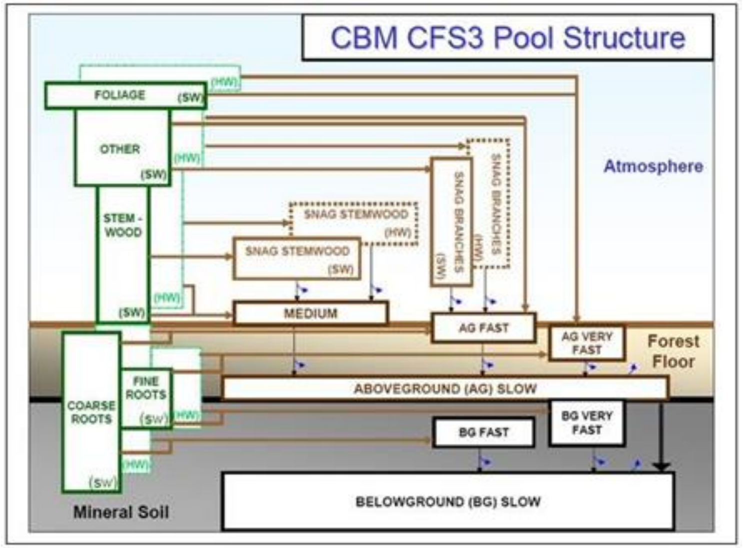
Forestry

fers



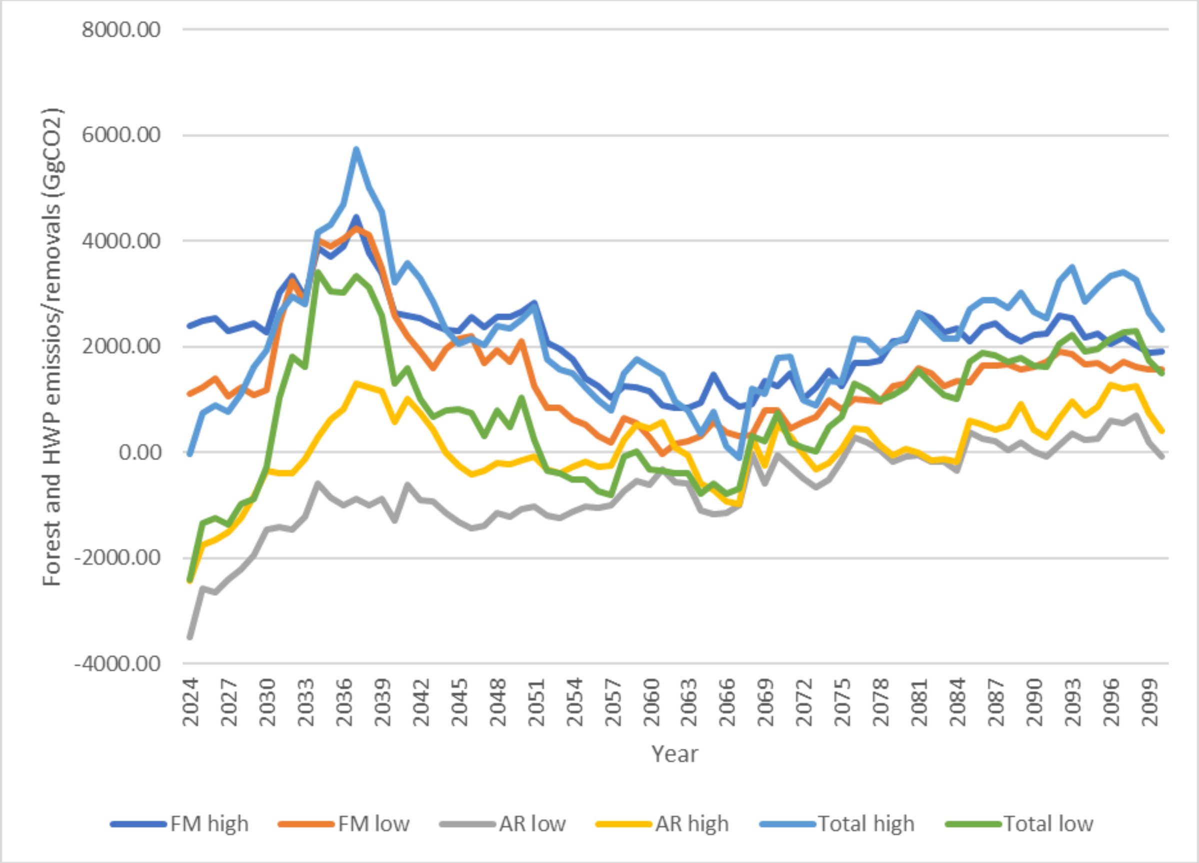
- Soils
  - 15% organo-mineral; 85% mineral
  - 100% mineral
- Management
  - Current silvicultural management
  - More sustainable management (longer rotations, enhanced long-term C retention, more continuous cover forestry)
- Planting rate
  - Current policy >>>
  - 50yr @ historic max

	2027-2030	2031-2080	2081-2125	AR area by 2125
		kha yr-1		ha
Standard planting rate	8,000	8,000	8,000	791,500
Maximum planting rate	16,000	25,000	4,000	1,497,500

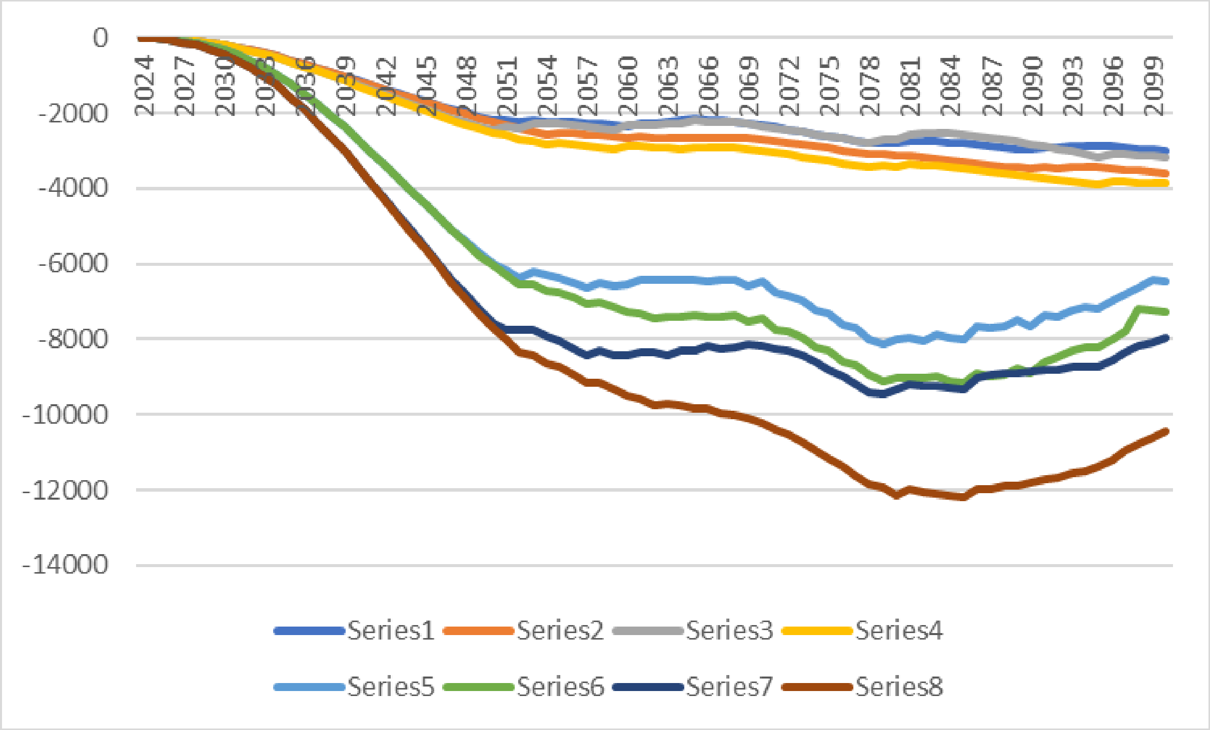
Forestry to 2100

Ex. BECCS

Existing forest

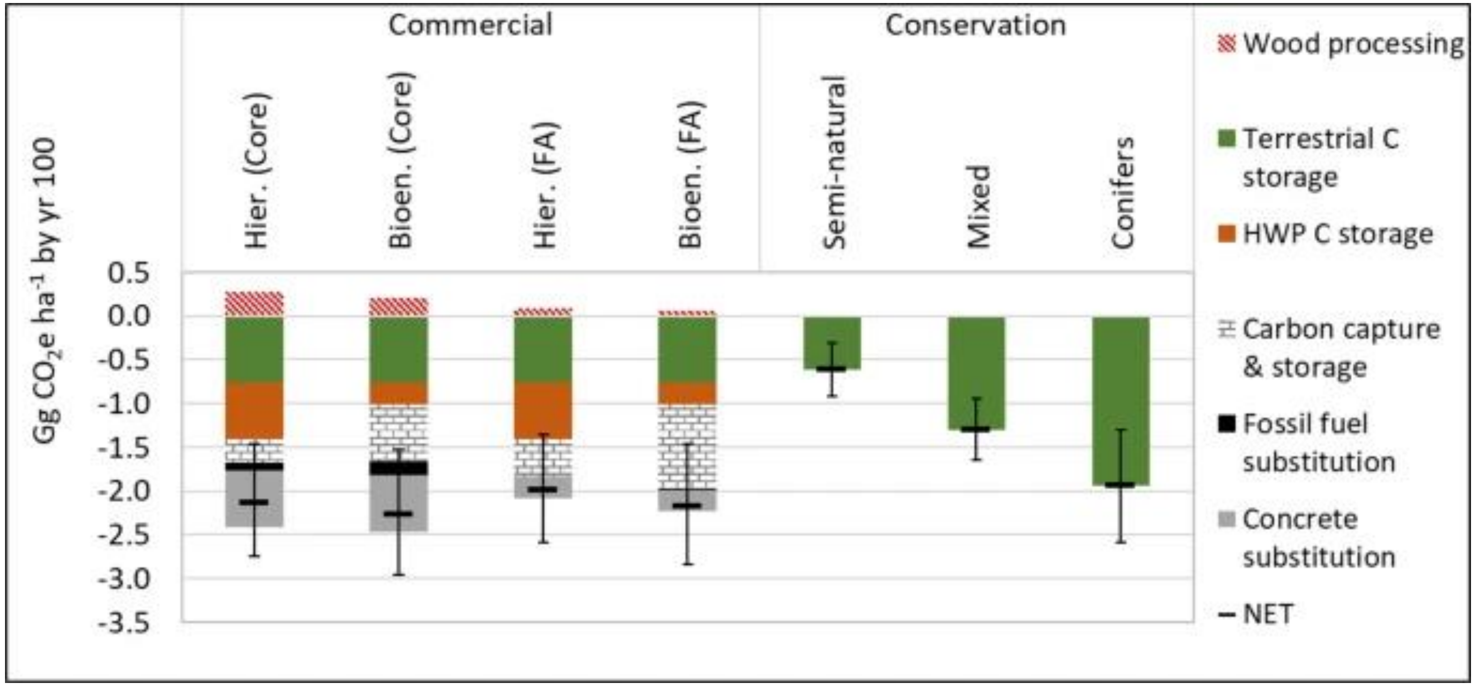


Afforestation 2025+



Range = rates, tree species & soils

HWP accounting



- Forster et al., 2021 https://www.nature.com/articles/s41467-021-24084-x
- Cascading uses and future CCS = substantial, ongoing mitigation potential ("carbon pump")
- Inventory reports carbon storage in first products (sawn wood and wood based panels)
  - Substitution credits elsewhere
  - Holmgren (2021) estimated 3.7 Mt CO_2e annually displaced by HWPs in Ireland
- Instant oxidation assumed at end-of-life via stock decay function

Wood products

- Current product NIR breakout assumed constant (conservative)
  - 10% bioenergy, 30% sawn wood, 20% panels
  - HWP CO_2 storage factors in core forestry numbers
- Indicative product substitutions for sawn-wood & panels
  - Holmgren (2021) factors: 1.5 and 1 t C per t C (but decline as economy decarbonises – coupled with CCS deployment)
- Indicative (future, 2030+) fossil energy substitution: natural gas
  - 10% harvest plus 20% from sawmill residues plus HWP outflow (wastes)
- Indicative (future) BECCS from above bioenergy
  - Same estimated CCS deployment rates used for AD

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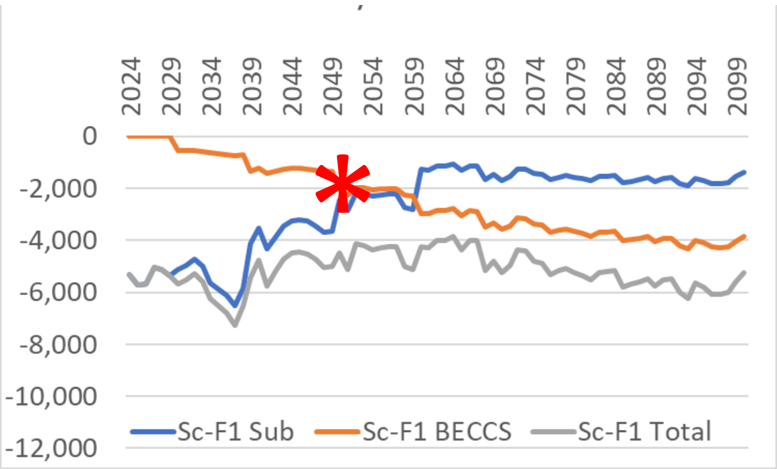
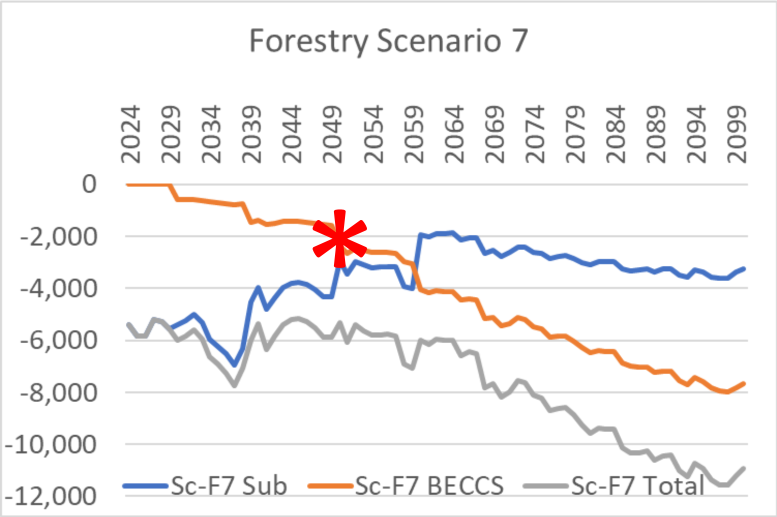
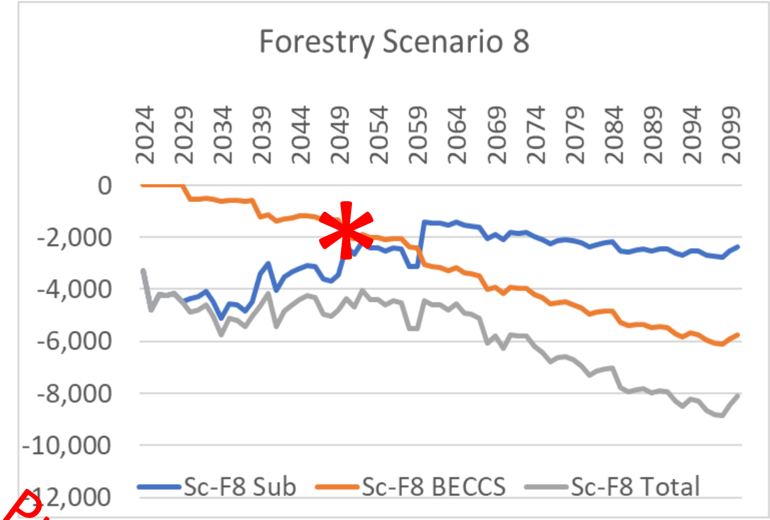
Indicative substitution & BECCS







- Sc-F1 = current policy planting, high harvest
- Sc-F7 = high planting rates, high harvest
- Sc-F8 = high planting rates, reduced harvest (as per overall Sc-3)

Preliminary tentative potentials - not necessarily reflected in NIR

* c.2 Mt CO_2e CCS estimates included in 2050 forestry balance (60% CCS deployment)

Holmgren (2021) factors applied for substitution - may be abroad (exported wood, or displacing imported steel, etc). Not included in forestry balance.

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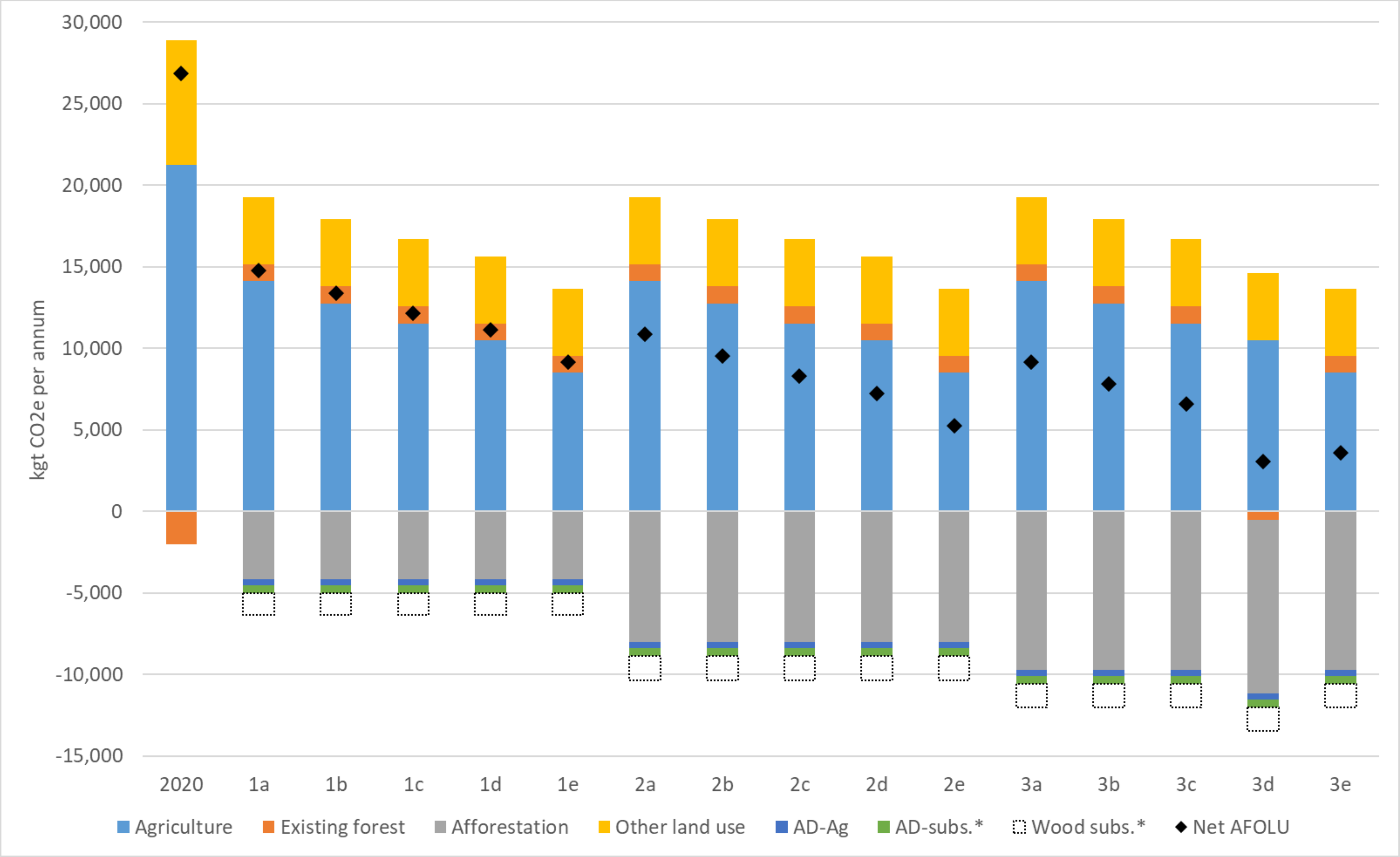
Scenario summary

- Spared land areas assigned to: (i) organic soil rewetting; (ii) AD for 5.7 TWh yr^{-1} biomethane (prioritising food waste and slurry); (iii) afforestation as specified below; (iv) biodiversity & other ES on remaining area

Scenario	Agriculture	Forestry
1a 1b 1c 1d 1e	• AG-30% (current herd structure, MACC+, 30% GHG reduction) • AG-40% (intermediate herd, MACC+, 40% GHG reduction) • AG-45% (dairy specialisation, MACC+, 45% GHG reduction) • AG-50% (dairy specialisation, high yield, MACC+, 50% GHG reduction) • AG-60% (dairy specialisation, high yield, MACC+, scaled to 60% GHG reduction)	BAU mix (50:50 C:BL), 15% on organo-mineral soils: 8 kha per year planting > 2030
2a 2b 2c 2d 2e	• AG-30% (current herd structure, MACC+, 30% GHG reduction) • AG-40% (intermediate herd, MACC+, 40% GHG reduction) • AG-45% (dairy specialisation, MACC+, 45% GHG reduction) • AG-50% (dairy specialisation, high yield, MACC+, 50% GHG reduction) • AG-60% (dairy specialisation, high yield, MACC+, scaled to 60% GHG reduction)	BAU mix (50:50 C:BL), 15% on organo-mineral soils: 25 kha per year 2030-2080
3a 3b 3c 3d 3e	• AG-30% (current herd structure, MACC+, 30% GHG reduction) • AG-40% (intermediate herd, MACC+, 40% GHG reduction) • AG-45% (dairy specialisation, MACC+, 45% GHG reduction) • AG-50% (dairy specialisation, high yield, MACC+, 50% GHG reduction) • AG-60% (dairy specialisation, high yield, MACC+, scaled to 60% GHG reduction)	70:30 C:BL mix, 100% mineral soils: 25 kha per year 2030-2080

2050 GWP_{100} balance



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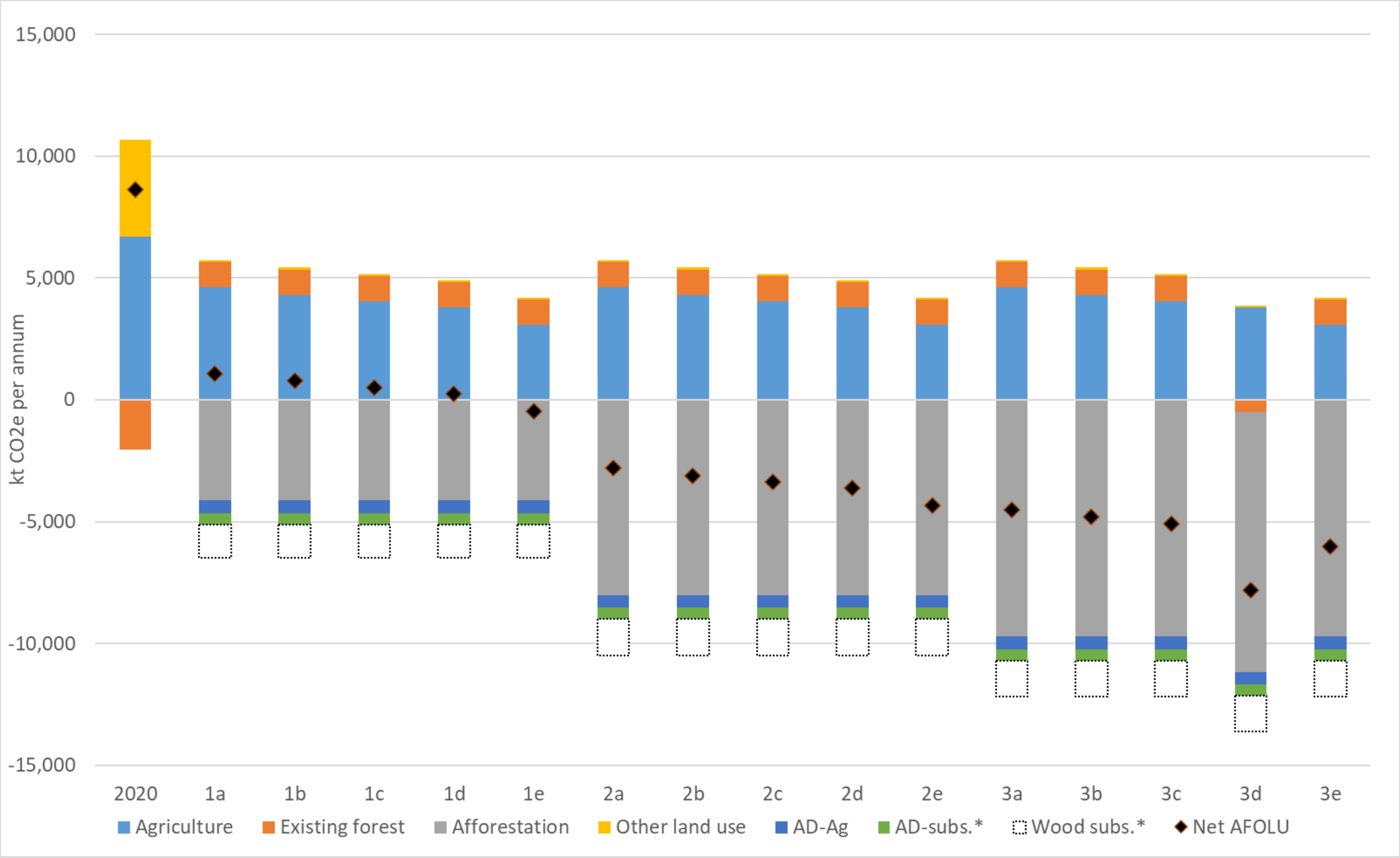
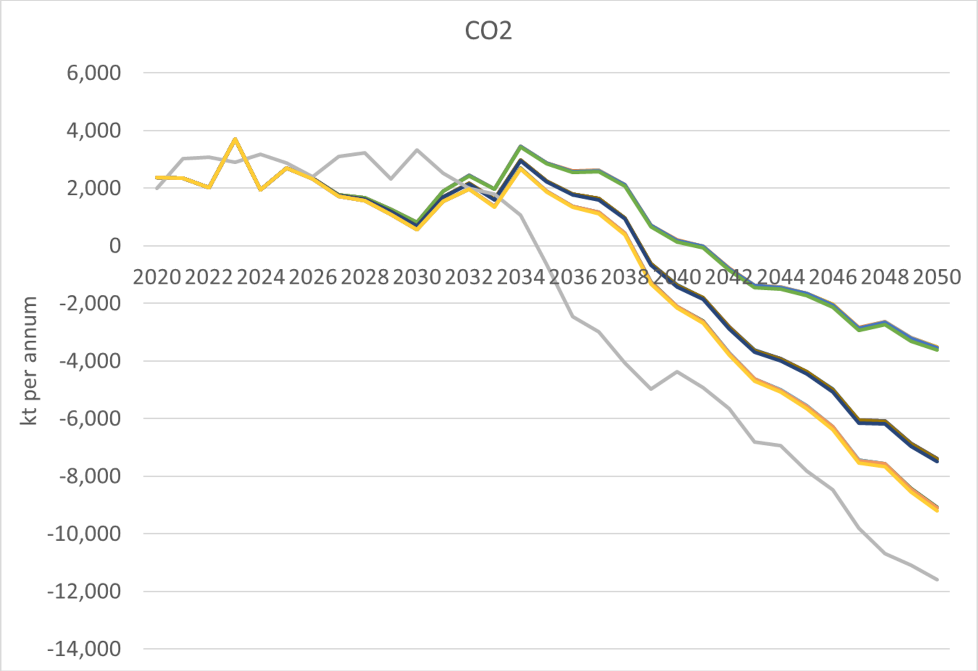
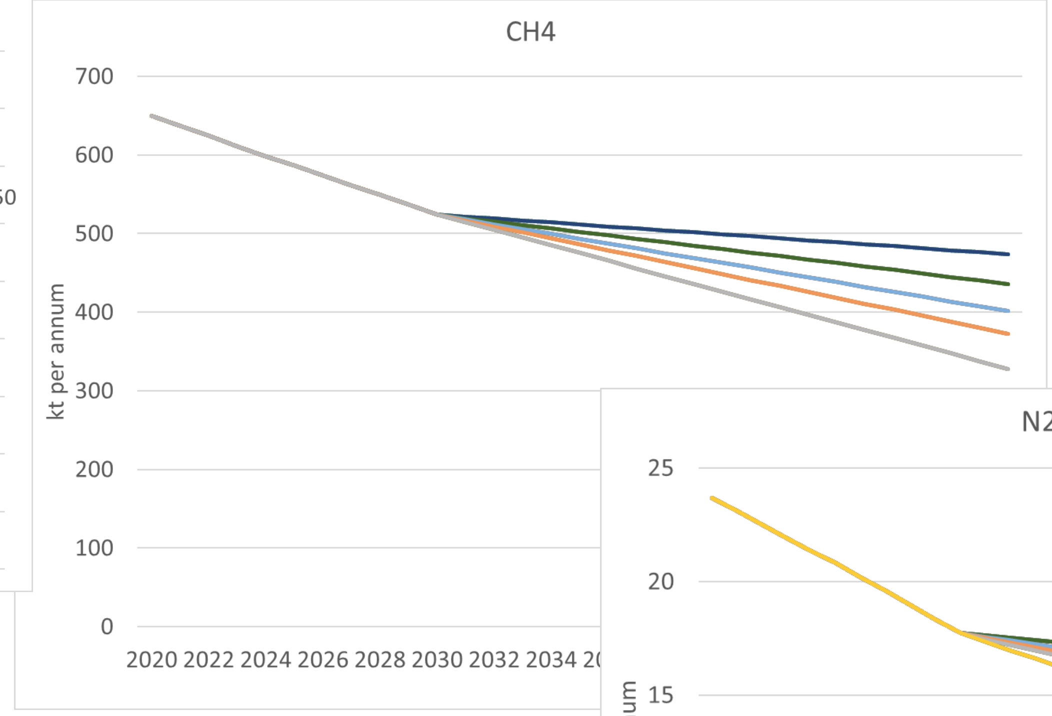
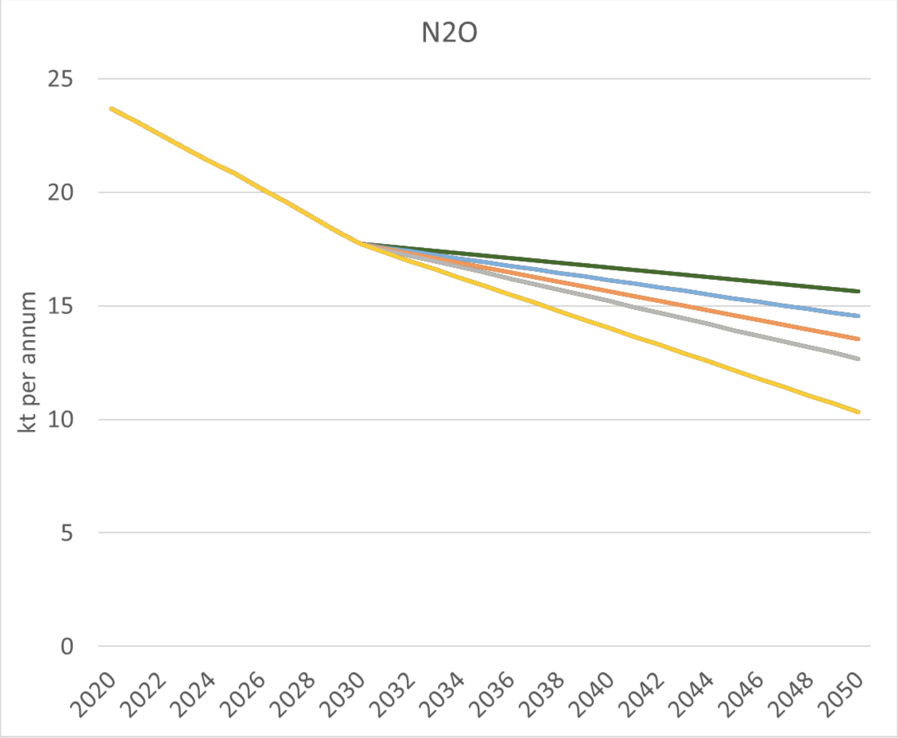
2050 GWP_{100} ex. CH_4



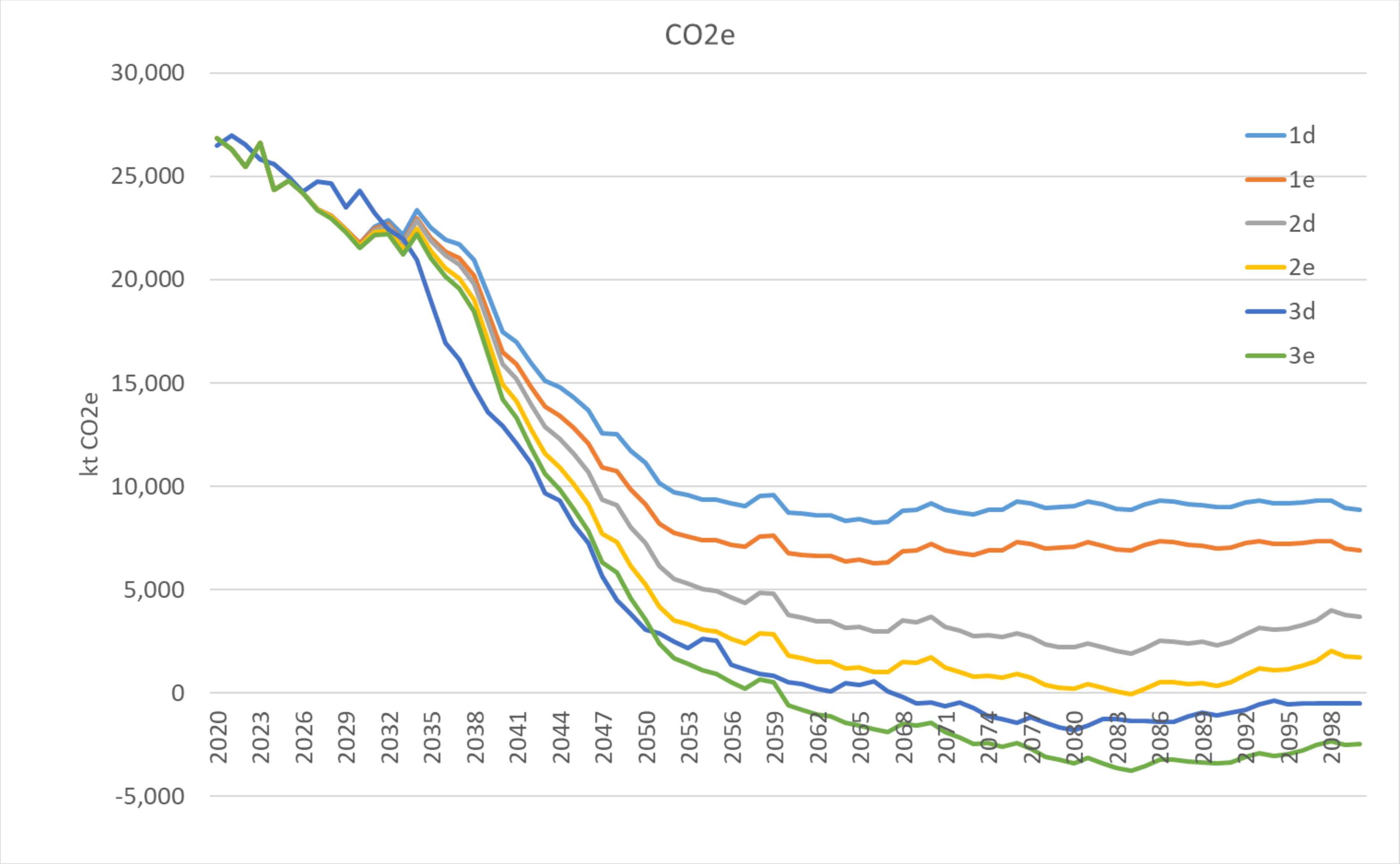
Gas time series



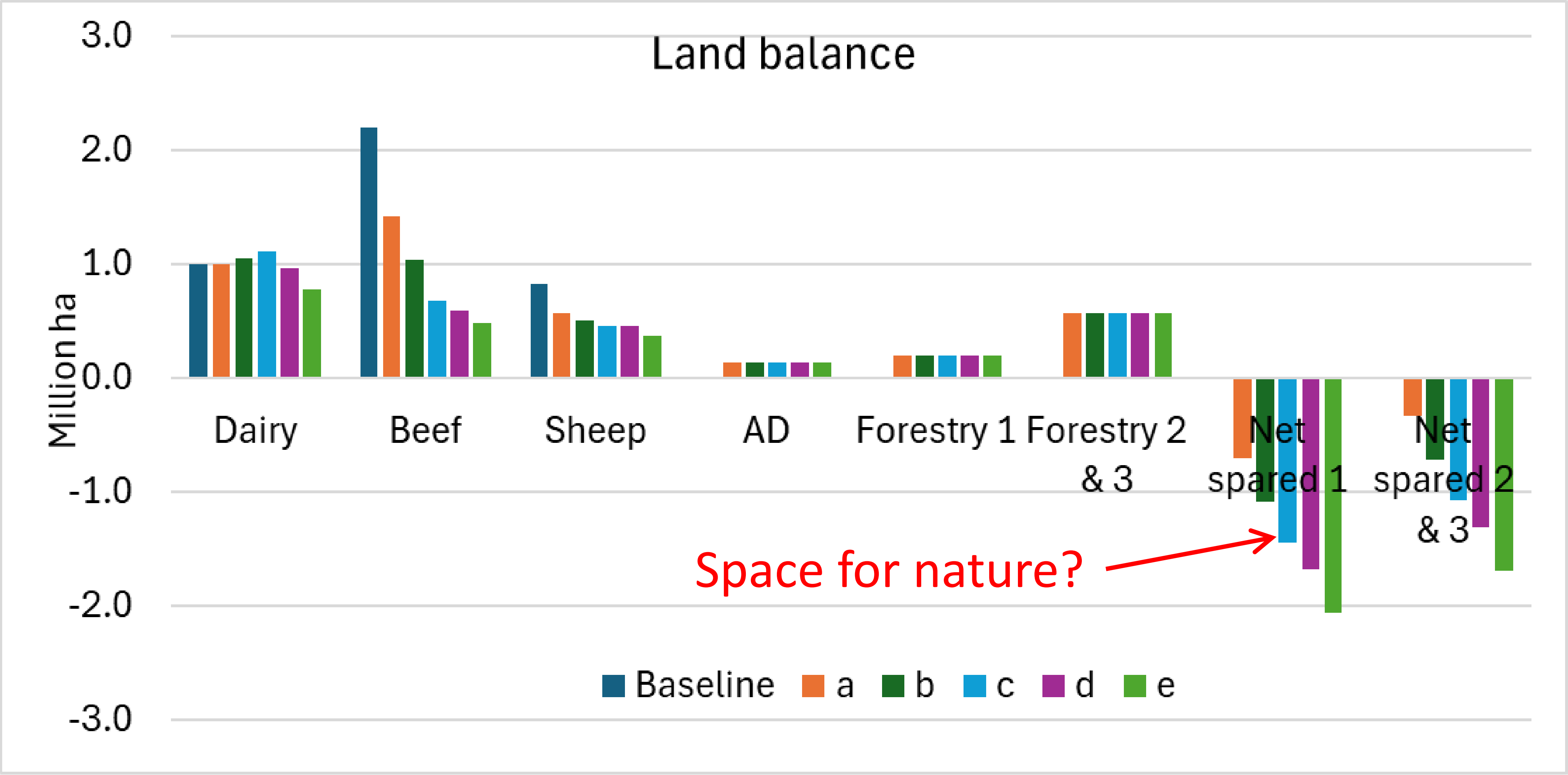




Long-term (GWP_{100})



Land balance & biodiversity



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Summary

- Even with dairy specialisation and maximum abatement, net zero a massive challenge for AFOLU
  - Not achieved with afforestation 25 kha/yr from 2030 with GWP_{100}
  - However, net zero possible if CH_4 set a separate target
  - Productivity improvements reduce animals & spare large areas (for biodiversity, dairy-beef extensification?)
- AD can make a useful contribution to GHG mitigation if fed with wastes
  - Max mitigation when replacing diesel, up to 1.6 Mt $CO_2e\ yr^{-1}$
  - Mitigation wanes as economy decarbonises > inefficient land use also for BECCS
- Commercial forestry drives large downstream mitigation (carbon pump)
  - Substitution effect up to 7 Mt $CO_2e\ yr^{-1}$ (not necessarily all in Ireland though!)
  - HWP C storage (change) effect up to 4 Mt $CO_2e\ yr^{-1}$
  - BECCS potential circa 2 Mt CO_2 by 2050, and 8 Mt CO2 by 2100 (if waste streams cleaned and diverted - which country & sector gets credit?) Worth €bns @ future CO_2 prices
  - Could help mitigate risk of large AFOLU C losses in soils and forests (extreme events)
- 50-100 yr land sector planning needed for a climate neutral (bio)economy
  - Long-term forestry dynamics
  - Improved biogenic C management and accounting critical (along with water, biodiversity assessments….)

CAPACITY
CLIMATE ACTION PATHWAYS & ABSORPTIVE CAPACITY

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

CCAC Carbon Budgets Working Group
May 23rd, 2024

Hannah Daly, Vahid Aryanpur & Bakytzhan Suleimenov

MaREI
Energy · Climate · Marine

Environmental Research Institute

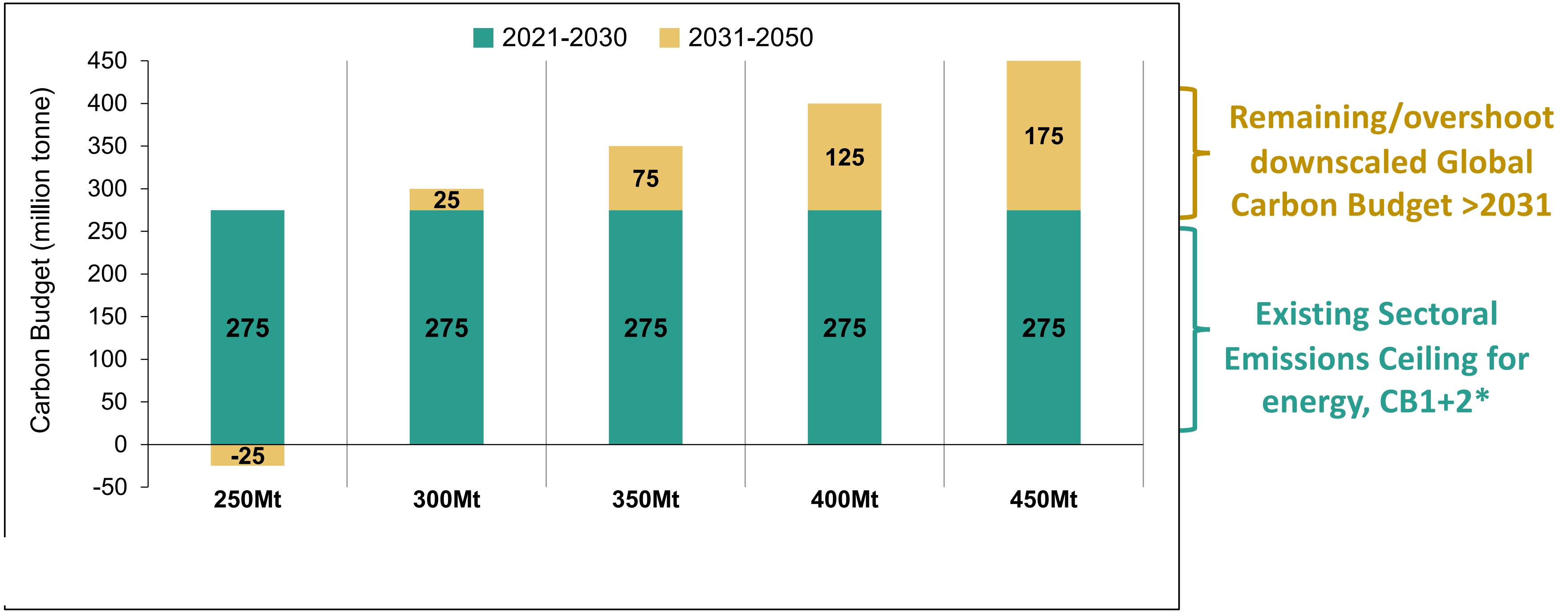
UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Model updates since 1st iteration

- ***New results web portal:***
  - https://epmg.netlify.app/TIM-Carbon-Budget-2024/results/
- ***Engagement***
  - Engaged with SEAI Modelling team for feedback and peer review of results
  - Feedback from CCAC
  - Engagement with NTA on vehicle activity scenarios
  - Engagement with Biodiversity sub-group
- ***Submitted paper for review in nature Climate Action journal***
  - Title: *National Carbon Budgets and Implications of Accelerated and Delayed Climate Action*

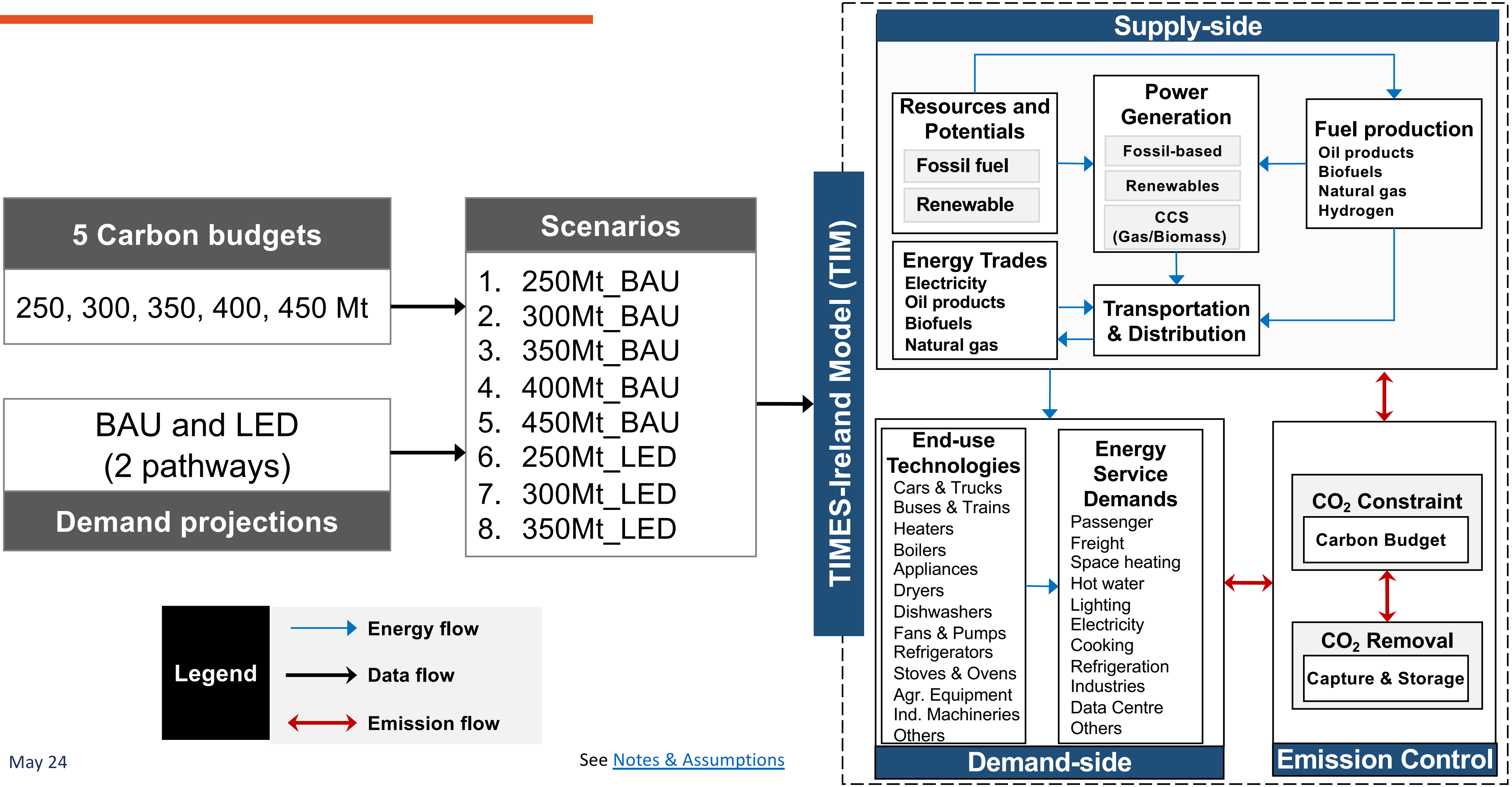
- ***Model input and structure***
  - New scenarios based on CCAC feedback: 250Mt, 350Mt & 450Mt
  - Bioenergy updates:
    - Updated domestic bioenergy potential based on the SEAI National Heat Study.
    - Revised bioenergy imports based on the SEAI National Heat Study.
    - Updated wood bioenergy emissions intensity using SEAI emissions factor.
    - Set the start date for BECCS from 2035 with an upper bound of 0.5 GW.
  - Addressed calibration issues for 2018-2023, including waste incineration and landfill biogas plants
  - Better representation of power storage options for hourly and seasonal storages & updated capacity factors for renewables
  - Technology data updates for power and residential sectors on efficiencies and costs
  - Updated CB1&2 based on CAP24.
  - Adjusted transport demand for 2023-2030.
  - Lower/upper bound defined for new vehicle sales.
  - Deactivated LNG for Heavy-Duty Vehicles.
  - Updated 2023-24 solar & wind installations and expected development to 2030 based on SEAI feedback & EirGrid GCS2024

Core Carbon Budget Scenarios



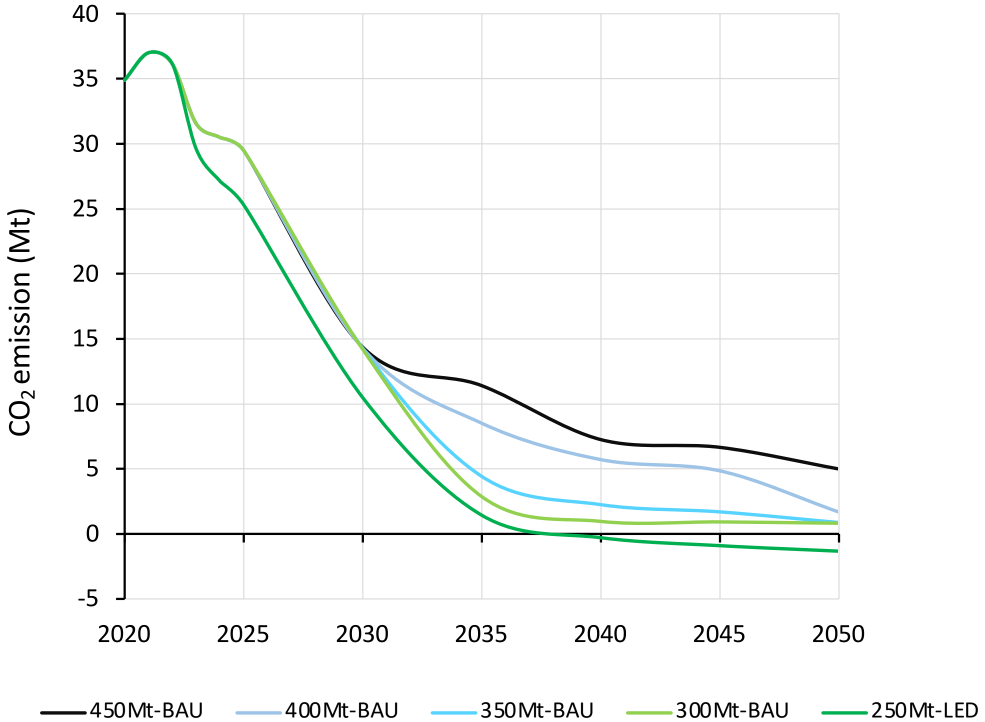
*SECs for energy sectors for CB1+CB2 add to 269 Mt. For these scenarios, we allowed model greater CB in these periods – 275Mt - to allow more flexibility

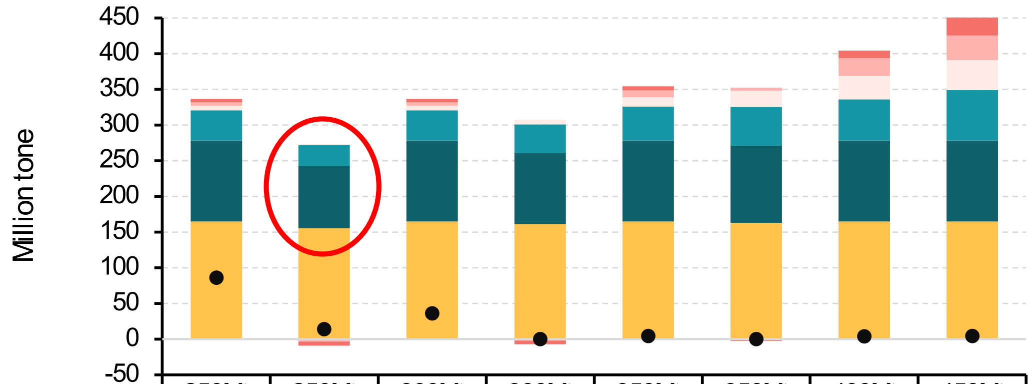
Carbon budget & scenario definition



See Notes & Assumptions

Detailed 5-year carbon budgets for each sector



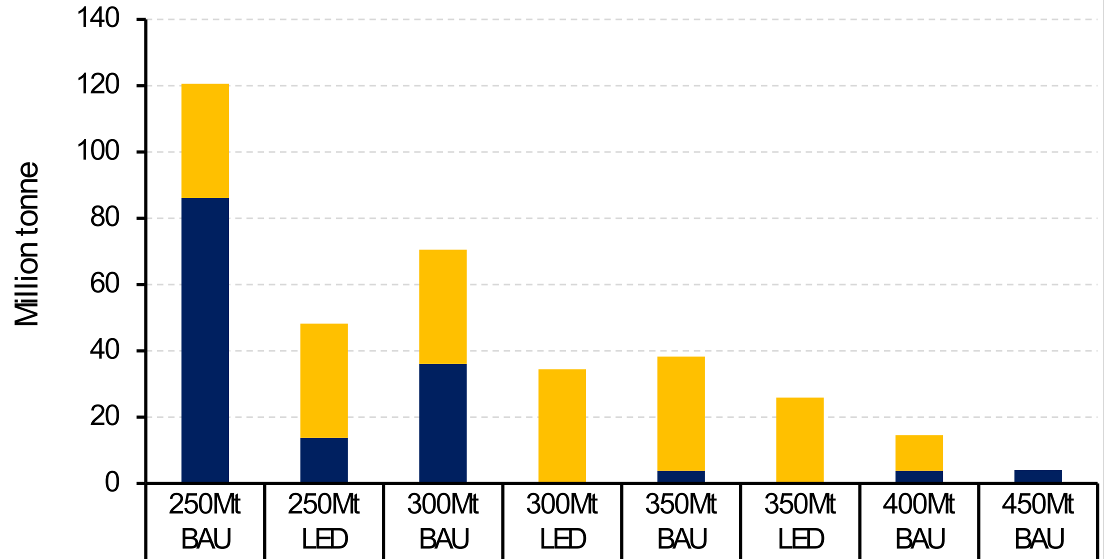


	250Mt BAU	250Mt LED	300Mt BAU	300Mt LED	350Mt BAU	350Mt LED	400Mt BAU	450Mt BAU
2046-50	4	-6	4	-5	6	-2	11	29
2041-45	5	-3	5	-2	9	5	25	35
2036-40	7	1	7	6	13	22	33	42
2031-35	42	30	42	40	48	55	58	71
2026-30	113	87	113	100	113	108	113	114
2021-25	165	155	165	161	165	163	165	165
● Overshoot	86	14	36	0	4	0	4	4

To meet 250Mt & 300Mt scenarios with limited overshoot, a reduction in CB2 is necessary (here enabled by LED), along with net-zero by ~2037

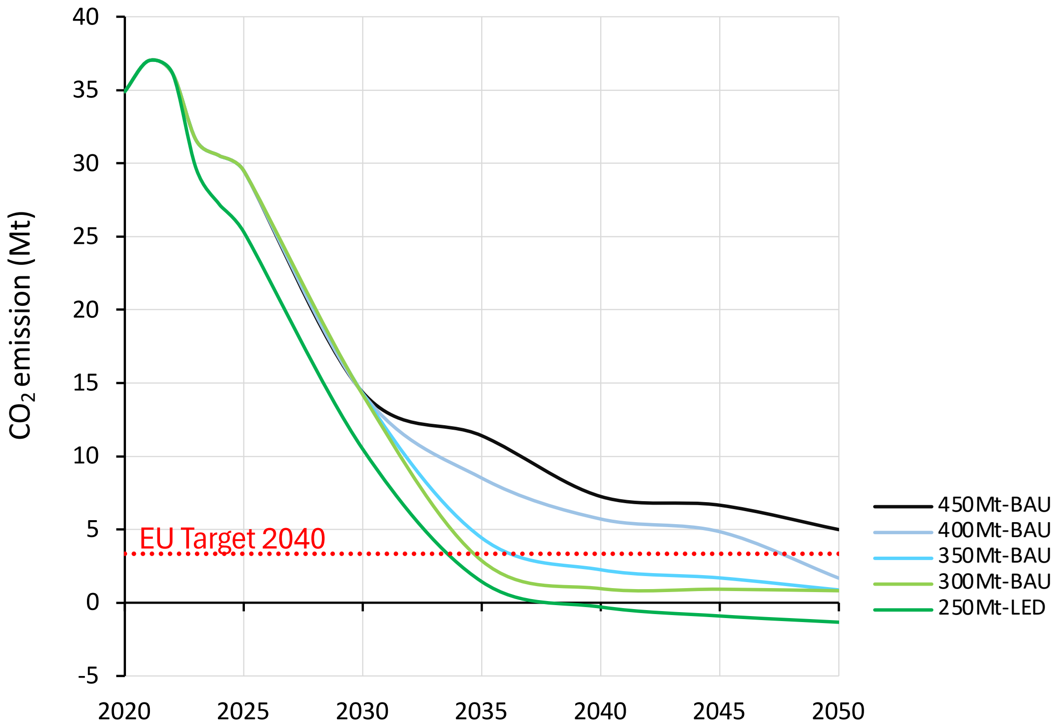
Carbon dioxide removal & BECCS

- All pathways rely on some removals
- BECCS removes up to 14% of the overall budget in 250Mt scenarios
- Additional Carbon Dioxide Removal (CDR e.g., ongoing BECCS, direct air capture, afforestation) will be necessary for stringent scenarios & BAU energy demand
- Overshoot of 4Mt in pre-2030 carbon budgets in BAU scenarios. i.e., model requires some LED to fully meet CB1 & CB2



	250Mt BAU	250Mt LED	300Mt BAU	300Mt LED	350Mt BAU	350Mt LED	400Mt BAU	450Mt BAU
BECCS	34	34	34	34	34	26	11	0
Unabated	86	14	36	0	4	0	4	4

Comparison with (indicative) EU target



Notes:

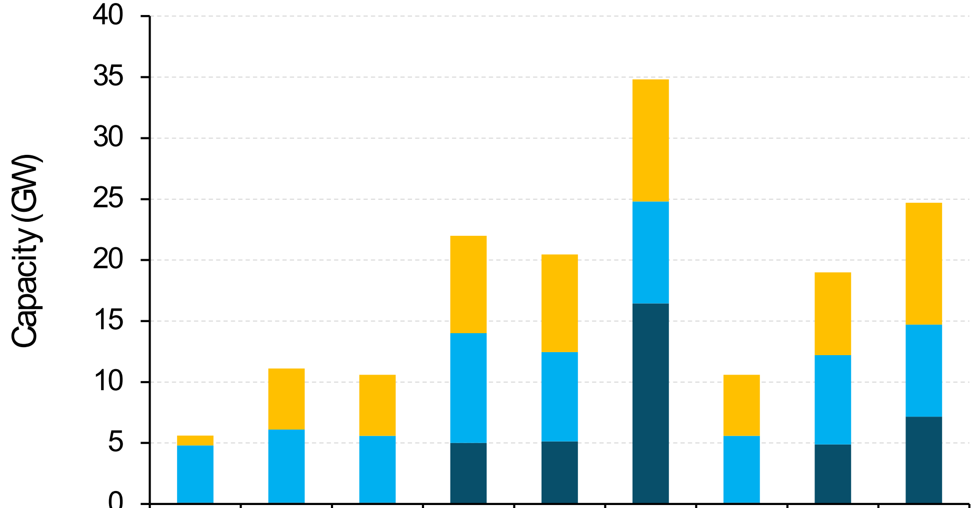
- This calculates targets based on energy CO_2 only

Calculations:

- GHG emissions (energy-related):
- 1990: 33.4Mt
- Indicative/possible 2040 target for energy (90%↓): 3.3Mt

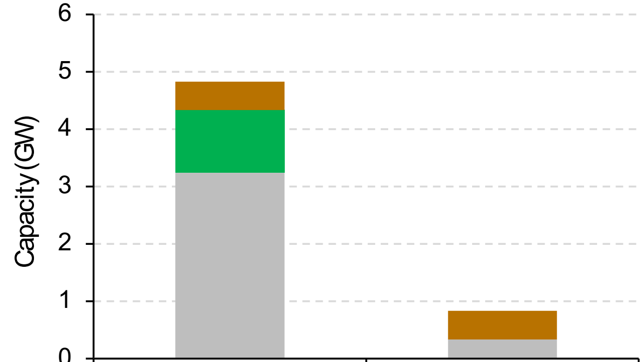
Installed capacity in power generation

Variable renewable power capacity



	2023	2025-target	2025-BAU	2030-target	2030-BAU	2050-BAU	2025-LED	2030-LED	2050-LED
Solar	0.8	5.0	5.0	8.0	8.0	10.0	5.0	6.8	10.0
Onshore wind	4.7	6.0	5.5	9.0	7.3	8.4	5.5	7.3	7.5
Offshore wind	0.1	0.1	0.1	5.0	5.1	16.5	0.1	4.9	7.2
Generation share	41%	50%	49%	80%	87%	93%	47%	92%	93%

Other technologies in 2050



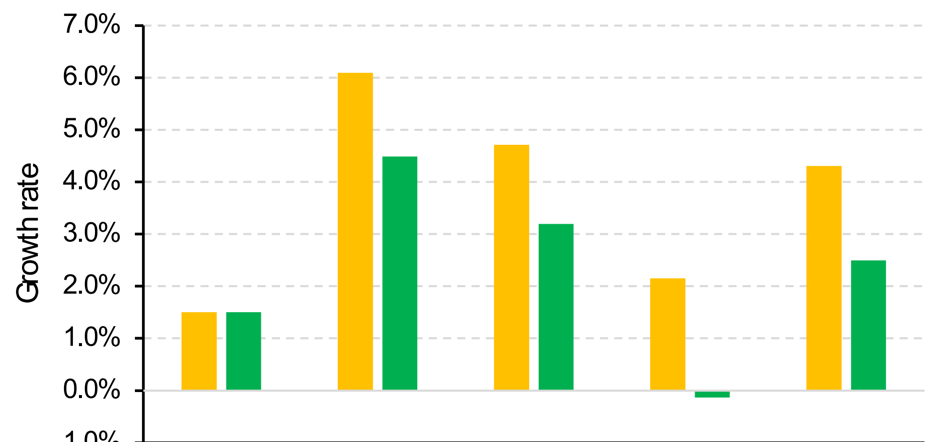
	BAU	LED
BECCS	0.5	0.5
H2	1.1	0.0
Others	3.2	0.3

Others: Gas, MSW, Hydro

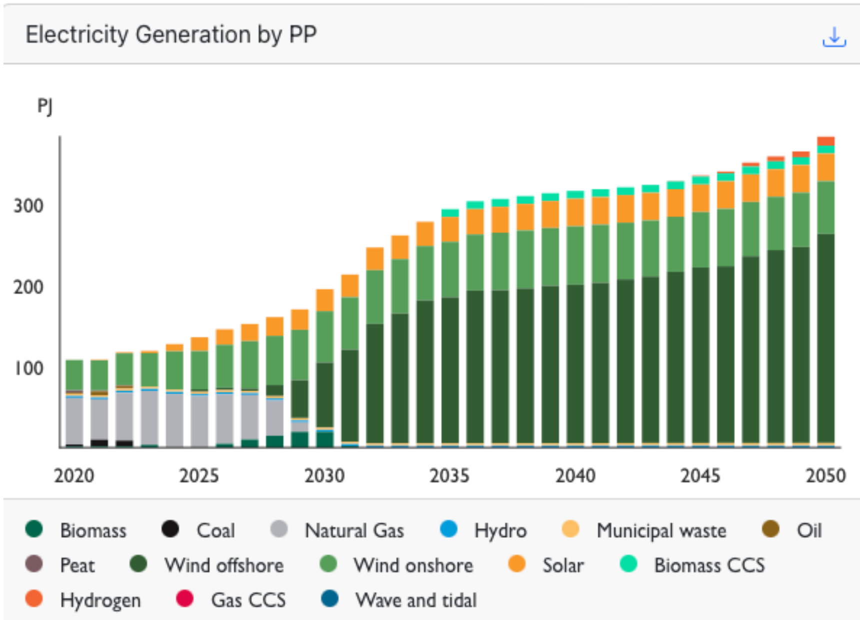
Key assumption: CAP24 power generation targets constraint total wind & solar deployment to 2030

Unprecedented growth in power generation

Average annual growth rate in power generation

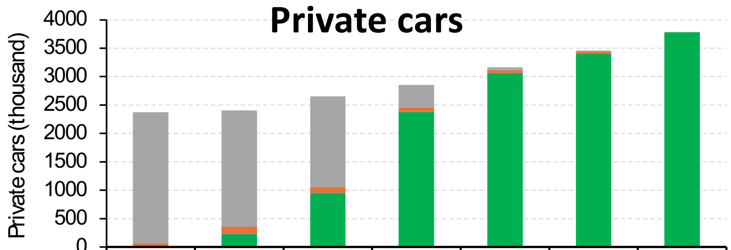


	2010-20	2020-30	2030-40	2040-50	2020-50
BAU	1.5%	6.1%	4.7%	2.2%	4.3%
LED	1.5%	4.5%	3.2%	-0.1%	2.5%

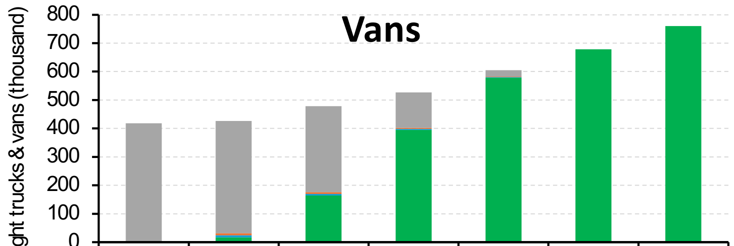


300Mt-BAU scenario

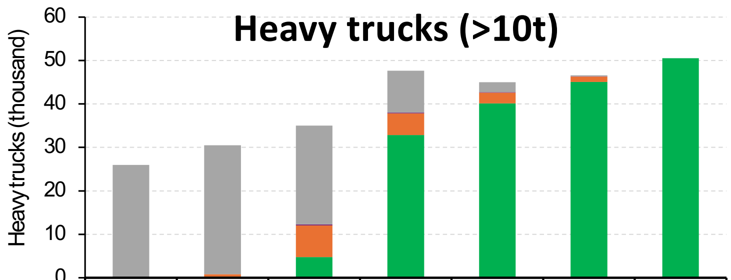
Electrification of vehicles



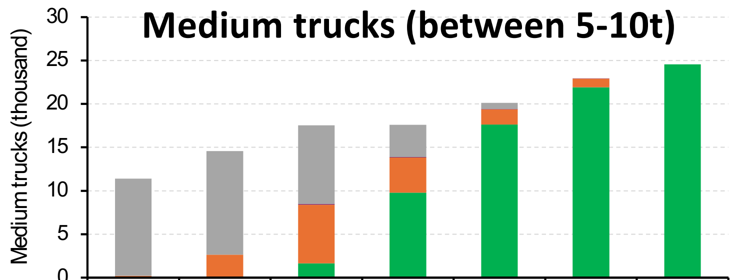
	2020	2025	2030	2035	2040	2045	2050
ICE	2304	2046	1591	399	52	23	0
FCV	0	0	0	0	0	0	0
HEV	54	130	104	72	44	33	0
PHEV	3	10	8	6	4	3	0
BEV	12	220	947	2376	3061	3399	3784



	2020	2025	2030	2035	2040	2045	2050
ICE	417	395	302	125	22	0	0
FCV	0	0	0	0	0	0	0
HEV	0	8	6	4	2	0	0
PHEV	0	7	6	4	2	0	0
BEV	1	17	164	395	579	679	761

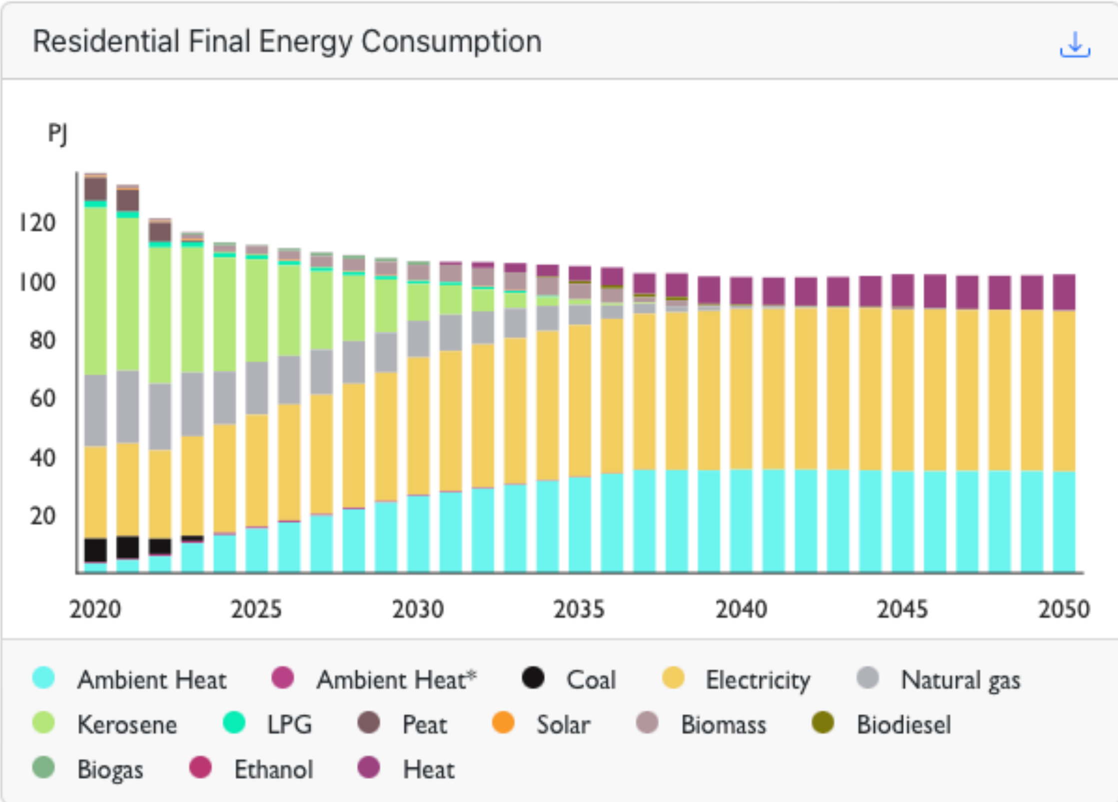


	2020	2025	2030	2035	2040	2045	2050
ICE	26	30	23	10	2	0	0
FCV	0	0	0	0	0	0	0
HEV	0	1	7	5	2	1	0
BEV	0	0	5	33	40	45	51



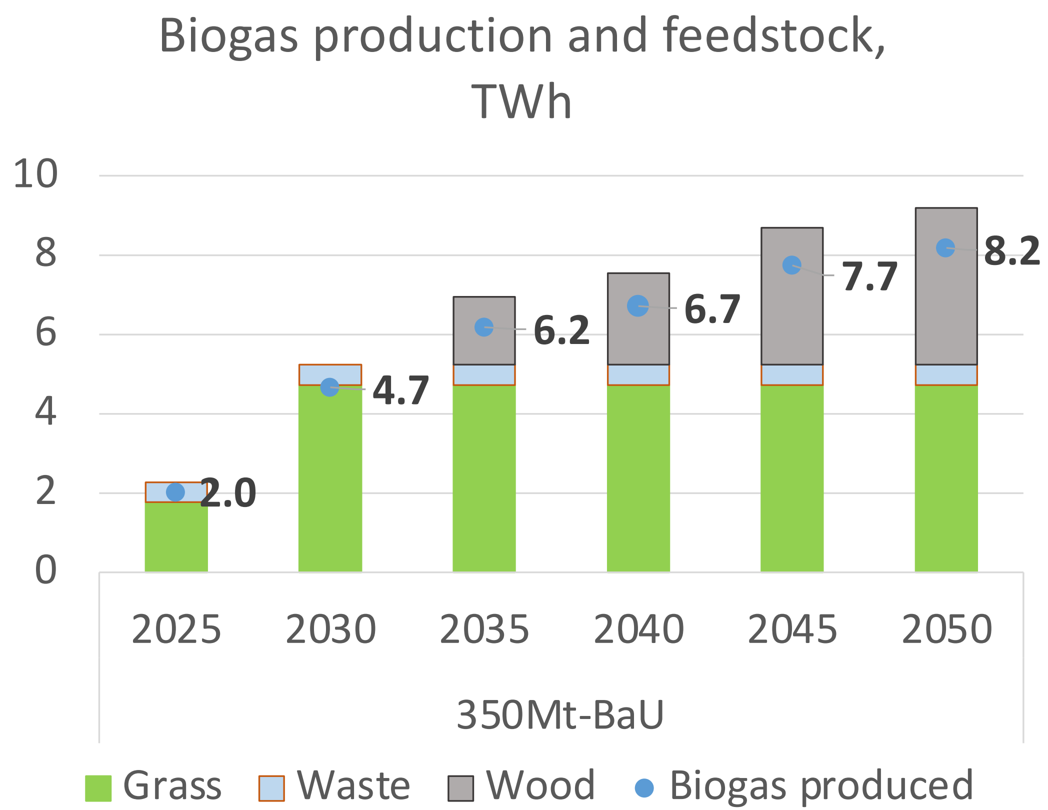
	2020	2025	2030	2035	2040	2045	2050
ICE	11	12	9	4	1	0	0
FCV	0	0	0	0	0	0	0
HEV	0	3	7	4	2	1	0
BEV	0	0	2	10	18	22	25

Clean heat in homes



350Mt-BAU scenario

Biogas



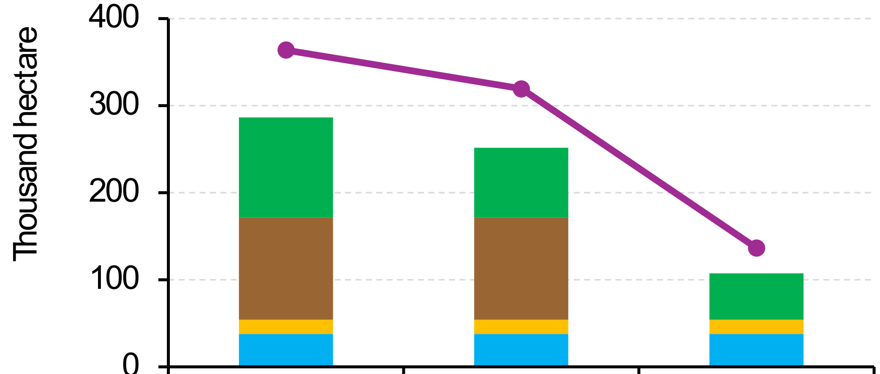
- Up to 81% of biogas used in industry sector across scenarios
- Grass resource from SEAI Heat Study
- Some biogas is used in the power sector
- Up to 95% of biogas produced from grass and wood showing that this requires purposely developed technologies, not only waste processing

Delivering more stringent carbon budgets

- Earlier phase out of fossil fuels:
  - Diesel in transport, oil in residential, gas in residential & industry
  - Enabled by
    - Lower energy demand – this allows faster decarbonisation in CB2
    - Earlier deployment of energy transition technologies, e.g., electric trucks
    - Early retirement of fossil fuel technologies (vehicles, home boilers)
    - Greater electricity demand in transport & residential sectors
    - Greater use of novel technologies, e.g., biogas, hydrogen, district heat
    - Increasing RE speed & scale could enable deeper FF phase-out, with more bullish assumptions
- Bioenergy concentrated in more valuable areas
  - e.g., industry and BECCS rather than heating
- More BECCS; earlier BECCS
- Higher overshoot (more CDR post-2050)

Potentially significant land use implications of deep decarbonisation

Agricultural land area required in 2050



	<350Mt	400Mt	450Mt
Grass	115	80	53
BECCS	117	117	0
Solar	17	17	17
Wind	38	38	38
% of agricultural land	6.4%	5.6%	2.4%

- More stringent climate change scenarios, and greater NETs, requires more land area
- Land for solar & wind can complement other uses
- Assumes majority of utility-scale solar is on greenfield, rather than unused areas
- Assumes all biomass for BECCS is derived from purpose-grown perennial crops, like miscanthus. This could potentially instead be derived from waste products – requires further analysis

Preliminary analysis based on MSc dissertation research by Ciara Doherty, UCC

Critical model assumptions

- Important assumptions that require further consideration: “feasibility”
  - Cement CCS technology is available in 2029 for all Irish cement plants
  - Offshore wind operating as per CAP24 target in 2030
  - Bioenergy & BECCS pathways: requires significant new fuel supply chain
  - Nearly-zero carbon power system by early 2030s
  - All scenarios see full phase-out of new ICE personal vehicles in 2024. More stringent scenarios bring forward date that all new freight vehicles are electrified (to 2030 in 250Mt-BAU)
  - By 2030, 80% increase in electricity demand across all BAU scenarios. 250% increase by 2050. Major implications for distribution and transmission grid: are upgrades being planned?

Next steps: Engagement

- Drafting report for CCAC based on these scenarios, including commentary on the practical implications associated with delivery:
  - Rates of deployment, costs, comparison with CAP24 milestones, impact of CB1/CB2 overshoot, role of negative emissions, investments etc.
- Feedback & engagement is welcome from all CBWG members
  - Interpretation of carbon budgets & methodology for downscaling Global RCB
  - Land use/biodiversity/bioenergy
  - Macroeconomic analysis - COSMO
- We plan to publish report and the set of modelled scenarios by June 22nd for broader consultation: this will feed into final scenarios and report for final iteration
- Journal publication under peer review.

Next steps: Ongoing & future modelling work with TIM

Ongoing – for 3rd iteration of scenarios

- Industrial electrification
  - Heat pumps & thermal storage have potential to accelerate industrial sector decarbonisation by 2030
  - This will lead to lower biogas demand
- Explore greater RE (solar & onshore wind) potential
- Greater analysis of bioenergy implications/risk analysis required
  - Preliminary land use assessment shows potentially significant implications
  - Some bioenergy pathways in TIM (e.g., woody biomass -> biogas) may be removed

Longer-term model developments

- International aviation & shipping
  - SAF will require significantly greater renewable energy capacity to power DACS/green hydrogen/offsets (e-fuels) or land area for biocrops for bio-jet kerosene: these are likely to be produced where renewable energy is cheapest, which may not be Ireland
- Energy security

Conclusions [from 1st iteration – still hold]

- Nearly complete **phase-out of all fossil fuels** required in 2040s in all scenarios.
  - Phase out of coal & oil most urgent
  - Nearly 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

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 (see here)
  - 5 energy-related CBs for Ireland, **rounded** to 250 to 450 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** CO_2 emissions (excluding Int. Aviation and Shipping, excluding LULUCF)
  - Acknowledgement that downscaling on a per-capita basis, and starting from 2020, are conservative assumptions from the perspective of climate justice (Mintz-Woo, *in prep*)
- **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 and production, energy technology investments and partially infrastructure costs

- **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**
  - **Trucks:** V. Aryanpur, F. Rogan, "Decarbonising road freight transport: The role of zero-emission trucks and intangible costs" *Scientific Reports*, vol. 14, 2024 (Link)
  - **District Heating:** Mc Guire *et al.*, "Is District Heating a cost-effective solution to decarbonise Irish buildings?" *Energy*, vol. 296, 2024 (Link)
  - **Private cars:** 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**
  - link
- **TIM Source Code on GitHub**
  - https://github.com/MaREI-EPMG/times-ireland-model

Agricultural Activity and Agricultural GHG projections to 2050

Trevor Donnellan and Kevin Hanrahan

CBWG 14, May 23 2024

Teagasc

Agriculture and Food Development Authority

FAPRI-Ireland Annual Projection Cycle

- **FAPRI-Ireland model** provides projections to EPA annually
  - agricultural activity projections to **10 year** (medium term) **horizon** (currently 2034)
  - associated GHG emissions projections are also calculated
- Each year **three sets of projections** are provided to the EPA
  - **Baseline**, no policy change projection **(S1)**
  - **Low** agricultural activity projection **(S2)**
  - **High** agricultural activity projection **(S3)**
- The 3 sets of projections serve as a **reminder that the future is uncertain**
- Following a request from the CCAC
  - These projections are now extended to a (longer term) **2050 horizon**

Projections to 2050 are beyond normal 10 year horizon

- Projections for agricultural activity **to 2050** require key projections to 2050
  a) e.g. macro growth, population growth, inflation, exchange rates **(ESRI COSMO)**
  b) projections of agricultural output and input prices **(nobody projects these!)**
- **Need some assumptions** for agricultural **output and input prices**
  - assumed to evolve in line with the development of prices in the wider economy over period 2035 to 2050
- Projections for agriculture **to 2050 also require assumptions about policy**
  - **agricultural policy**, **EU trade policy**, and **agri-environmental policy all remain unchanged**
  - **CAP income supports** assumed to **remain decoupled from production**

Projections to 2050 come with a health warning: Much acknowledge major uncertainties

- **Normal** projections horizon is **10 years (2034)**
- Projection horizon to **2050** is a **big challenge**
  - far beyond that commonly used with models like FAPRI-Ireland model
- **Detailed model based projections** of agricultural and general commodity prices are **unavailable to 2050** from other sources
  - FAPRI (US), OECD, FAO, World Bank
- Must therefore be clearly understood that Teagasc projections to 2050 are **not** forecasts
  - we are doing this because you asked us

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Activity scenarios and mitigation adoption rates

- Teagasc MACC analysis to 2030
  - evaluated two alternative mitigation measure uptake pathways (P1 and P2)
- **P1 technology adoption rates**
  - assumed to be in line with previous Teagasc MACC analyses & AgClimatise
- **P2 technology adoption rates**
  - assumed higher and more rapid adoption rates,
  - with many measures approaching/reaching likely biophysical limits by 2030
- Currently have **3 complete scenarios** to 2050
  - But these involve no mitigation technology adoption evaluated
- Remaining **6 scenarios currently incomplete** [redacted]
  - based on the 2 alternative MACC measure adoption pathways x 3 Agricultural Activity Scenarios
  - to be completed when [redacted]

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MACC Measures (Lanigan et al. 2023)

MACC Measure #	Measure	Mitigation S1_P2 2030 ($MtCO_2e$)	CH_4 ($MtCO_2e$)	N_2O ($MtCO_2e$)
# 1	Dairy EBI	0.255	0.255	
# 4	Extended Grazing	0.041	0.041	
# 5	**Reduced Age at Finishing**	**0.732**	**0.732**	
# 6	Liming	0.162		0.162
# 7	Clover & Multispecies Swards	0.286		0.286
# 8	Improved Soil P	0.116		0.116
# 9	Reduced Crude protein in animal Feed	0.093		0.093
# 10	**Altered Fertiliser Formulation**	**0.553**		**0.553**
# 11	Dietary Lipids	0.125	0.125	
# 12	**Feed Additives (3-NOP)**	**0.788**	**0.788**	
# 13	Low Emissions Slurry Spreading (LESS)	0.087		0.087
# 14	Manure Acidification and Amendments	0.245	0.244	0.001
# 15	Slurry Aeration	0.286	0.286	0.002
# 16	**Drainage of wet mineral soils**	**0.363**		**0.363**
# 17	**Use of AD digestate in place of slurry**	**0.308**	**0.194**	**0.113**
# 18	**Agricultural Activity Diversification**	**0.417**	**0.362**	**0.055**
Total		**4.857**	**3.026**	**1.831**

Mitigation in 2030

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Teagasc Scenarios to 2050

Agricultural Activity Scenario (No Mitigation Assumed)	Teagasc MACC measure adoption pathway P1	Teagasc MACC measure adoption pathway P2
Scenario 1 (S1) Base ✓	S1 with P1 MACC (S1_P1) X	S1 with P2 MACC (S1_P2) X
Scenario 2 (S2) Lower Activity ✓	S2 with P1 MACC (S2_P1) X	S2 with P2 MACC (S2_P2) X
Scenario 3 (S3) Higher Activity ✓	S3 with P1 MACC (S3_P1) X	S3 with P2 MACC(S3_P2) X

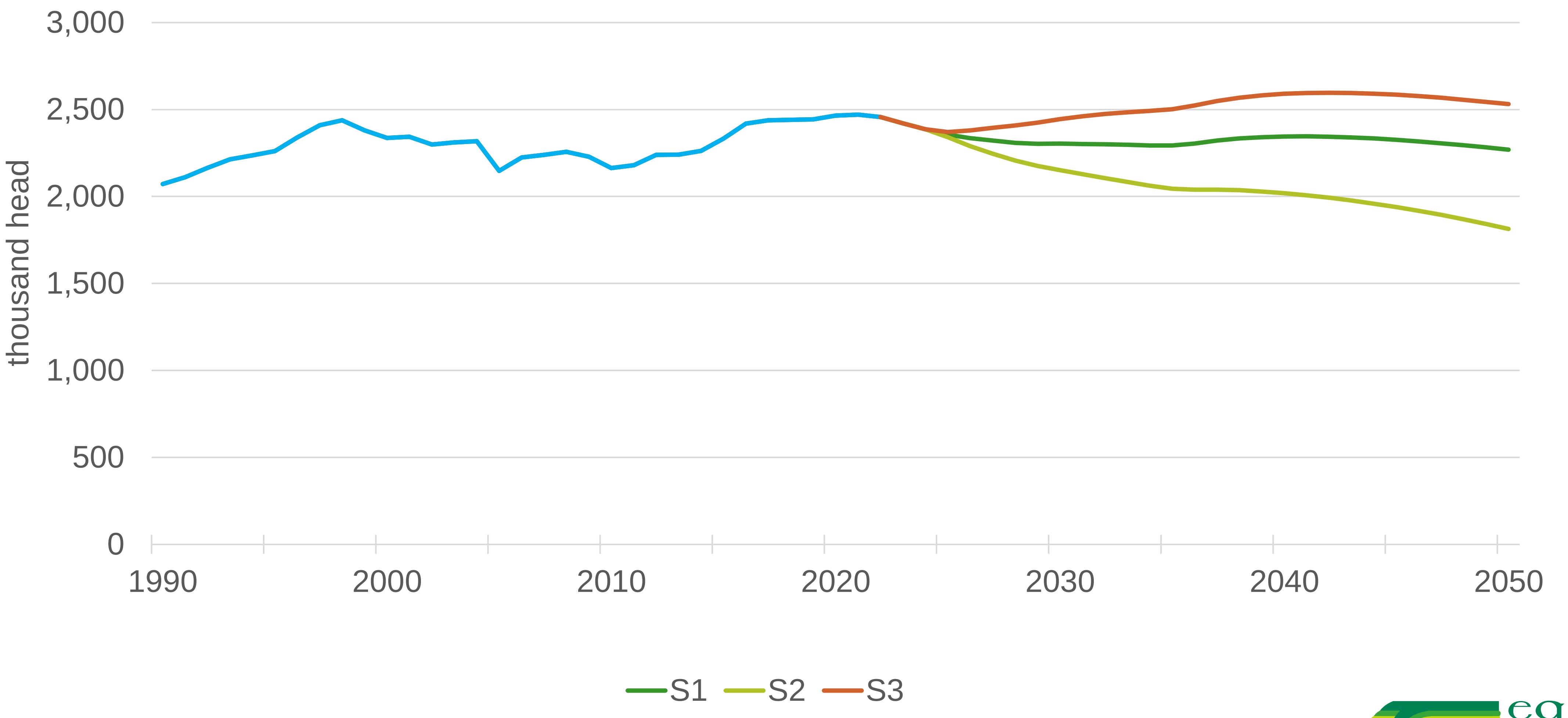
MACC Measure Mitigation to 2050

- **Mitigation achievable** a **function of** projected **activity levels**
  - **measure efficacy** and assumed **uptake rates**
- Changed agricultural activity levels 2030-2050 has implications
  - **volume of emissions** AND **volume of mitigation** from MACC measures
- **Very high uncertainty** attached to longer term **mitigation developments**
  - for example with measures such as **feed additives**
  - can these technologies be **deployed at pasture** ? **How effective** will they be if this happens ?
  - how **can uptake be incentivised** ?
- For some MACC measures **mitigation** at or near **biophysical limits**
  - e.g. significant further reductions in cattle age at finishing unlikely post 2030

Key features of the scenarios (activity levels)

- **Bovine agriculture is key** to understanding Irish Ag GHG emissions
  - central to agricultural activity
  - central to agricultural GHG emissions in Ireland
- **Differences** in **activity levels** in **S2 and S3** (relative S1)
  - based on exogenous **changes** in **dairy and bee**f supply inducing “**prices**”
  - **S2**: assumes **reduction** in supply inducing **prices** in period to 2050
  - **S3**: assumes **increase** in supply inducing **prices** in period to 2050
- Focus on bovine breeding inventory levels
  - total **cattle inventories** (emission from the animals and their waste)
  - **nitrogen fertiliser use** (emissions from application)
- In all scenarios **land** assumed to **move from agriculture for forestry**
  - **Total forestry** area increases by **> 200kha** by 2050

Bovine Breeding Inventories: S1, S2 & S3



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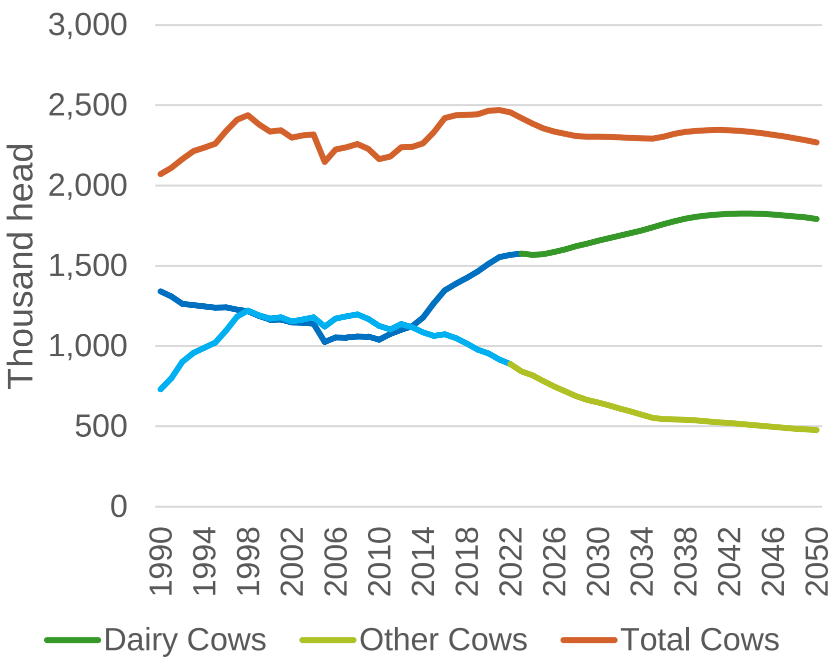
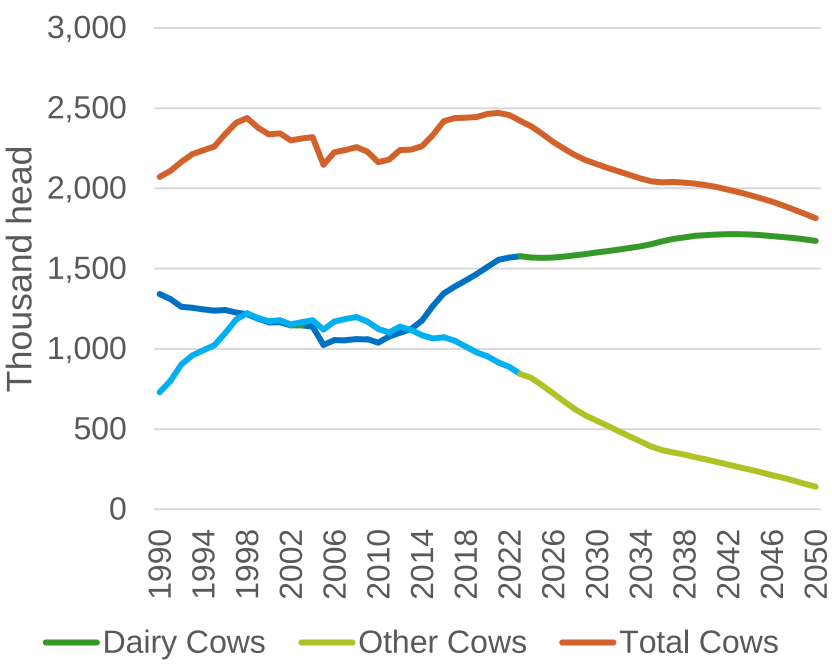
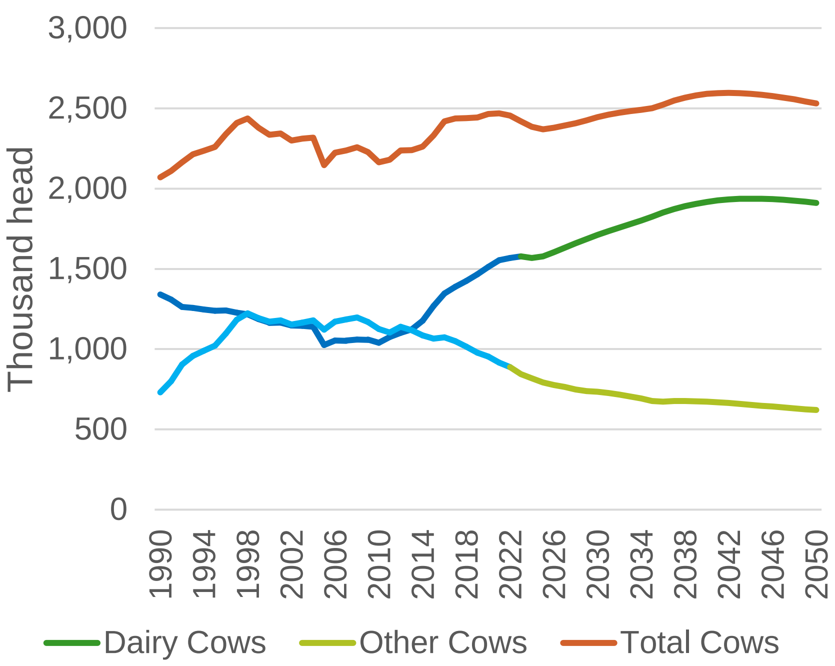
Dairy and Other (Suckler) Cow Inventories



S1 (Baseline)



S2 (Lower Activity)



S3 (Higher Activity)

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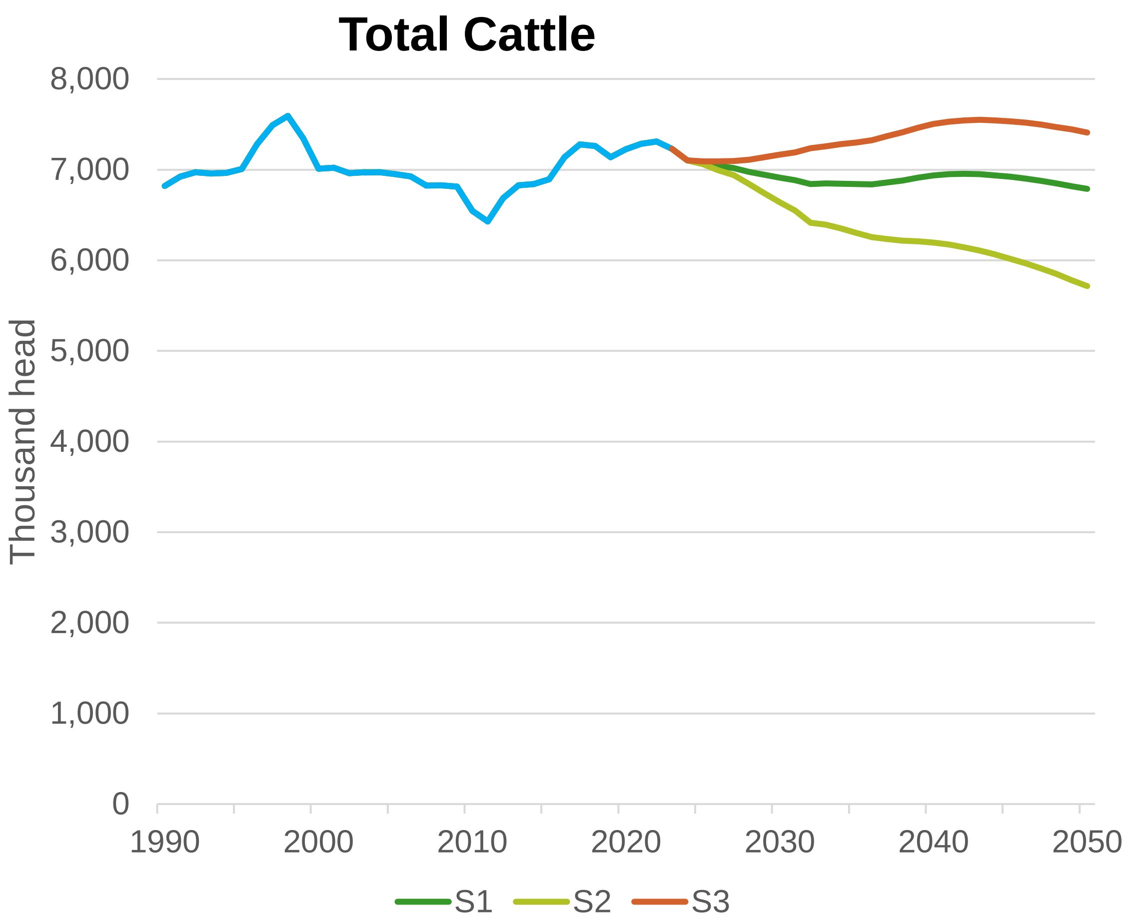
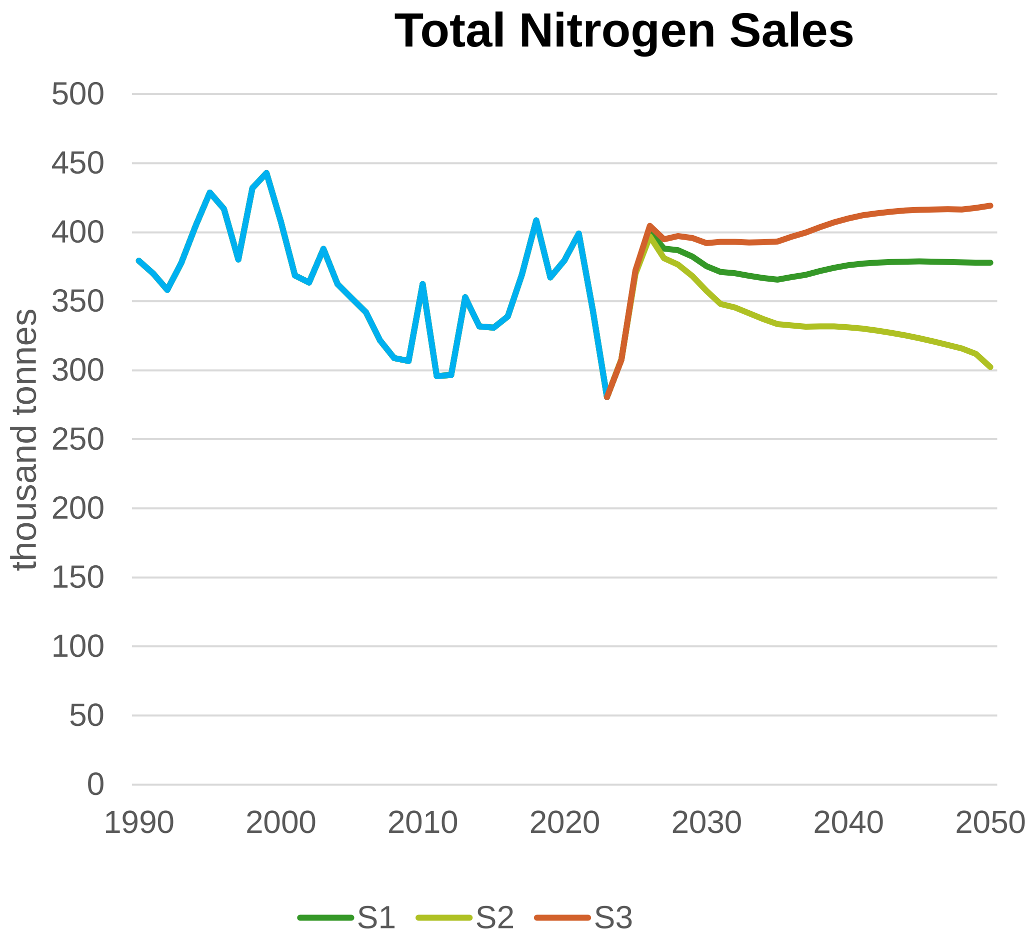
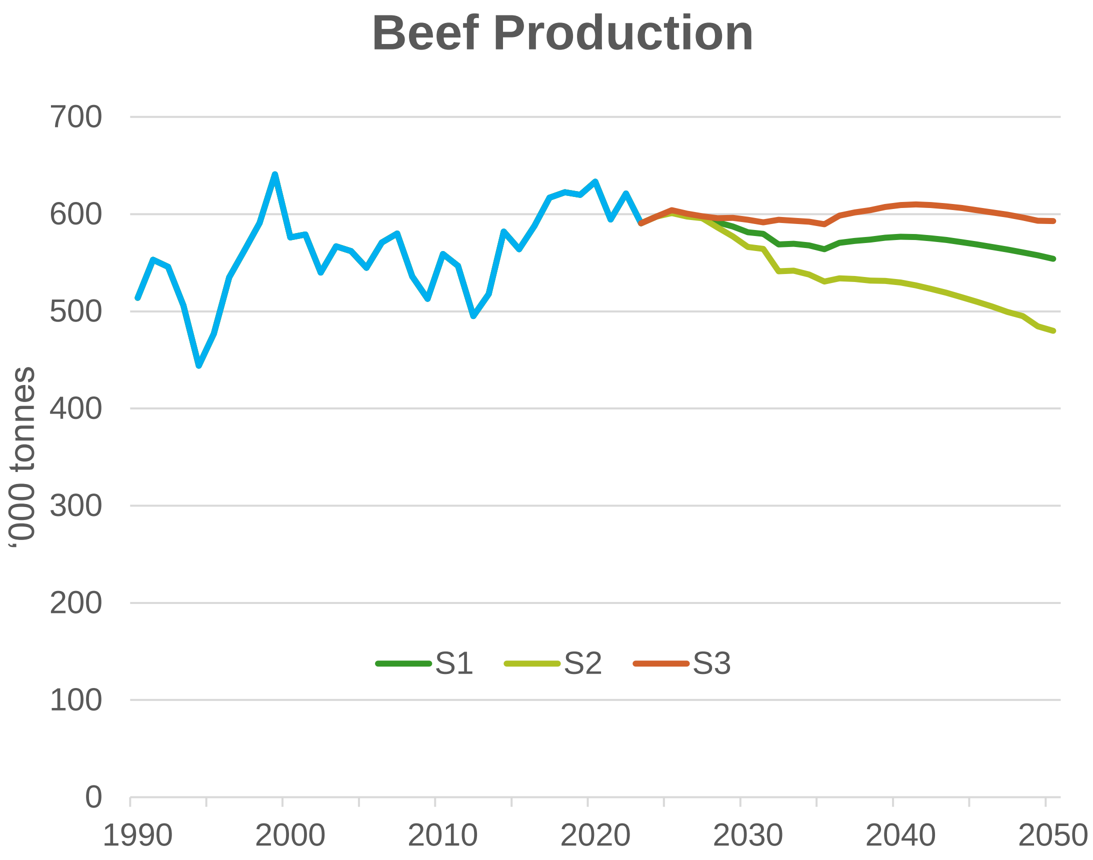
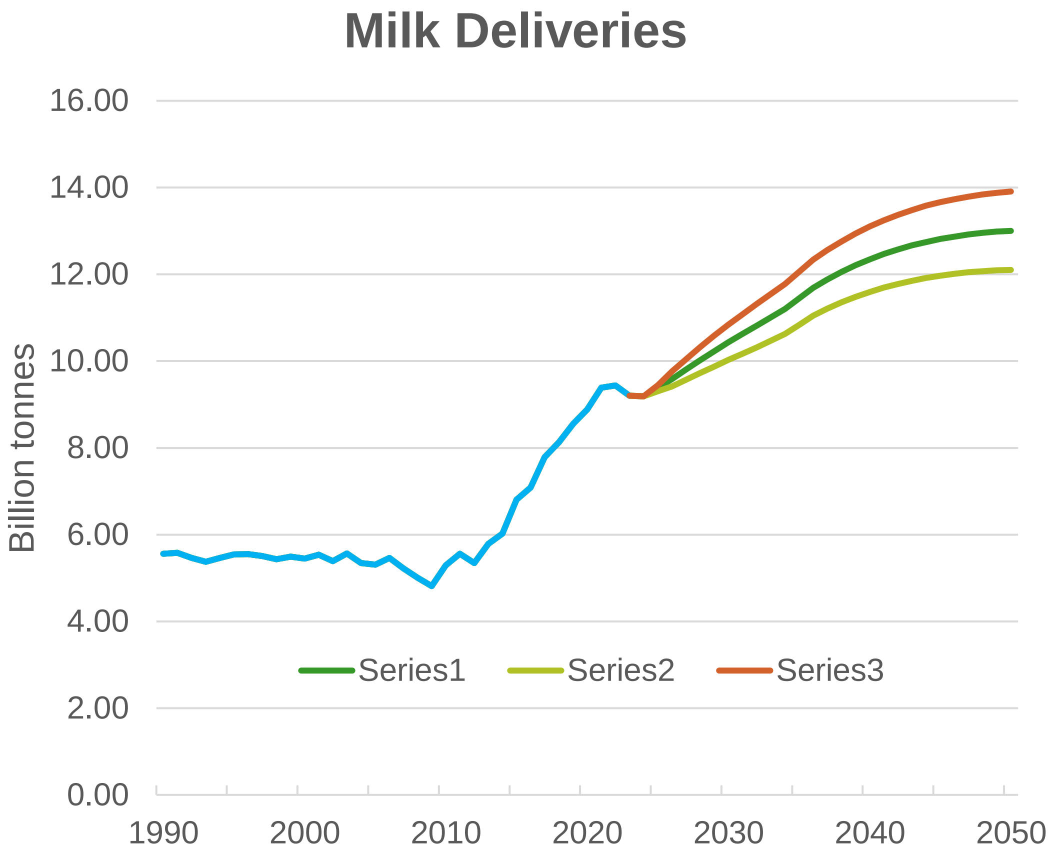
Total Cattle inventories & N Fertiliser Sales without MACC measures





Agricultural Output Ireland





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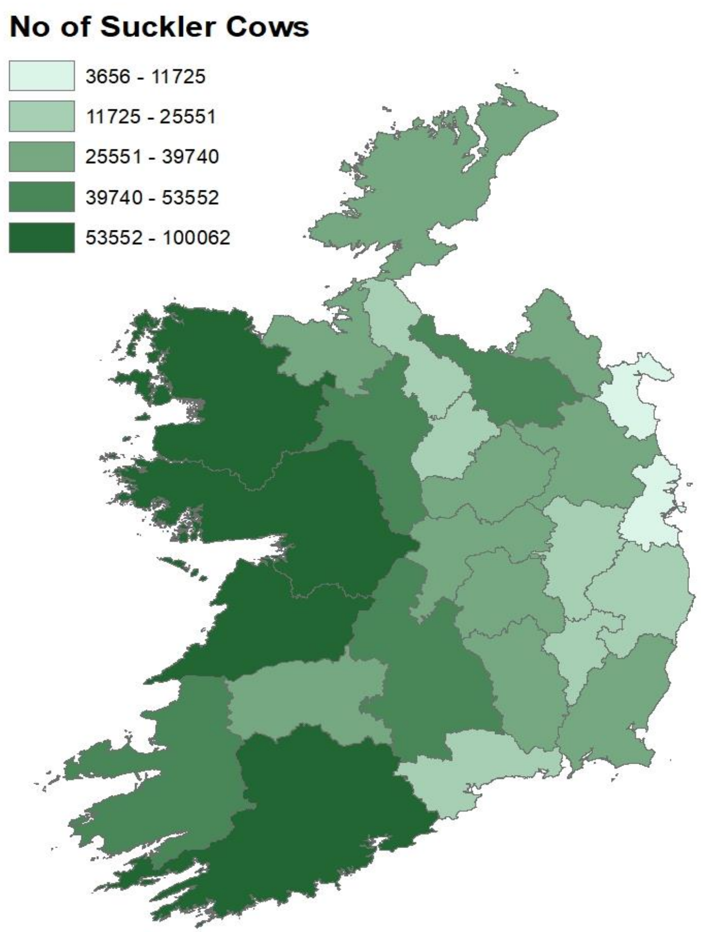
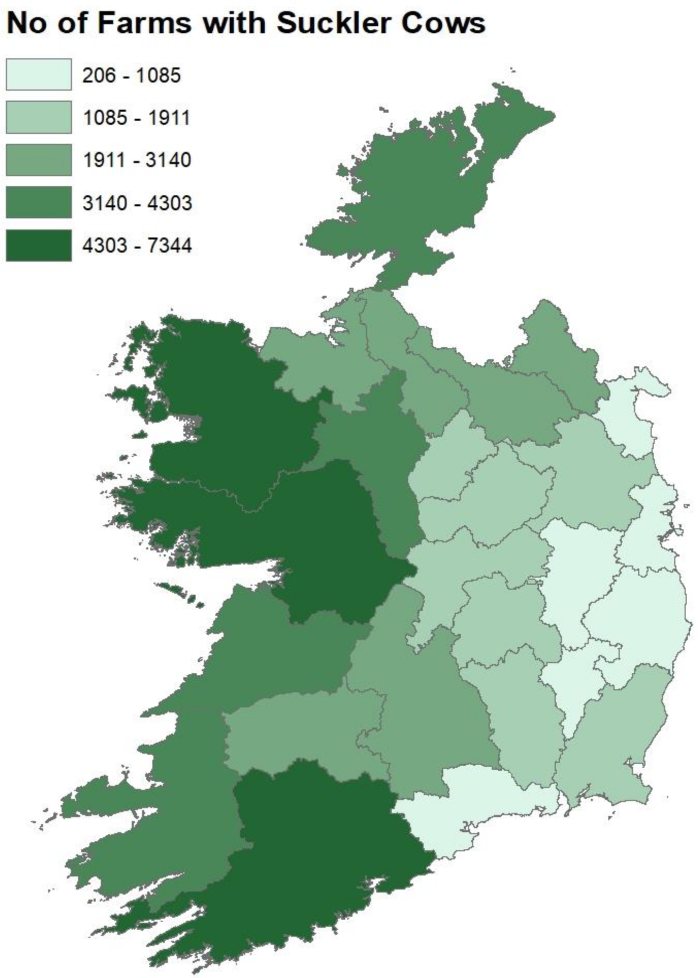
Where in Ireland are Other (Suckler) Cows farmed ?

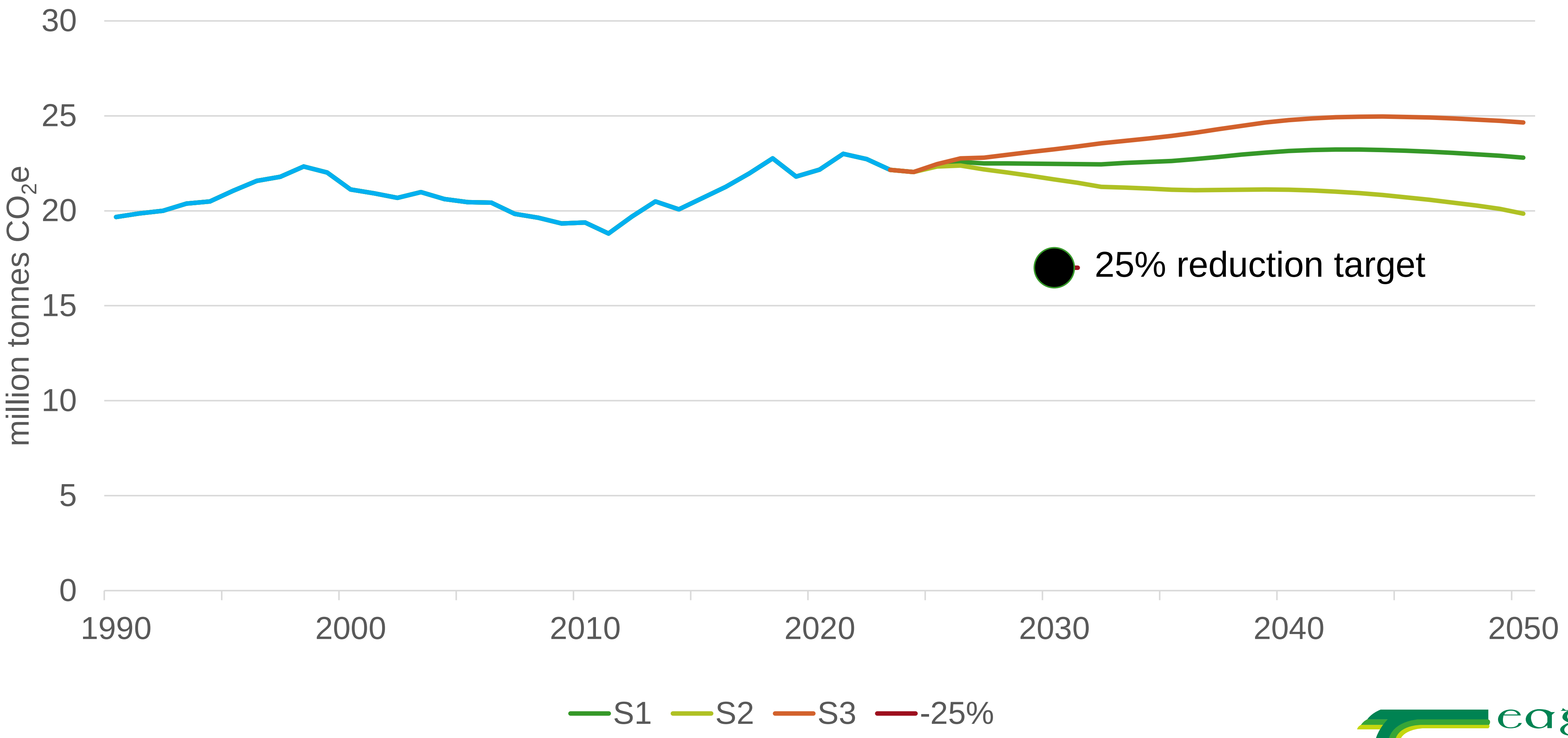




Note the East West divide

Source: CSO Census of Agriculture 2020

Agriculture GHG (excl. Fuel) without MACC Measures



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MACC Mitigation 2030

- While we do not yet have MACC mitigation figures to 2050
- But note the MACC mitigation figures to 2030
  - Prepared in 2023

Agricultural Activity Scenario (No Mitigation Assumed)	Teagasc MACC measure adoption pathway P1 MT CO_2 eq	Teagasc MACC measure adoption pathway P2 MT CO_2 eq
Scenario 1 (S1) Base	2.8	4.9
Scenario 2 (S2) Lower Activity	2.7	4.7
Scenario 3 (S3) Higher Activity	2.9	5.0

Other Observations on the Scenario activity levels

- **Total cattle numbers**
  - **S2** fall to low levels last seen in **late 1960s**
  - **S3** approach record high levels of the **late 1990s**
- **Fertiliser use** projected to remain > 300 kt 2030 target
  - MACC measures key to reducing N_2O emissions
- **S2 reductions** in **total cattle numbers** of **> 20%**
  - could lead to **land abandonment**
  - **much reduced** average **stocking rates**
  - possibly **increased tillage** or
  - even **more afforestation**
- In all scenarios land assumed to leave agriculture for forestry
  - Total forestry area increases by **> 200kha** by 2050

Conclusions

- **Many** of the **MACC measures** are the focus of **current advisory programmes**
  - e.g. Teagasc Signpost Programme
- **Teagasc & industry initiative to improve farm understanding a promote mitigation action** (e.g. AgNav)
  - providing **accurate and verifiable data** to farmers on their **farm's carbon footprint**
  - **providing advice** on **how farm emissions can be lowered** through **MACC actions**
- Important to stress that **achieving MACC measure adoption rates** that are assumed in P2 (or P1) **cannot be taken as given**
  1. Policy action
  2. Advisory supports
  3. Industry/Consumer support

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