TEAGASC CLIMATE CENTRE

Marginal Abatement Cost Curve 2023

Executive Summary

SIGNPOST
Farmers for Climate Action

Teagasc
Agriculture and Food Development Authority

Contents

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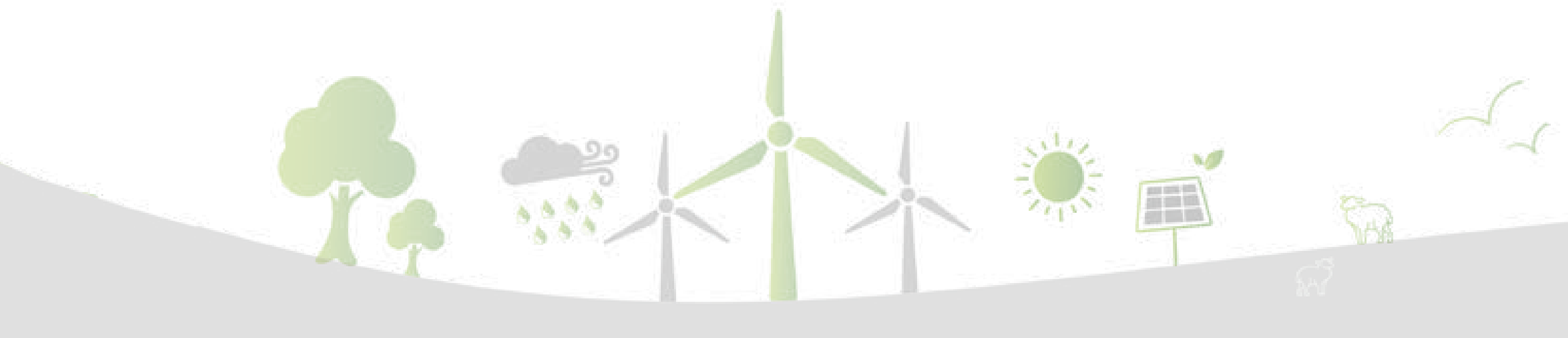

Key take-home messages

- The Agriculture sectoral target of a 25% reduction in greenhouse gas (GHG) emissions by 2030 was not achieved with Pathway 1 for any of the three agricultural activity scenarios investigated. This highlights the importance of maximising the adoption rate of GHG mitigation measures.

What's a scenario?

A projection of how animal numbers will evolve to 2030.
Scenario 1:
most likely, base case
Scenario 2:
lower than base case
Scenario 3:
higher than base case

What's a Pathway?

A set of assumed adoption rates for each mitigation measure
Pathway 1:
Adoption rates similar to the last MACC
Pathway 2:
Higher adoption rates

- In Scenario 1, sectoral targets can be achieved by the high adoption rates of GHG mitigation measures as outlined in Pathway 2. New science in the future may expand the set of mitigation measures available to farmers.

- In Scenario 2, sectoral targets can be met through combining high adoption rates in Pathway 2 for age of finishing, feed additives, diversification, fertiliser use and type, with the lower adoption rates in Pathway 1 of other measures.

- Diversification into organic farming, increased tillage and forestry or biomethane feedstock production has the potential to aid in herd stabilisation and thereby contributing to meeting the agricultural emissions targets.

- Reductions in LULUCF emissions above 13% (the EU LULUCF target) could not be achieved due to the large uncertainties in inventory emission factors. Improvements in the inventory (i.e. refinement of emission/land-use factors and land management data, particularly for peat soils) emission factors could change the estimates quite significantly.

- Bioenergy production based on biomethane and woody biomass can contribute significantly to the wider decarbonisation of the Irish energy sector.

- Increased advisory and extension services will be key to helping guide farmers and land-owners on the path to reduced GHG emissions by 2030 and towards climate neutrality.

- Continuing research and development of emission mitigation technologies and inventory adjustments remains a priority to expand and/or enhance the set of mitigation measures available to farmers.

SIGNPOST Farmers for Climate Action

Teagasc Agriculture and Food Development Authority

TEAGASC CLIMATE CENTRE

Introduction

The Teagasc Marginal Abatement Cost Curve (MACC) identifies the most cost-effective pathway to reduce greenhouse gas (GHG) emissions and enhance carbon sequestration in the Agricultural, Land-Use, Land-Use Change and Forestry sectors plus (Bio) energy. This is the third iteration of the Teagasc GHG MACC; previous iterations were published in 2012 and 2018. In the current version of the MACC the FAPRI Ireland was used to model three potential agricultural activity scenarios on how animal numbers will evolve in 2030; Scenario 1 (S1) is the most likely base case, while Scenario 2 (S2) and Scenario 3 (S3) project lower and higher numbers respectively. Additionally, two assumed adoption rates for each mitigation measure were assumed; Pathway 1 (P1) had an adoption rate similar to the last MACC, while Pathway 2 (P2) assumed a higher adoption rate that represented the maximum technically feasible.

What is a MACC?

A Marginal Abatement Cost Curve (MACC) is a graph that visualises the abatement potential of GHG mitigation measures, and the relative costs associated with each of these measures. The MACC helps stakeholders make informed decisions about how to allocate resources for emissions reductions. It provides insights into the cost-effectiveness of different abatement options and helps identify the least costly ways to achieve a given emissions reduction target.

51%

Ireland has committed to reducing overall GHG emissions by 51% from 2021 to 2030.

Why is a new Teagasc MACC needed?

It is important to note that a MACC cannot be static or definitive. The potential for GHG abatement, as well as the associated costs/benefits will change over time as on-going research programmes deliver new mitigation measures, or as

Agricultural Activity Scenarios and Adoption Levels

ACTIVITY LEVELS: Total activity data associated with Irish agriculture (dairy and other cattle, sheep, pig and poultry populations, tillage production and fertiliser use) were modelled using the Teagasc FAPRI-Ireland economic model. Three potential agricultural activity scenarios have been examined and two potential adoption pathways.

SCENARIO 1 (S1): Most likely base case scenario predicts growth (8% relative to 2022) in dairy cow numbers and reductions (-29%) in suckler cow numbers over the period to 2030. The 2030 GHG emissions are estimated to be 21.9 $MtCO_2eq$. This forms the central "Business-as-Usual" scenario and MACC mitigation figures within the report have been calculated using this scenario.

SCENARIO 2 (S2): Assumes lower growth in dairy cow numbers than Scenario S1 (4% relative to 2022) and a higher reduction (-43%) in suckler cow numbers. The 2030 GHG emissions are estimated to be 21.1 $MtCO_2eq$.

SCENARIO 3 (S3): Assumes a stronger growth in the dairy sector than in Scenario S1 (12% relative to 2022) and weaker reductions (-16%) in suckler cow numbers. The 2030 GHG emissions are estimated to be 22.8 $MtCO_2eq$.

PATHWAY 1 (P1): Assumes adoption rates similar to the previous MACC.

PATHWAY 2 (P2): Assumes more ambitious adoption rates of measures. It represents the maximum technically feasible adoption rate.

RATES OF ADOPTION: Variable speeds of adoption across the individual MACC measures have also been included to reflect differing levels of technology readiness.

Table 1. Animal numbers in 2022 and projected animal numbers plus mineral N fertilizer and associated greenhouse gas emissions projections (FAPRI) for the three scenarios in 2030 with no greenhouse gas mitigation.

2030 Projected activity data and emissions

	2022 '000 head	Scenario 1 '000 head	Scenario 2 '000 head	Scenario 3 '000 head
Total cattle	7,132	6,785	6,541	7,015
Dairy cows	1,568	1,692	1,627	1,756
Suckler cows	887	632	504	748
Total sheep	5,223	4,656	4,664	4,649
Total pigs	1,676	1,629	1,629	1,630
Total poultry	19,765	20,911	20,912	20910
Total mineral N fertiliser tonnes	343,200	399,156	369,806	420,989
Total GHG emissions Mt CO_2eq		21.9	21.1	22.8

Animal inventories align with the activity level used in the EPA Agriculture GHG inventory. See Ireland's Informative Inventory Report 2023 (EPA, 2023)

socio-economic conditions evolve. New agriculture GHG mitigation measures have been added to the current MACC. Additionally the Russian-Ukrainian War has added considerable volatility in terms of energy and commodity prices.

Changes in international, EU and Irish climate change policy

The Paris Agreement in 2015 sets out a global framework to avoid the impact of climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C. The following EU policy developments have occurred:

- In **December 2020**, EU leaders agreed to reduce EU GHG emissions by at least 55% (compared to 1990 levels) by 2030 as part of the European Green Deal.
- In **June 2021**, the EU Council adopted the **European climate law** legally obliging EU countries to reach both the 2030 and 2050 climate goals.
- In **2023** Ireland's commitment under the EU Effort Sharing Regulation increased from a 30% to 42% reduction in GHG emissions by 2030, relative to 2005 levels.
- The EU Land-Use, Land-Use Change and Forestry (LULUCF) Regulation was revised in 2023 for the period up to 2030, with a separate land-based net carbon removals target of 310 million tonnes of CO_2eq by 2030. This EU-wide target is to be implemented through binding national targets for the LULUCF sector.

In line with EU ambition, Ireland has committed to achieving the following:

- A reduction of 51% in overall GHG emissions from 2021 to 2030 based on 2018 levels and achieving Climate Neutrality no later than 2050. These legally binding objectives are set out in the Climate Action and Low Carbon Development Act 2021.

- In 2022, a 25% reduction in GHG emission relative to 2018 levels was set for the Irish agriculture sector by 2030.
- The finalisation of the sectoral emissions ceiling for the Land-Use, Land-Use Change and Forestry (LULUCF) sector was deferred for 18 months (Q4 2023) to allow for the completion of the Land-Use Strategy.

What's different compared to the last MACC?

There are a number of key differences to the previous MACC. These include:

- The FAPRI Ireland model has been used to update the animal number projections to 2030 (Table 1). This projects a small decline in the overall bovine herd size. These projections are the same as those provided by Teagasc for the 2023 EPA projections of GHG inventories.
- The agricultural efficiency measures (which reduce the carbon footprint but only reduce absolute emissions if the volume of farm output is not increasing) have been separated from those measures that will reduce the absolute emissions.
- New measures have been added, including age at finishing, feed additives, diversification etc. The contribution of some existing measures have been adjusted based on new science (particularly dairy EBI), which has emerged over the last five years and coupled it with forthcoming science.
- Two adoption pathway rates for GHG mitigation measures have been established along with three possible scenarios for how animal numbers might evolve.

Projected GHG emissions without any abatement

- The 2030 GHG emissions are estimated to be 21.9 $MtCO_2eq\ yr^1$ for Scenario 1, 21.1 $MtCO_2eq\ yr^1$ for Scenario 2 and 22.8 $MtCO_2eq\ yr^1$ for Scenario 3.

How have potential reductions been calculated?

In order to assess the potential contribution of the Agriculture (both mitigation and efficiency), Land-Use, Land-Use Change and Forestry (AFOLU) and (Bio)Energy sectors, four distinctive MACCs were developed:

1) **Agricultural Mitigation MACC** – The reduction potential associated with measures that reduce the total GHG emissions associated with agriculture.
2) **Agricultural Efficiency MACC** – The reduction potential associated with measures that reduce the carbon footprint of agricultural produce.
3) **Land Use, Land Use Change and Forestry (LULUCF) MACC** – The reduction potential

Table 2. The carbon budget targets in 2030 plus the estimated agricultural GHG emissions in 2030 using three animal number scenarios and two adoption pathways. Note the 2018 baseline for agriculture used was 23* $MtCO_2eq\ yr^1$

		Emissions in 2030 after mitigation $MtCO_2eq\ yr^1$	Carbon Budget Cumulative emissions 2030 $MtCO_2eq$	Cumulative Emissions Reduction 2021-2030 $MtCO_2eq$
	Carbon Budget Target	**17.25**	**202.0**	
Scenario 1	Pathway 1	19.1	206.8	13.1
Scenario 2	Pathway 1	18.4	203.6	12.7
Scenario 3	Pathway 1	19.7	210.2	13.5
Scenario 1	Pathway 2	17.0	198.9	21.1
Scenario 2	Pathway 2	16.4	196.1	20.3
Scenario 3	Pathway 2	17.7	202.2	21.7

*These values do not include the inventory changes in sheep methane emissions that will be included in the EPA National Inventory Report 2023

associated with measures that reduce emissions and enhance sinks associated with Land-Use, Land-Use Change and Forestry (LULUCF).

4) **(Bio)Energy MACC** – The fossil fuel CO_2eq offsetting potential associated with bioenergy or energy-saving measures in the Agriculture and LULUCF sectors.

In contrast to previous MACC analyses, linear rate of uptake for all measures was not assumed. The rate of uptake was tailored for individual measures. Measures already being adopted, e.g. LESS, were assumed to be taken up more rapidly, whilst those still under development, e.g. animal feed additives, were assumed to start slowly and have accelerated rates of uptake in later years.

Mitigation potentials

Agriculture MACC – absolute greenhouse gas reduction measures

- Using S1 level of activity, GHG abatement measures have the potential to reduce emissions associated with agriculture by between 2,820 ktCO_2eq yr^{1} (Pathway 1) and 4,857 ktCO_2eq yr^{1} (Pathway 2) by 2030 (Fig. 1 and 2 and Table 3).
- Over the ENTIRE period (2021-2030), the cumulative emissions reductions potential for Agriculture ranges from 12.7 million tonnes CO_2eq for S2 level of activity in combination with P1 level of GHG abatement to 21.7 million tonnes CO_2eq for S3 level of activity in combination with P2 level of GHG abatement when each year is summed together.
- The quantum of abatement over the entire commitment period depends on how quickly a measure is taken up (uptake rate) and the number of farmers/land-owners that adopt a measure (adoption rate).
- Using P1 level of uptake, the top five abatement measures are reduced age of finishing, altering fertiliser formulation, feed additives, dairy EBI, and the adoption of clover/MSS which by 2030, would account for 62% of total mitigation potential.
- Uptake ambition of an individual measure is NOT mutually exclusive to a pathway.

4,857
ktCO_2eq yr^{1}

In Pathway 2, measures have the potential to reduce emissions associated with agriculture by 4,857 ktCO_2eq yr^{1}

Agricultural MACC – greenhouse gas efficiency measures

- Measures have the potential to reduce emissions associated with C footprint by between 1,524 ktCO_2eq yr^{1} (Pathway 1) and 1,954 ktCO_2eq yr^{1} (Pathway 2) by 2030 (Fig. 3 and Table 4).
- While these measures have a direct impact on the Carbon footprint or emissions intensity of agricultural produce, they only indirectly affect total emissions.
- Animal health and improved beef maternal/terminal index contribute to reducing the finishing age of beef cattle.
- In order for increased efficiency measures to deliver reductions in 'absolute' GHG emissions, agricultural output would have to be stable over the period to 2030.

> **"Over the entire period (2021-2030), the cumulative emissions reductions potential for Agriculture ranges from 12.7 million tonnes CO_2eq to 21.7 million tonnes CO_2eq"**

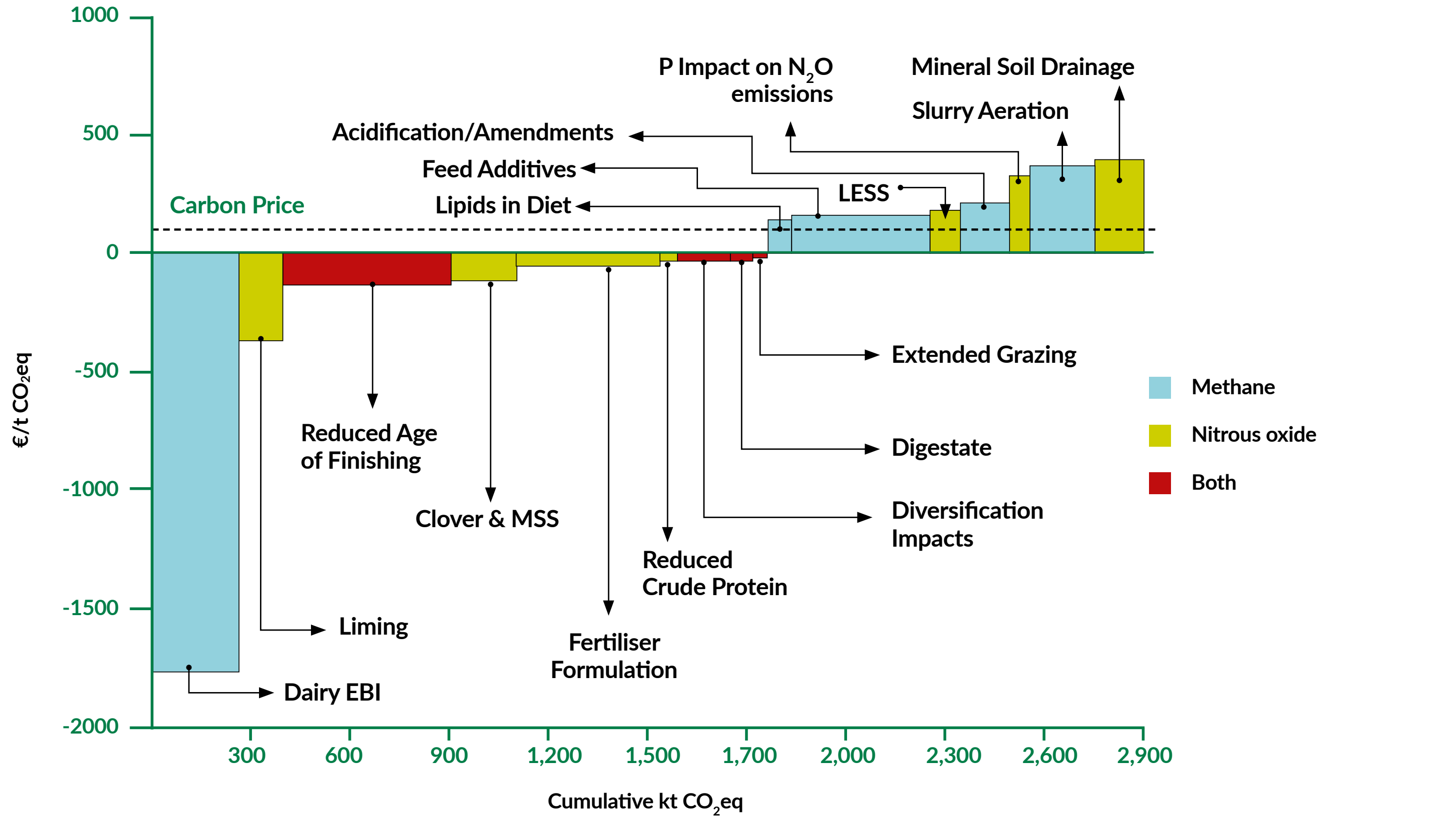

Figure 1: Agricultural MACC for the expected animal numbers (Scenario 1) with a similar level of measure adoption to that previously used (Pathway 1) for methane, nitrous oxide and both gases. The dashed line indicates a Carbon Price of €100 per tonne CO_2eq.

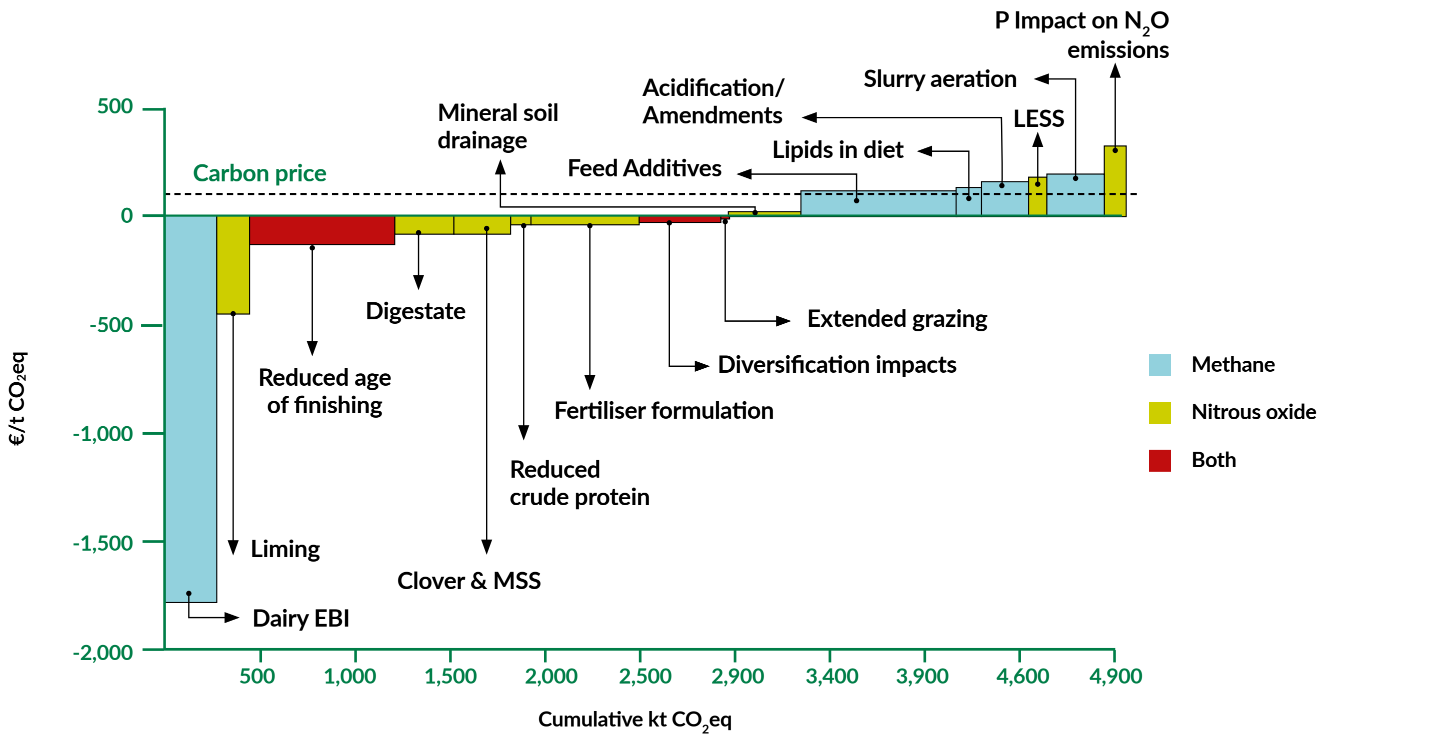

Figure 2: Agricultural MACC for the expected animal numbers (Scenario 1) with a high level of measure adoption (Pathway 2) for methane, nitrous oxide and both gases. The dashed line indicates a Carbon Price of €100 per tonne CO_2eq.

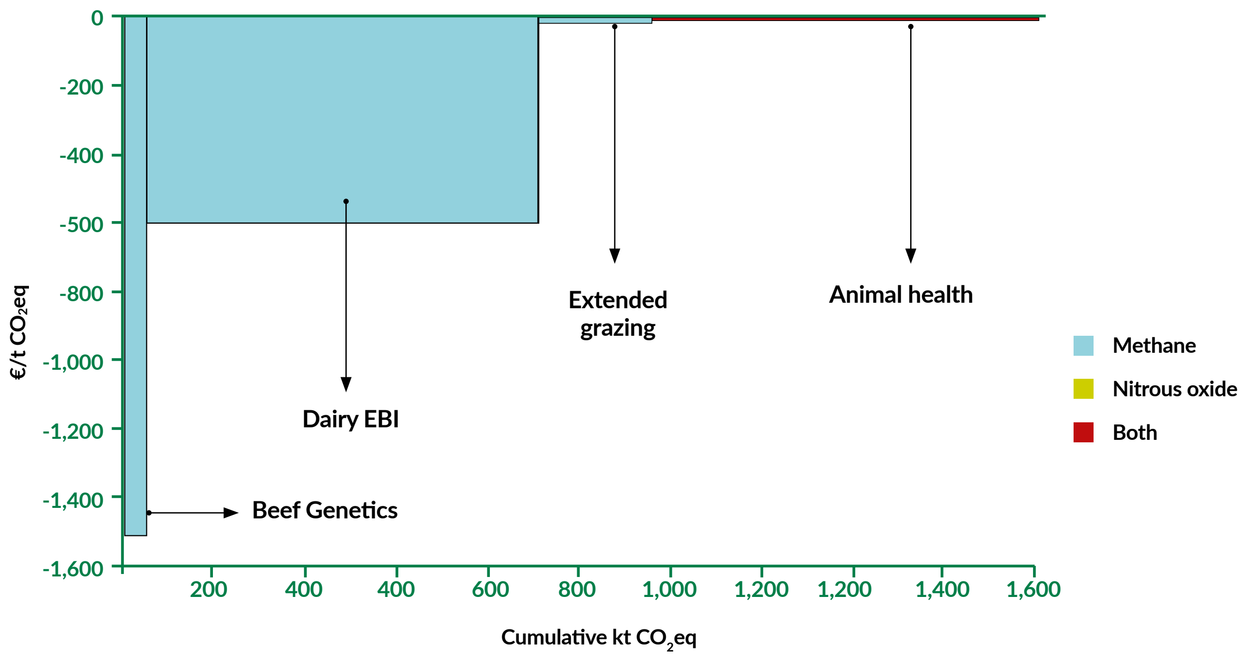

Figure 3: Agricultural Efficiency MACC for the expected animal numbers (Scenario 1) with a high level of measure adoption (Pathway 2).

Key measures: what should farmers and policy makers focus on first?

Nitrous oxide mitigation

- Management of and reductions in use of nitrogen fertilisers should be the first focus. This can be achieved through a combination of reduced N fertiliser application and altered fertiliser formulation (either protected urea or ammonium-based compound fertilisers).
- Key technologies for achieving a reduction in nitrogen fertiliser use include the greater use of white and red clover, achieving optimum soil pH and soil P/K status in combination with enhanced use of legumes and multi-species swards and the use of Low Emissions Slurry Spreading (LESS). These can reduce fertiliser use to between 322,590 tonnes N (P1) and 285,727 tonnes N (P2) by 2030.
- Altering fertiliser formulation (switching from CAN to protected urea or an ammonium-based compound) will reduce emissions in 2030 by between 418 ktCO_2eq yr[1] (Pathway 1) and 553 ktCO_2eq yr[1] (Pathway 2). Reduced crude protein in animal feed concentrates will also contribute to reduced nitrogen loading in soils.
- The cumulative abatement over the period 2021 to 2030 for nitrogen fertiliser is between 6.8 million and 11.1 million tonnes CO_2eq.

Methane mitigation

- Reduced age at finish could reduce emissions in 2030 by 470 and 732 ktCO_2eq yr[1] for Pathways 1 and 2, respectively. This is equivalent to a reduction of average finishing age by 2 and 3 months, respectively.
- EBI could reduce absolute levels of methane by 255 ktCO_2eq yr[1] by 2030 under both Pathway 1 and 2.
- Feed additives that inhibit methane production in the rumen, could reduce methane emissions in 2030 by between 396 ktCO_2eq yr[1] (P1) and 788 ktCO_2eq yr[1] (P2). These still require a lot of research for development and deployment.
- Diversification into organic farming, forestry or particularly feedstock (grass) production for biomethane production could reduce emissions in 2030 by between 150 ktCO_2eq yr[1] and 417 ktCO_2eq yr[1].
- Manure management, in terms of slurry additives and aeration but also biomethane and extended grazing could reduce manure methane emissions by between 423 ktCO_2eq yr[1] and 879 ktCO_2eq yr[1] by 2030.

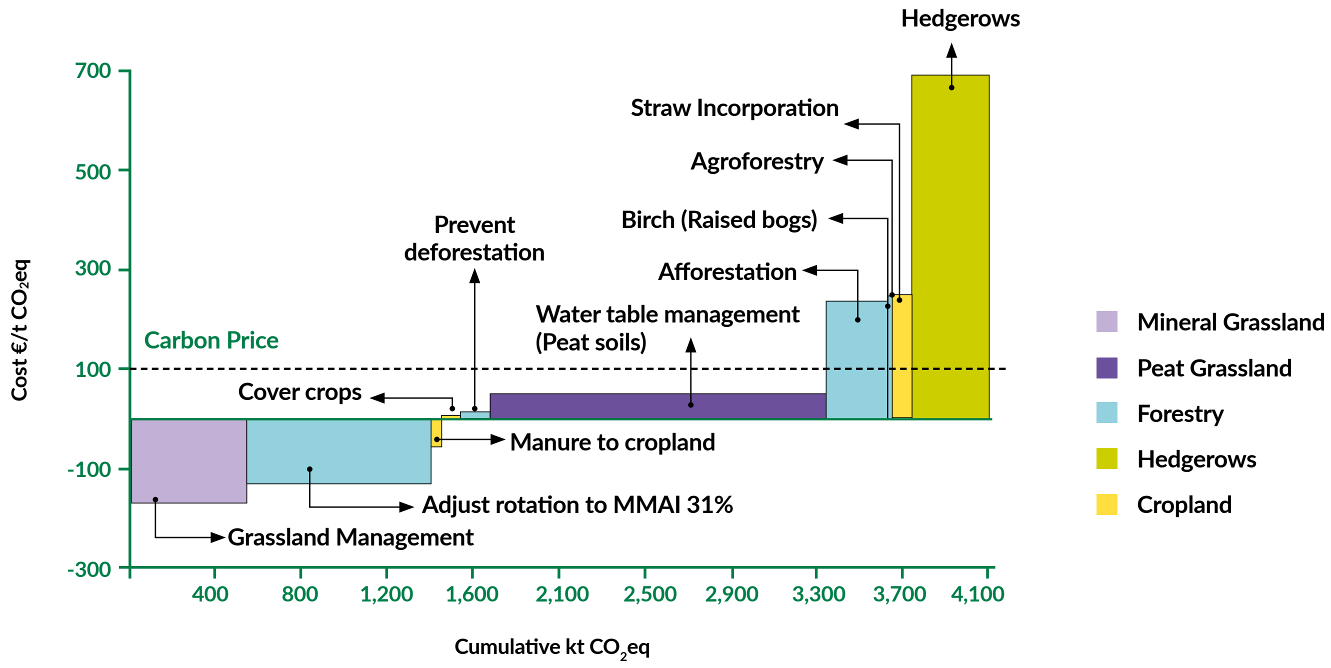

Figure 4: Marginal Abatement Cost Curve for LULUCF in 2030 (carbon abatement and sequestration associated with forestry, land management and land-use change) for Pathway 2 uptake levels. Values are based on linear uptake of measures between 2021-2030. Dashed line indicates Carbon cost of €100 per tonne CO_2.

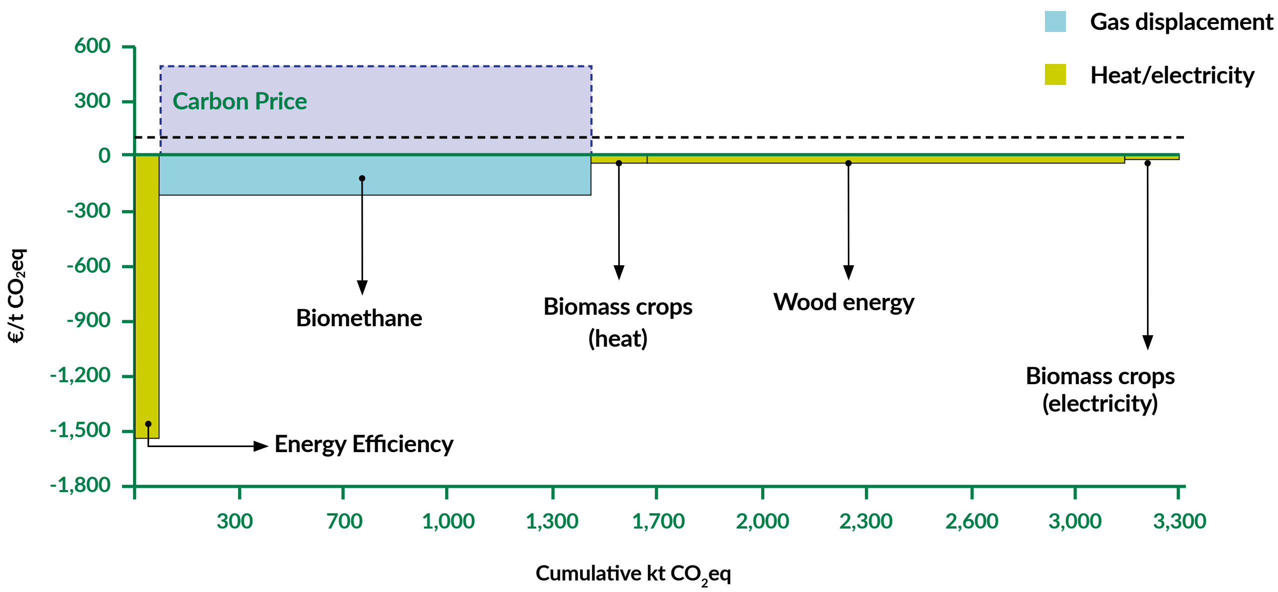

Figure 5: Marginal Abatement Cost Curve for 2030 bioenergy abatement produced in the agriculture and forestry sectors using Pathway 2 uptake levels. The dashed column indicates the biomethane marginal cost at pre-2022 energy price levels (low cast scenario). The dashed column indicates the cost of biomethane at pre-2022 gas prices. The dashed line indicates Carbon cost of €100 per tonne CO_2.

> **The lower animal numbers scenario (Scenario 2) combined with the higher adoption levels (Pathway 2) would come in under target by 850 $ktCO_2eq\ yr^{1}$ by 2030.**

Can Agriculture meet the 2030 reduction and carbon budget targets?

- As set out in the Climate Act the agriculture sector has been set a target to reduce GHG emissions by 25% (5.75 Mt CO_2eq) by 2030 or 17.25 Mt CO_2eq relative to 2018 levels.
- To achieve the emission reduction targets, the agriculture sector requires a combination of high levels of measure adoption, limiting animal number increases and development of new science.
- For the most likely animal numbers scenario in 2030 (Scenario 1) a very ambitious rate of measure adoption (Pathway 2) achieves the 2030 emission reduction and comes in under the carbon budget.
- The lower animal numbers scenario (Scenario 2) combined with the higher adoption rates (Pathway 2) would come in under target by 850 $ktCO_2eq\ yr^{1}$ by 2030.
- Scenario 3 does not meet the 2030 25% reduction target or the carbon budget targets for either pathway.
- The quicker measures are taken up, the more cumulative mitigation can occur over the entire 2021 to 2030 commitment period. For example, Low Emission Slurry Spreading (LESS) mitigates at most 87 $ktCO_2eq\ yr^{1}$, but as mitigation is front loaded, the cumulative abatement is 772 $ktCO_2eq$ over the entire 2021-2030 period. In contrast, manure acidification/amendments could mitigate 245 $ktCO_2eq\ yr^{1}$ (almost three times that of LESS). However, because adoption is back-loaded, cumulative mitigation over the 2021-2030 period is only marginally higher at 985 $ktCO_2eq$.
- The two pathways representing the upper and lower limits of GHG abatement and uptake rates of individual measures are not mutually exclusive to a given adoption pathway. In other words, adoption rates from both Pathways can be 'mixed and matched' in any combination that will achieve the targets.

What about Land Use, Land-Use Change and Forestry?

The LULUCF sector faces a range of challenges. Under Business as Usual, LULUCF emissions are projected to increase substantially to circa. 10.5 million tonnes $CO_2eq\ yr^{1}$ by 2030. This projected increase in land-use emissions is due to a) the age profile of Irish forestry, b) the relatively low afforestation rate over the last decade and c) emissions from peat soils (both peat grassland and managed peatland). It should be noted that there are considerable uncertainties in the LULUCF inventory in relation to the extent of some of the land use categories and the emissions factors associated with them. Research is underway to increase the accuracy of both land use data and the associated emissions, thereby reducing the uncertainty in this inventory, which may help the sector to meet its targets. This MACC uses the assumptions in the national inventory at the time of writing, but these are likely to change substantially as knowledge improves based on new science. For example, recently published research by Teagasc has found that the area of deep drained peat soil is less than 30% of the area currently used in the national LULUCF inventory. The incorporation of this new science into the national LULUCF inventory may reduce emissions by up to 60% from this source.

How much mitigation can be achieved?

- By 2030, the maximum annual rate of mitigation will range from 2,367 $ktCO_2eq\ yr^{1}$ under Pathway 1 to 4,110 $ktCO_2eq\ yr^{1}$ under Pathway 2 (Fig. 4 and Table 5). Much of this mitigation will simply offset the projected increase in emissions over the 2021-2030 period.

- The cumulative mitigation between 2021 and 2030 is projected to be between 12.8 million tonnes CO_2eq (Pathway 1) and 21.6 million tonnes CO_2eq (Pathway 2).
- Under the very ambitious Pathway 2, it is possible to achieve the EU LULUCF reduction target of 13.1%.
- Higher levels of emissions reduction from the sector will be difficult to achieve unless mitigation measures (such as grassland/cropland management) can be incorporated into the LULUCF inventories. A considerable body of scientific work is underway to both refine the land-use and land management factors in the inventory and to collate the activity data required to measure, verify and report emissions reduction or increased carbon sequestration.

How can forestry contribute?

- By 2030 afforestation rates of 8,000 ha yr^{1} could deliver 287 ktCO_2eq yr^{1}; achieving afforestation rates of 8,000 ha yr^{1} will be a vital measure for achieving 2050 climate neutrality.
- Forest management (by incentivising extension of the age of rotation on between 21% and 31% of the current forest stock) could reduce emissions in 2030 by 394 and 890 ktCO_2eq yr^{1} for Pathways 1 (21% forest area) and Pathway 2 (31% forest area), respectively. This measure could increase timber yields, but it could reduce feedstock for sawmills and it may undermine confidence amongst forest owners in terms of their ability to harvest at a time of their choosing.
- Preventing deforestation on 752 ha yr^{1} will reduce sectoral emissions by 140 ktCO_2eq yr^{1} in 2030.

What about grasslands and tillage?

- Altered water-table management on between 40,000ha and 80,000ha of peat-based grassland would reduce emissions by between 646 kt ktCO_2eq yr^{1} and 1,616 ktCO_2eq yr^{1} under Pathways 1 and 2 respectively in 2030. These targets may need to be revisited in light of the new (lower) estimates of peat grassland that is field drained.
- Optimal management of grassland on mineral soils could sequester an extra 358 ktCO_2eq yr^{1} under Pathways 1 and 556 ktCO_2eq yr^{1} under Pathway 2 in 2030.
- Planting new hedgerows and improved

> The achievement of the Government's 5.7TWh of biomethane by 2030 would deliver 1,518 ktCO_2eq yr^{1} and cumulatively over the 2021 to 2030 period could displace 4.1 million tonnes CO_2eq.

management of existing hedgerows could reduce emissions by 229 and 379 ktCO_2eq yr^{1} in 2030 respectively under Pathways 1 and 2.

- On tillage land, straw incorporation and cover crops could increase sequestration by 125 and 182 ktCO_2eq yr^{1} in 2030 respectively under Pathways 1 and 2.

How can Bioenergy contribute?

Bioenergy contributes to national decarbonisation. However, the majority of emissions reductions achieved will accrue to the energy-consuming sectors (power generation, transport, residential/commercial power consumption). The majority of fossil fuel displacement is projected to be due to the use of wood biomass (as wood thinnings and residues). However, the achievement of the Government's 5.7TWh of biomethane by 2030 would also deliver 1,518 ktCO_2eq yr^{1} and cumulatively over the 2021 to 2030 period could displace 4.1 million tonnes CO_2eq (Fig. 5). In total, bioenergy could contribute to over 10% of the combined energy sector's targets. The marginal cost of biomethane is highly dependent on both feedstock cost and the unit price of gas.

Further information

Read more about the Signpost programme at www.teagasc.ie/signpost

Visit the decision support and planning tool Agnav at www.agnav.ie

How will KT/Advisory and a whole-of-sector effort contribute?

The amount of GHG emissions reduction achieved through the adoption of the identified mitigation measures is dependent on both the rate and extent of adoption of the various measures by farmers. A targeted programme to enable this is the Teagasc-led, whole of industry Signpost Programme, www.teagasc.ie/signpost. Launched since the publication of the previous MACC in 2018, this major knowledge transfer initiative aims to lead climate action by all Irish farmers. This initiative includes:

1. **Signpost Farms:** a network of over 120 demonstration farmers who can be amongst the first to adopt climate mitigation technologies, and can share their experiences with other farmers;
2. **Signpost Advisory Programme:** a targeted advisory service which will be available to all farmers to provide enhanced advisory and training support to enable farmers to identify, select and implement climate and sustainability actions for their farms.

The involvement and support of industry in the Signpost Programme is a critical element in its success, and sustainability bonus schemes or similar initiatives introduced by industry can give an impetus to farmer adoption of mitigation measures.

In another important development, Teagasc, Bord Bia and ICBF, with the support of the Department of Agriculture, Food and the Marine, are developing a digital platform (www.agnav.ie), to provide a science-led, decision support and planning tool to farmers to enable climate action. AgNav will be a key enabling tool for advisors in the delivery of the Signpost Advisory Programme. The AgNav platform will allow farmers to quantify their farm's gaseous emissions (both GHG and ammonia, referred to as "Know My Number") while then facilitating the creation of a farm specific, action list (referred to as "Make My Plan"). The digital platform will provide individual farmers with farm specific indicators of their current status (baseline or starting point) and progress made over time in the uptake of mitigation measures and reductions in emissions.

Cumulative greenhouse gas mitigations from 2021 to 2030 and maximum annual mitigation in 2030

Table 3. Absolute Agricultural greenhouse gas mitigation measures based on Scenario 1 for the cumulative period 2021 to 2030 and maximum annual mitigation in 2030 for both Pathway 1 and Pathway 2

Activity Scenario/Measure	Pathway 1		Pathway 2	
Scenario 1	Cumulative mitigation 2021-2030 ($ktCO_2eq$)	Mitigation in 2030 ($ktCO_2eq$)	Cumulative mitigation 2021-2030 ($ktCO_2eq$)	Mitigation in 2030 ($ktCO_2eq$)
Reduced Beef Finishing Age	2,371	470	3,649	732
Fertiliser Type	1,901	418	2,616	553
Dairy EBI	1,561	255	1,561	255
Clover & MSS	1,063	193	1,574	286
Feed Additives	964	396	1,745	788
Slurry Aeration	821	182	1,173	286
Diversification	818	150	2,231	417
Low Emission Slurry Spreading	772	87	772	87
Mineral Soil Drainage	742	145	1,630	363
Acidification/Amendments of slurry	572	136	985	245
Liming	381	112	553	162
Reduced Crude Protein	316	45	545	93
Lipids in Diet	270	67	514	125
Increase Soil Phosphorus	219	58	441	116
Digestate (biomethane)	182	64	872	308
Extended Grazing	181	41	181	41
Total	**13,134**	**2,820**	**21,041**	**4,857**

Table 4. Agricultural efficiency greenhouse gas mitigation measures based on Scenario 1 for the cumulative period 2021 to 2030 and maximum annual mitigation in 2030 for both Pathway 1 and Pathway 2

Activity Scenario/Measure	Pathway 1		Pathway 2	
Scenario 1	Cumulative mitigation 2021-2030 ($ktCO_2eq$)	Mitigation in 2030 ($ktCO_2eq$)	Cumulative mitigation 2021-2030 ($ktCO_2eq$)	Mitigation in 2030 ($ktCO_2eq$)
EBI	3,295	842	3,295	842
Animal Health	2,261	411	4,521	822
Beef Genetics	146	28	245	47
Extending Grazing	1,047	245	1,047	245
Total	**6,794**	**1,524**	**9,108**	**1,954**

Table 5. Land-Use, Land-Use Change and Forestry greenhouse gas mitigation measures for the cumulative period 2021 to 2030 and maximum annual mitigation in 2030 for both Pathway 1 and Pathway 2

Activity Scenario/Measure	Pathway 1		Pathway 2	
Scenario 1	Cumulative mitigation 2021-2030 ($ktCO_2eq$)	Mitigation in 2030 ($ktCO_2eq$)	Cumulative mitigation 2021-2030 ($ktCO_2eq$)	Mitigation in 2030 ($ktCO_2eq$)
Extend rotation	4,479	379	7,862	890
Water Table Management-Peat soils	2,909	808	6,504	1,616
Grassland Management	1,714	358	2,687	556
Prevent Deforestation	1,120	140	1,120	140
Hedgerows	777	229	1,283	379
Afforestation	762	287	762	287
Straw Incorporation	345	67	465	95
Cover Crops	325	63	436	87
Birch (Raised bogs)	197	-2	206	-2
Manure to cropland	120	32	197	56
Agroforestry	24	7	48	15
Total	**12,772**	**2,367**	**21,569**	**4,110**

Table 6. Energy mitigation greenhouse gas measures for the cumulative period 2021 to 2030 and maximum annual mitigation in 2030 for both Pathway 1 and Pathway 2

Activity Scenario/Measure	Pathway 1		Pathway 2	
Scenario 1	Cumulative mitigation 2021-2030 ($ktCO_2eq$)	Mitigation in 2030 ($ktCO_2eq$)	Cumulative mitigation 2021-2030 ($ktCO_2eq$)	Mitigation in 2030 ($ktCO_2eq$)
Biomethane	959	266	4,080	1,518
Wood Energy	14,217	1,512	14,217	1,512
Biomass Crops	1,224	339	1,224	339
Energy Efficiency	295	77	295	77
Total	**16,695**	**2,195**	**19,816**	**3,446**

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