A Response to the Draft National Mitigation Plan

Teagasc submission to the

Department of Communications, Climate Action & the Environment

Prepared by the Teagasc Greenhouse Gas Working Group

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Teagasc is pleased to avail of the opportunity to make a submission to the National Mitigation Plan on the potential for Greenhouse Gas (GHG) mitigation within the Agriculture and Forestry sector, published by the Department of Communication, Climate Action and the Environment.

Since publication of or last report on C neutrality and previous MACC analysis, the context of discussions on agriculture and greenhouse gas emissions has continued to evolve. Specifically, we have witnessed the following three developments:

1. The revised European Union Climate and Energy Framework and subsequent Effort Sharing Proposals (COM/2016/482) has changed the European policy environment on approaches to mitigating agricultural greenhouse gas emissions;

2. At national level, the FoodWise 2025 strategy has built on targets in Food Harvest 2020

3. Science and knowledge transfer activities in relation to agricultural greenhouse gas emissions have continued to evolve and are delivering further opportunities for a low-carbon agricultural sector.

This submission details the mitigation potential of agriculture to shortly be published as an update to the Marginal Abatement Cost Curve (MACC) for Agriculture and and describes how the MACC mitigation strategies relate to the measures in the National Mitigation Plan.

1. The Policy Context

Foodwise 2025: The Food Harvest development plan has been further extended under the Food Wise 2025 Strategy, which envisages a further increase in dairy production as well as significant expansion of the arable, pig, poultry and forestry sectors. The principal targets include a) increasing the value of agri-food exports by 85% to €19 billion, b) increasing value added in the agri-food, fisheries and wood products sector by 70% to in excess of €13 billion, c) increasing the value of Primary Production by 65% to almost €10 billion and d) creating an additional 23,000 direct jobs in the agri-food sector all along the supply chain from primary production to high valued added product development. However, this expansion will have to be carried out whilst maintaining environmental sustainability. Indeed, the strategy has adopted as a guiding principle that "… environmental protection and economic competiveness will be considered as equal and complementary, one will not be achieved at the expense of the other." Sustainability is understood to encompass economic, social and environmental attributes and the subsequent strategic environmental assessment of FW 2025 proposed the need for a Sustainable Growth Strategy (SGS). The definition of this sustainable growth scenario recognises the need to achieve a balance between economic, environmental and social objectives. The SGS should seek to increase the value added by the sector per unit of emissions (GHG or ammonia) produced.

EU Climate and Energy Legislation: Current and future EU Climate targets pose considerable challenges for Irish agriculture. Under the current EU 2020 Climate and Energy Package and associated Effort Sharing Decision (Decision No. 406/2009/EU), Ireland was given a 20% reduction target for the period 2013-2020 relative to 2005. This was the largest reduction target (along with Denmark) and was based on a GDP per capita basis. Importantly, offsetting emissions via carbon (C) sequestration was not allowed, due to the perceived uncertainty surrounding terrestrial C sinks. The Paris Agreement aims to tackle 95% of global emissions through 188 Nationally Determined Contributions (NDCs) which will increase in ambition over time. Ireland's contribution to the Paris

Agreement will be via the NDC proposed by the EU on behalf of its Member States. This is a binding EU target of an overall EU reduction of at least 40% in greenhouse gas emissions by 2030 compared to 1990 levels. A proposal on the non-ETS targets for individual Member States, the Effort Sharing Regulation (ESR), was published by the European Commission in July 2016. The ESR proposal suggests a 39% GHG reduction target for Ireland, based on GDP per capita, for the period 2021 to 2030. This target has been adjusted downward for cost-effectiveness by 9% to give a headline target of 30%. In addition, Ireland has been offered flexible mechanisms, with 4% of the target achievable through the purchase of carbon credits and 5.6% achieved via offsetting emissions by sequestering CO_2 in woody perennial biomass and soils through land use management and land-use change (Figure 1).

Figure 1: National targets for EU member states with flexibilities under the 2030 Effort Sharing Proposals.

The implications of climate legislation, particularly the national allocations under effort-sharing are problematic for the sector due to the fact that while agriculture accounts for 33% of national emissions, it comprises 42% of non-ETS emissions, particularly when set against Foodwise targets (Duffy et al. 2015). However, unlike other sectors, where emissions reductions are measurable, reportable and verifiable (MRV), there is a high degree of uncertainty surrounding both the extent and reduction capacity of sectoral emissions. This means that agriculture has to be part of the national solution on reducing greenhouse gases. Does it also mean that Irish farming is inefficient? No, in fact, the carbon footprint of Irish produce is low compared to the same produce from other countries. But since Ireland produces and exports a lot of beef and milk and has a relatively small population, agricultural emissions make up a large proportion of total emissions. However, the revised 2030 proposals offers flexibilities as 5.6% of the target can now be met via carbon sequestration in forests and soils and 4% from the purchase of credits.

2. The GHG efficiency of Irish Agriculture

Recent estimates put the global GHG emissions from the agriculture sector at 14-18% of global GHG emissions (Denman et al., 2007 and US-EPA, 2006, respectively), with 75% arising from non-Annex 1 countries, principally South and East Asia and Latin America (Smith et al., 2007). FAO projections suggest that increases in global population and wealth will increase demand for dairy and meat by more than 50% by 2050 (Bruinsma, 2009). The FAO (2006) predicted that the increase in demand for both meat and dairy products will slow after 2030. More recent assessments forecast an 80% increase in dairy demand between 2000 and 2050 (Huang, 2010). Most importantly, there are significant concerns that this increase in food production will be associated with (among other impacts on natural resources) increased global GHG emissions from agriculture and particularly from land-use change. For example, Smith et al. (2007) estimated that, by as soon as 2020, global GHG emissions from agriculture will increase 38% relative to 1990 (24% relative to 2005). In light of the sustained future demand for dairy and meat, it is essential that the GHG emissions per unit product (GHG emissions intensity) are reduced. The Joint Research Centre conducted an analysis of the C footprint of a range of agricultural products across the EU-28 member states. It concluded that Ireland had the joint lowest C footprint for milk production and the fifth lowest for beef production in the EU, respectively (Leip et al., 2010). This supports the finding by the FAO that the carbon footprint of milk is lowest in 'temperate grass-based systems', such as those that are commonplace in Ireland (FAO, 2010). An earlier assessment and comparison of water quality shows that Ireland is in fifth place in the ranking of the proportion of 'good status' water bodies across the EU (European Commission, 2010). This positive environmental performance has been driven by on-going gains in resource use efficiency by Irish agriculture since 1990. Recent Teagasc data shows that that the carbon footprint of Irish produce has been reduced by c. 15% since 1990 (Schulte et al., 2012). Similarly, the 'Nitrogen-footprint' of Irish produce has been reduced by c. 25%. This means that Irish farmers now apply 25% less nitrogen fertilizer per kg food produced, through more efficient production methods and use of inputs such as fertilizer. Data from the Teagasc National Farm Survey shows that these efficiency gains present a win: win scenario for environmental and economic sustainability. For example, an analysis of data from 2013 shows that the most profitable dairy farms were those with the lowest carbon footprint per litre of milk (Hennessy et al., 2013).

3. The Challenge of Mitigation

Over the last number of years, Teagasc's Greenhouse Gas Working Group has been working hard to develop solutions for both farmers and policy makers: most cost-effective ways to reduce greenhouse gas emissions from farming have been researched. Put simply: which farm practices are good for the climate and also for farm margins? The answer lies in farm efficiency: if we can produce food with fewer inputs, then this reduces emissions to the atmosphere and costs to the farmer. Efficiency means more productive animals, extending the grazing season, informed nutrient management (e.g. Nutrient Management Planning, NMP online). Emerging technologies that promise to reduce greenhouse gas emissions even further. Examples include the improved genetic merit and the development of novel, low-emission fertilizers.

3.1 Capturing Mitigation: Inventory Improvement

Emissions inventories are compiled for individual sectors of a nation-state by collating those activities that produce emissions (such as fertiliser spreading, methane belched by dairy cows, fossil fuel burning from cars, etc). For each activity, a quantitative stock is measured, usually from national statistics (eg. Cattle population, fertiliser sales, etc) and multiplied by an emission factor (eg. amount of methane produced from enteric fermentation per cow) to generate national emissions for that activity. The degree of accuracy of the inventory will therefore be dependent on accurate collation of activity data (eg. Cattle population) and also the emissions associated per activity (called the emission factor). Inventories have a relatively low level of uncertainty for emissions associated with fossil fuel burning or industrial activity. Power consumption and fuel sales are relativity easy to measure and the amount of CO_2 generated from burning coal or oil is a generally constant value regardless of location. Likewise mitigation is easy to capture. For example if replacing fossil fuel burning for energy generation with wind energy, one can simply minus those emissions. However, agricultural inventories are more complex and have a much higher degree of associated uncertainty due to the biogenic nature of the emissions. For instance, nitrous oxide emissions associated with nitrogen addition to soil will vary with soil type, the form of nitrogen applied and climatic factors such as precipitation and temperature. As a result there is considerable temporal and spatial variation in emissions which is not reflected in the inventories. This results in considerable uncertainty in agricultural inventories. In addition, whilst mitigation that affects the *amount* of an activity can be counted (eg. Reduced fertiliser sales, cattle population, etc) any mitigation that affects the *emission factor* cannot currently be captured (eg. Changing fertiliser type, timing of fertiliser application, use of chemical amendments to reduce methane/ nitrous oxide and altering animal breed to reduce methane). As a result, a substantial portion of potential mitigation cannot currently be captured in the inventories (O'Brien et al. 2014). This is particularly true for nitrous oxide where IPCC Tier 1 default emission factors are currently being used. However, this will be required as all mitigation must be *measurable, reportable and verifiable* (MRV). Thus inventory refinement is crucial to meeting 2020 and 2030 emissions reduction targets as well as the long-term goal of carbon neutrality as envisaged under the National Mitigation Plan.

Similar challenges arise in relation to soil carbon sequestration. This is due to the fact that the input rates of organic C into most soil systems is very small (< 1 t C ha^{-1} yr^{-1}) compared to the background SOC levels (typically 80 - 140 t C ha^{-1}). Whereas quantity and quality of input of carbon via litter fall and plant residues after harvest might be directly measurable, inputs via roots and rhizodeposition are more difficult to assess. The fundamental mechanisms involved are not yet fully understood and there is still no proper quantification of the release of organic and inorganic C compounds from roots or the assessment of seasonal dynamics. This low rate of change also requires that management practices are in place for a minimum of ten years before any statistically significant shift in soil organic carbon (SOC) is detectable (Smith et al. 2005). In addition, high resolution land-use and land management activity data is required in order to assess and verify the impact of land-use/ land management change on carbon sequestration. As a result MRV for the impact of agricultural management to enhance soil carbon sinks is problematic. Teagasc are currently participating in an initiative sponsored by the FAO Livestock Environmental Assessment Programme (LEAP) to establish guidelines and systems to verify carbon stock changes in agricultural grasslands and also to design measures to incentivise the maintenance of soil C stocks.

3.1.1 The Impact of Improved N_2O Inventories

As stated above, current IPCC Tier 1 emission factors cannot capture a range of mitigation measures. There has been considerable research undertaken by the DAFM-funded Agricultural Greenhouse Gas Research Initiative for Ireland (AGRI-I, http:\\www.agri-i.ie) to produce national-specific Tier 2 factors that will dis-aggregate the N_2O emission factors based on fertiliser type, dung and urine deposited N, timing of application and impact of soil type. Under this initiative, further refinement of methane and ammonia emission factors is also being explored. However, this increased flexibility will bring its own challenges: the verification methods (ie. the collation of activity data around timing of fertiliser spreading and land parcel information for instance) will require considerable resourcing, particularly in terms of the National Farm Survey, the Ordnance Survey and farming stakeholders (see Section 4).

New disaggregated N_2O emission factors (EF) defined as (%N_2O per kg N applied have now been developed for mineral fertilisers and dung/urine deposition at pasture (Table 1). **The default emission factor (EF1) for fertilisers was 1% regardless of N form or soil type (IPCC 2006).** The emission factor for mineral fertilisers has been disaggregated between Calcium ammonium nitrate (CAN) and urea.

- Grassland: N_2O emissions were on average across all sites three times higher for CAN compared to other fertilisers and much more variable for CAN across soil types (Harty et al 2016, Carolan et al. In Prep; Higgins in Prep, Hyde et al., 2016, Krol et al., In Prep). On all occasions the N_2O emissions for CAN were higher than for urea in grassland. Novel fertiliser products containing urease inhibitors (to reduce ammonia) and nitrification inhibitors were also assessed (see Section 3.3).

Table 1. Summary of fertiliser type direct N_2O emissions factors

		Direct fertiliser type N_2O Emission Factor (%)				
Study	**Landuse**	**CAN**	**urea**	**urea+ NBPT**	**urea+NBPT+ DCD**	**urea+ DCD**
Harty et al. 2016	Grassland	0.58-3.81	0.1-0.49	0.21-0.69	-0.05-0.27	-0.08-0.25
Krol et al. (in review)	Grassland	2.39	0.25	0.17	0.06	0.02
Higgins et al (In Prep)	Grassland	0.44-3.81	0.3-0.49	0.25-0.43		
Mean Emission Factor	Grassland	1.49	0.25	0.4	0.11	0.11
Roche et al. 2016	arable	0.35	0.27	0.20	0.13	0.16

- In grasslands, Soil type had a large impact on emissions with the range in emission factor (%N_2O per kg N applied) for WELL drained compared to POOR drained as follows: CAN (0.58% to

3.81%), urea (0.1% to 0.49%), Harty et al. 2016, Higgins et al., In prep, Hyde et al., 2016, Krol et al., In review)

- Arable: N_2O emissions were lower than on grassland. There was no significant difference between CAN and other fertiliser types in terms of N2O emissions, although the trend was for higher N2O from CAN (Roche et al., 2016).

- Ammonia loss from urea was significantly higher than for CAN. When urea was treated with the urease inhibitor NBPT urea ammonia loss was cut by 79%. Urea treated with the urease inhibitor NBPT was not significantly different to CAN (Forrestal et al., 2016).

The emission factor for dung and urine deposited during grazing is defined as the Pasture, Range and Paddock (PRP) emission factor. **The default PRP emission factor (EF3) was 2% regardless of N form or soil type effects (IPCC 2006).** The revised EFs averaged 0.31 and 1.18% for cattle dung and urine, respectively, with large variations across soil type both of which were considerably lower than the IPCC default value of 2% (Krol et al. 2016).

These revised factors are currently under assessment by the Environmental Protection Agency and will have implications for the national inventories . Total N_2O emissions will be reduced by 0.75 MT CO_2-e yr^{-1} with a rebalancing between emissions arising from fertiliser and PRP (Figure 2). As absolute emissions will be reduced, there will be a concomitant impact of inventory refinement on the emissions intensity of agricultural products. Indeed, it will result in a 7% reduction in the C footprint of beef and milk, driven mainly be a reduction in the PRP emission factor.

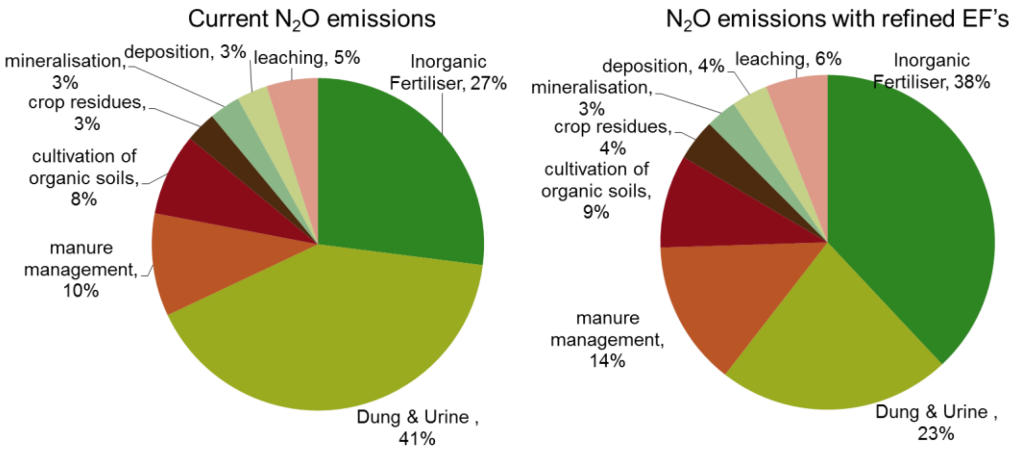

Figure 2: Impact of country=specific Tier 2 emission factors on national N_2O emissions

3.2 Optimising Mitigation: Marginal Abatement Cost Curves (MACC)

A national Marginal Abatement Cost Curve MACC for Irish agriculture was developed in 2012 by Teagasc, the Irish agriculture and food development authority (Schulte and Donnellan, 2012). It was designed in response to 2020 Climate targets as input into the public consultation of Irelands mitigation capacity and has since then been used to informed Irish climate change policy development (See, NESC, 2012a; 2012b). While abatement cost curves for agricultural mitigation had been created before at EU-level and in other member states, this was the first comprehensive attempt to do so in the Irish context.

Achieving FH 2020 targets was calculated to increase agricultural annual GHG emissions in Ireland (inclusive of emissions from fuel combustion) from 18.8 Mt CO-e in 2010 to 20.0 Mt CO_2e by 2020, a relative increase of 1.2 Mt CO_2e, or c. 7% (Donnellan and Hanrahan, 2012). Against this reference scenario, the Teagasc MACC analysed the potential of individual measures for climate change mitigation. Costs to the farmer arising from the measures were calculated in Euro per ton of carbon dioxide equivalent saved.

The analysis aimed to cover all measurers that were relevant to the Irish farming situation and where both data on abatement potential from completed scientific research and activity data for Ireland were available (Schulte and Donnellan, 2012). While for most measures values were based on experimental results and calculations, in some cases (like the number of grazing days) expert judgement was used. In total, 15 measures were analysed. Where measures were perceived to interact with each other, potential of individual measures was adapted to prevent double accounting of mitigation potential. This was marked in the methods sections for the respective measures. However, complex interactions between measures cannot be accounted for in this type of MACC. Cross compliance with other environmental impacts, such as the Nitrates Directive and NEC Directive were also considered. The total maximum biophysical abatement potential of the mitigation measures, using the IPCC methodology amounted to just under c. 2.7 Mt CO_2-e. Of this total (c. 1.1 Mt CO_2-e) of this accountable abatement potential will be attributed to the agricultural sector. The abatement potential of biofuel/bioenergy measures (including anaerobic digestion of pig slurry) which are attributed to the transport and power generation sectors, accounted for 1.4 Mt CO_2-e yr^{-1}. Almost all of the 1.1 Mt CO_2-e yr^{-1}abatement potential that can be attributed to the agricultural sector consisted of measures relating to improved production efficiency ("green" measures"). These included dairy economic breeding index (EBI), extended grazing, improved live-weight gain, improved N-efficiency and minimum tillage. Fossil fuel displacement from bioenergy was envisaged to come from biomass and bioenergy crops and woodchip from forestry as well as anaerobic digestion from pig slurry. It is clear that while heat generation from woodchip is growing, the anticipated adoption of biomass crops has not occurred and AD is still in a developmental phase.

As carbon sequestration was not allowable under the 2020 Climate and Energy Package, sequestration measures were not considered.

3.3 Mitigation capacity 2013-2020

3.3.1 Context for the MACC development

Marginal abatement cost curves are not static due to a) the development of new mitigation strategies, b) modifications to national inventories and c) alterations in policy context both in terms of new emissions legislation and production targets. An updated MACC is required as the new 2030 Climate and Energy Framework have set new targets for 2030, while FoodWise 2025 has revised production targets for the sector. Research in the interim period has quantified the impact of altered fertiliser use on emissions and will be used to alter N_2O emission factors (see Section 3.2). In addition, the 2030 targets allows for 5.6% of the reduction target to be met by enhancing carbon sinks (forestry and soils). Therefore sequestration measures have to be assessed, particularly as the IPCC have merged the agriculture sector and land-use, land-use change to forestry sector (LULUCF) into a single Agriculture, Forestry and Other Land Use (AFOLU) sector. A new 2017 MACC will shortly be published. The following section summarises the principal findings.

3.3.2 Impact of FoodWise 2025 on Agricultural Emissions

The FAPRI-Ireland model (Donnellan & Hanrahan, 2006; Binfield et al., 2009) has been used extensively in the analysis of agricultural and trade policy changes in Ireland over the last 15 years. Using the FAPRI-Ireland model, Donnellan & Hanrahan (2011) had previously assessed the impact of Food Harvest 2020 on animal numbers and fertiliser use in order to estimate future agricultural GHG emissions in conjunction with the EPA. In this analysis, the model was used to assess the impact of the Sustainable Growth Scenario on levels of agricultural production and to determine the associated level of input usage. In this scenario, production increases over the period to 2025 to give higher levels of production by 2025 than previously projected under Food Harvest 2020 scenarios analysed (Donnellan and Hanrahan 2015). Projections indicate that GHG emissions will rise by 6% by 2030. This is quite low considering the increase in dairy production. This is projected to be achieved by a rebalancing between dairy and non-dairy bovines. The overall cow population is projected to decrease by 3% by 2030 relative to the 2012-14 reference period. Over the period to 2030 projected growth in the dairy cow herd is matched by the projected decline in the suckler herd.

3.3.3 Cutting animal numbers to mitigate GHG emissions

Agri-food in Ireland contributes €24 billion to the national economy annually and provides up to 10% of national employment. Large reductions of the national herd in order to aid meeting emissions targets while substantially reducing GHG emissions, would have a disproportionate impact on the economic and social life of rural Ireland. An analysis by Lynch et al. 2016 investigated the impact of removing the suckler herd and found that while it would deliver 3 Mt CO2-e, this still would not meet a 30% pro-rata sectoral target and beef production would be substantially reduced. This is a deficit that may be filled by countries with a higher beef C footprint, resulting in higher total global agriculture emissions.

3.3.4 Mitigation Potentials

Mitigation was broken down into three parts: a) Agricultural mitigation of methane and nitrous oxide, b) Carbon sequestration and c) Offsetting via fossil fuel displacement. New measures include altered fertiliser formulation, drainage of mineral soils, beef genomics, dietary strategies (reduced crude protein in pigs and increased fatty acids in bovines), the use of sexed semen, manure management in housing and storage and use of sexed semen.

Methane & Nitrous oxide: The average annual mitigation potential for methane and nitrous oxide was calculated assuming linear uptake of measures and was calculated at **2.1 Mt CO_2-e yr^{-1}**. This represents a 3.7% reduction relative to 2005 over the period 2020-2030. However, if all options were adopted in full at the start of the commitment period, the reduction would be 9%. **This highlights the urgent requirement for a strong link between research and knowledge transfer.** Cost negative strategies, similar to the 2012 MACC consist of dairy EBI, optimised liveweight gain, extended grazing, N efficiency and improved animal health (dairy, beef and sheep). The total cost-negative abatement was 0.34 Mt CO_2-e yr^{-1} which is **additional** to 1.1 Mt CO_2-e yr^{-1} from the 2012 MACC. Low-cost solutions (under €40 per tonne GHG abated) include fertiliser formulation, drainage and reducing dietary crude protein, with altered fertiliser formulation the single largest abatement measure (circ. 0.6 Mt CO_2-e yr^{-1} by 2030). **Adoption of these measures will also result in a 25% decrease in the C footprint of dairy and beef products.**

Carbon sequestration: The Commission proposal included the allocation of 26.8 million tonnes (CO_2-e) of land-use, land-use change from forestry (LULUCF) credits to Ireland over the 10 year period (5.6% of 2005 base year emissions). The Commission confirmed that Member States with a larger share of emissions from agriculture were allocated a higher share of LULUCF credits. This translates to 2.68 Mt CO_2-e yr^{-1}. It is projected that the full allocation could be met, with the bulk of the sequestration due to forestry sequestration. However, a substantial portion could also be delivered by optimal management of grasslands, water table manipulation on organic soils and tillage management (cover crops and straw incorporation).

Offsetting fossil fuel emissions: The capacity for offsetting fossil fuel emissions is highly uncertain. In the previous iteration of the MACC, bioenergy was estimated to deliver 1.4 Mt CO_2-e yr^{-1}, yet much of this has remained unrealised as the land area of biomass crops is low and anaerobic digestion uptake is very low. A mean annual mitigation potential of 2.2 Mt CO_2-e yr^{-1} between 2021-2030 could be realised and is primarily met by forestry utilisation in heat and power generation and would require a significant adoption of AD. Anaerobic digestion of biomass produced from Irish grassland would produce biogas (55% methane) that could be used directly for heat and electricity generation, or the biogas could be upgraded to the same standard as natural gas (bio-methane – 97% methane), injected into the natural gas grid and subsequently used for a range of commercial purposes (Smyth et al., 2011). It should be noted that under the 2050 Carbon-Neutrality as a horizon point for Irish Agriculture Report (Schulte et al. 2013), bioenergy plays a major role in closing the emissions reduction gap. It should also be noted that under this scenario, the primary feedstock for AD would be grass-based, with some contribution from pig slurry and poultry litter. Large scale digestion of cattle slurry would not be envisaged as a) it would not contribute substantially to energy generation, b) there are other effective means to reduce slurry methane emissions c) digestate produced as a by-product would have the potential to increase ammonia emissions.

The total costs of mitigation for AFOLU emissions is calculated to range from €78 – 130 M per annum with a further €60- €100M for fossil fuel displacement .

3.3.5 Relationship between mitigation options and Draft National Mitigation Plan

Clearly a number of the measures listed are associated with measures listed in the National Mitigation Plan. Knowledge transfer (KT) and associated measures are covered under measures AF2B, AF4, AF5, AF7, AF8 and AF9. Knowledge transfer has been detailed as being vital due to the impact of uptake rate of emissions reduction across the whole period with reductions estimated at between 4.7 and 6.1 Mt CO_2-e yr^{-1} for AFOLU measures. Beef genomics (Measure AF2A) is estimated to deliver circa. 110 kT CO_2-e yr^{-1} from 2021 to 2030. Measure AF2E – Targeted Agricultural Modernisation Schemes (TAMS II) includes altered slurry spreading and manure management from housing and accounts for 102 kT CO_2-e yr^{-1} from 2021 to 2030 but has a proportionately larger impact on reducing ammonia emissions (see Section 3.3.5). The Pasture Profit index (Measure AF5) contributes to grassland sequestration and bioenergy (Measures RE2 , RE4) as a grass would be the principal feedstock to agricultural-based AD (see Section 4) which is estimated to deliver 0.3 Mt CO_2-e yr^{-1}, while AF6 Animal By-Products can contribute 0.14 Mt CO_2-e yr^{-1} and a proportion of the AD mitigation. Forestry is covered under AF10 and will deliver over 2 Mt CO_2-e yr^{-1} reduction.

3.3.6 Cross-compliance with ammonia emissions and Nitrates Directive

The requirement to reduce ammonia emissions is not only urgent in the context of Clean Air legislation, but as a principal loss pathway for agricultural nitrogen, it should be a key focus for improving farm efficiency and sustainability. This is particularly relevant in the context of the Food Wise 2025 Strategy. Similar to GHG, ammonia is projected to increase by 6% relative to 2005 with a 5% reduction target set for 2030 onwards. An ammonia MACC analysis has also been conducted, as ammonia indirectly contributes to N_2O production and also because ammonia mitigation and GHG mitigations can be additive or antagonistic. The analysis revealed that the 5% reduction target can be met with potential mitigation of 12 kT NH_3 yr^{-1} by 2030 at a cost of €36M per annum, with most abatement via coating urea fertiliser with a urease inhibitor, the adoption of trailing shoe technologies and covering external slurry stores. Some of these measures are covered under the National Mitigation Plan in AF2E. Most of the measures analysed have little impact on water quality or are positive, particularly dietary strategies, N efficiency and enhanced pasture management that reduce N excretion and fertiliser formulation. Two measures which are antagonistic are extended grazing and drainage of mineral soils, where more N excretion on pasture could increase nitrate leaching. Drainage will reduce N_2O emissions but could increase N leaching. Increased N use efficiency could enhance biodiversity where multi-species swards are used in the suite of measures to increase efficiency. Increased broadleaf forestry should also significantly enhance biodiversity.

3.4 2050 Towards Carbon Neutrality: The Role of Land-use and Functional Soil use

Using 2050 as a time horizon, the 2050 Carbon Neutrality report (Schulte et al. 2013) investigated scenarios whereby sectoral C neutrality could be achieved. It included strategies and technologies that may not yet be readily implemented in the short term, but that may become available or feasible in the period up to 2050. Defined by the difference between gross agricultural emissions and agricultural offsetting, the emissions gap was projected to likely to equate to c. 13 Mt CO_2-e or two-thirds of total agricultural emissions and this could widen in the event of reductions in forestry sequestration. Under the pathways analysed, increased sequestration and increased fossil fuel displacement were seen as likely pathways. However, these scenarios would require significant land-use change and the adoption of a national land-use strategy. Under these scenarios, substantial increases in afforestation (up to 20,000 ha per annum) and management of organic soils is required. Any Land–use Strategy should include a framework for managing soils is required to enhance C sequestration. Highly productive, trafficable soils should be prioritised to stay in production, enhanced grassland sequestration via optimal management should be promoted, SOC on organic soils should be maintained and where appropriate C emissions where organic soils have been drained should be reduced (Schulte et al. 2016, O'Sullivan et al. 2016). **Also, in order to maximise the use of sinks in offsetting emissions a cap on the use of C sequestration would have to be removed from future post 2030 EU legislation as there is capacity beyond the current limit to sequester or reduce losses of CO_2.** Several initiatives funded by both EPA and DAFM have begun which will develop analyses and decision-support tools to assess the impact of policy on functional land use. Irish grasslands are already high in soil organic carbon (SOC) with high levels of recalcitrant (permanent) C stocks and policies/measures to incentivise stock maintenance urgently need to be developed (Torres-Sallan et al. 2017).

Ultimately, achieving timely and substantial levels of mitigation will require a multi-actor approach involving primary production, industry research/KT and policymakers working in concert. Effective large scale mitigation will only occur if best practice can be communicated on the ground. This will involve a closer linkage between research/analysis to the development of relevant policies and effective translation on the ground via knowledge transfer. Thus, a coherent linkage of research and analysis, knowledge transfer and policy-making will be required in order to maximise adoption.

4. Knowledge Transfer

As both the 2020 and 2030 GHG reduction targets are multi-year targets, the total amount of abatement will be highly dependent on rates of uptake. This means that the role of knowledge transfer (KT) will be more important than ever. Research as of itself will not lead to emissions reductions without strong linkage to KT. There are twin roles of research and KT: whereas research into new GHG mitigation options aim to further reduce the carbon-intensity of farms that are already carbon-efficient, KT efforts focus on narrowing the spread in carbon-intensities between the most efficient producers and the main body of producers (see Figure 3).

Teagasc currently employs 255 advisers who work directly with farmers across the all the main enterprises including dairy, beef, sheep, crops, horticulture, organics, pigs, equine, and forestry these are supported by 25 specialists who provide technical and programme support and coordinate Monitor farm and BETTER farm programmes. There are 20 management posts and 75 administration posts involved, this equates to 375 posts and an annual paybill €33m plus non pay of €11m of which €6 is outsourced services (ie a total cost of €44m of which some €20m was recouped in fees and charges for services). Teagasc projects that two-thirds of this expenditure will be allocated to the advising on the climate and related cross compliance (ammonia/ water, etc.) measures listed over the period 2017-2030.

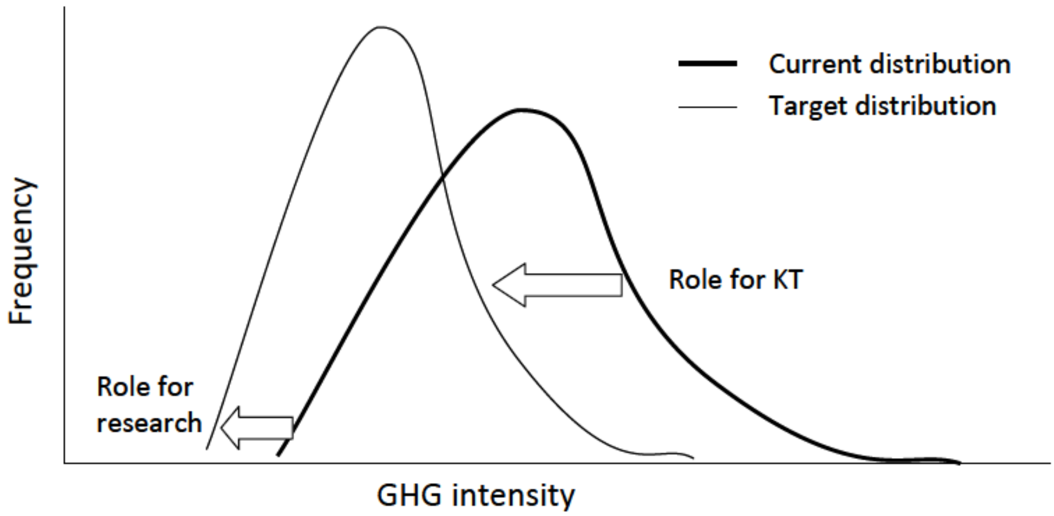

Figure 3: Conceptual illustration of the roles of research and KT in reducing the carbon intensity of produce: while new research outcomes can further reduce the minimum carbon footprint of produce, the role of KT programmes is to narrow the frequency distribution and lower the average

GHG intensity, by bringing the carbon intensity of the majority of producer closer to that of the top 10% most efficient producers.

Therefore, emissions reductions can only be realised if it is supported by a comprehensive KT programme. This finding concurs with one of the main recommendations of the Environmental Analysis of the FoodWise 2025 Strategy (Farrelly et al., 2016), commissioned by DAFM. In response to this KT challenge, Teagasc have a number of initiatives to aid in the uptake of new abatement measures. In the National Mitigation Plan, three have been highlighted (AF4 & AF7 BETTER Farms, AF5 Pasture Profit Index and AF9 Carbon Navigator). Each of these measures as stand alone would do little to reduce GHG emissions. However, taken as part of a linked strategy between research, KT and policy, they are key tools for achieving climate targets. Key measures include:

- Teagasc and Bord Bia have jointly developed the **Farm Carbon Navigator**, an on-farm KT tool to aid farmers and advisors in selecting cost-effective / cost-beneficial mitigation options that are customised for their individual farming system and environment. Importantly it is a simple tool, free of jargon, to help farmers decide what will work on their farm. These cost-effective mitigation measures were identified in the 2012 MACC (Schulte et al. 2012) and will be updated following publication of the 2017 MACC with the inclusion of new measures. Current measures include EBI, grazing season length, increased calving rate, better slurry management and improved nitrogen use efficiency. All beef farms and dairy farms in the Bord Bia Quality Assurance scheme have been carbon- audited and also received a Carbon Navigator report. The Navigator report compares a farmer's performance relative to similar farms and highlights the economic and GHG impact of adoption of the above measures. If all these measures were adopted by dairy and beef farmers in the scheme, a maximum 1Mt CO_2-e yr^{-1} would be abated by 2020 and a further 0.9 Mt CO_2-e by 2030.

- **The eProfit Monitor** programme is another useful management tool that will help farmers evaluate their performance. Even though this is an economics driven tool, many of the measures that will drive better farm margins will also reduce greenhouse gases. These include improved economic breeding index, improved animal health and improved pasture management. Maximum adoption of EBI and animal health would reduce GHG by 0.38 Mt CO_2-e per annum between 2017-2030.

- **The Pasture Profit Index** was developed in order to help farmers maximise utilisation of pasture by paddock grazing, along with optimising levels of Lime, NPK will help to maximise output per livestock unit. Taken in isolation maximising grass growth might lead to an increase in GHG due to increased use of fertilisers. However, combined with nutrient management planning (see below) and optimised slurry management, optimal pasture utilisation could reduce N_2O and also enhance carbon sequestration as long as overstocking does not occur. Grassland sequestration via enhanced growth and slurry management is estimated at a maximum of 0.3 Mt CO_2-e yr^{-1}. In addition, in agriculture-based AD facilities, the principal feedstock will most likely by grass rather than slurry. In addition, **PastureBase Ireland** aims to get livestock out to grass early and ensure an adequate supply of good-quality leafy grass. This will reduce methane emissions by minimising the amount of silage and supplemental feed in the diet and improving feed quality and promote grass regrowth. In addition, **Grass10** is a four year campaign to promote sustainable grassland excellence for Irish livestock. It aims to increase grass utilisation on Irish livestock farms. Its objective is to increase the number of grazings per paddock to 10 and the amount of grass utilised to 10 tonnes grass dry matter per hectare. Grass10 incorporates the roll-out and promotion of the re-launched PastureBase Ireland online grassland database. Livestock farmers can use this platform to record their grass covers, and easily monitor their performance in relation to the Grass10 targets of a number of rotations and grass utilised.

- **Nutrient Management Planning (NMP online):** Nutrient Management Planning is required in order to fulfil the terms pf the Nitrates Directive. Teagasc have developed an online system for developing nutrient management plans for environment and regulatory purposes called NMP online. This tool allows farmers to optimise nutrient requirements on a paddock by paddock basis. It requires farmers to soil test their fields and the tool then provides maps of the N,P,K and lime requirements in order to optimise output. The data underlying the tool has been obtained from Teagasc research and is synthesised in the Major and Micro-Nutrient Advice for Productive Agricultural Crops 'Green Book' (Wall & Plunkett 2016). Optimal liming reduces the requirement for mineral fertiliser and higher pasture primary production will increase soil C sequestration, which will in turn increase nutrient availability. NMP used in conjunction with pasture growth monitoring will, thus optimise Net Primary Productivity and hence sequestration. Optimal nutrient management will also decrease ammonia emissions as optimising N fertiliser replacement value by definition requires lower ammonia loss and reduces nitrate leaching and runoff. Optimal pasture management and increased N use efficiency will deliver 0.4 Mt CO_2-e yr^{-1}.

- **The Teagasc/Farmers Journal BETTER beef farms programme**, has at its heart, increases in efficiencies. Now in Phase 3, previous phases have led to increased gross margins by 52% for farmers who joined the programme in 2012, with technical efficiencies delivering 83% of this improvement. Other farmers in every region of the country have had the opportunity to see these improvements implemented on these farms. Key strategies for Phase 3 include increased fertility of the beef herd, improved animal health, increased soil fertility and incorporation of clover into 20% of swards, all measures which are projected to decrease GHG emissions, improve water quality and reduce ammonia emissions. Teagasc see the BETTER farm programme as a key demonstration tool with which to improve uptake of measures.

- Monitoring the progress of adoption of abatement measures, and assessing the success of tools such as C Navigator and NMP online will also be a key requirement over the next commitment period. Teagasc's **National Farm Survey (NFS)** has been incorporating features in to the survey that will allow for the monitoring of measures such as timing and application technique of slurry spreading, grazing season length, fertiliser type and use, EBI and herd makeup, finishing times and health. In addition, a survey of farm facilities is urgently required in order to inform measures for the abatement of GHG and ammonia emissions arising from manure management.

- **The Heavy Soils Programme.** The programme aims to improve the profitability of grassland farms on heavy soils through the adoption of key technologies including: appropriate drainage solutions, high quality pasture management, land improvement strategies and efficient herd management. Drainage of these mineral soils can aid in the reduction of nitrous oxide which is highest in poorly drained soils.

5. Summary and Recommendations

Achieving both 2020 and 2030 interim climate targets as well as delivering carbon neutrality will be extremely challenging for the agriculture, forestry and land-use (AFOLU) sectors. Foodwise 2025 is projected to increase GHG emissions by 6%. Mitigation of methane, N_2O combined with carbon sequestration can deliver a 13.5% for the periods 2021-2030 at a cost of circa. 130 million euro. An addition 2.2 Mt CO_2-e reduction can be contributed via fossil fuel displacement. Further reduction to 2050 will require an investment in research to develop breakthrough mitigation options combined with an integrated knowledge transfer strategy and the development of policies that will incentivise adoption.

Recommendations:

- Continued effort to promote maximum adoption of those efficiency measures identified in the abatement cost analysis is required, especially in terms of beef genomics and dairy EBI. Appropriate policy measures are required to incentivise best available technologies (particularly low cost measures) that have been identified. Continued monitoring led by Teagasc NFS will be fundamental to verification of efficacy.
- Increased N efficiency via appropriate nutrient management, slurry management and where possible, the use of grass legume mixtures is required as well as a move to more GHG-efficient fertilisers.
- Enhancing carbon sinks and reducing soil C losses are key strategies to reducing sectoral emissions. This will principally be achieved through increased afforestation, reducing losses on organic soils and enhancing pasture sequestration. Policies and mechanisms for incentivising soil C management and further incentivisation for afforestation are required. Removal of the cap on the use of sequestration in a post-2030 EU agreement would also be required as there is capacity to either sequester or reduce losses of carbon beyond the current 26.8MCO_2-e limit.

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