An Roinn Talmhaíochta,
Bia agus Mara
Department of Agriculture,
Food and the Marine

An Assessment of Socio-Economic Implications of the Transition to a Low Carbon Agriculture Sector

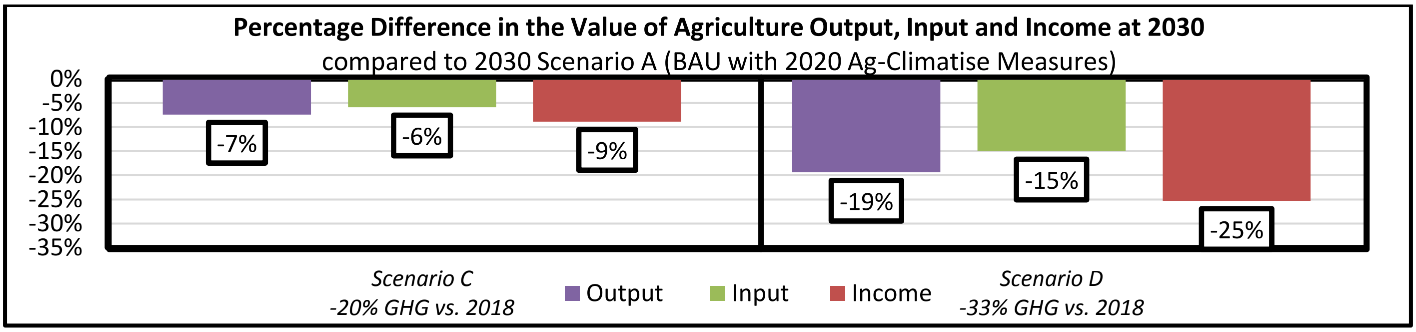
November 2022

Executive Summary

This report fulfils a commitment under the Climate Action Plan 2019. It assesses the implications of climate mitigation options for the socio-economic value of agricultural production and the rural economy in Ireland. Agriculture accounted for c. 37% of non-ETS emissions in Ireland in 2020, and the sector is expected to deliver a 25% reduction on its 2018 baseline emissions level by 2030 as part of the Climate Action Plan and Sectoral Carbon Budgets process. A number of other policies aim to assist the sector in achieving this target, including through Ag-Climatise, Food Vision 2030 and the new Common Agricultural Policy for 2023-2027.

Significant changes will be required for Irish agriculture to achieve its climate action targets. This is particularly true given the recent expansion of the dairy sector alongside the continued extensive number of beef farms, which together account for the majority of agricultural emissions. Total emissions from agriculture have increased in recent years despite improvements in production efficiency, with the three-year average for agriculture sector emissions 12% higher within 2018-2020 compared to 2008-2010. Achieving climate action targets will impact farming sectors and regions differently, and wider implications around indirect up- and down-stream impacts will be important, as will the opportunities that will arise from transition. This report presents an overview of the current available published evidence on these issues to provide context and highlight the need to conduct further research in these areas.

An economic evaluation was carried out using the Teagasc FAPRI model of the agriculture sector – to inform the Carbon Budgets allocation process by the Climate Change Advisory Council in 2021 – to highlight these implications under various scenarios of GHG mitigation. A summary of the findings of the analysis has already been published in the CCAC Technical Report on Carbon Budgets in 2021; however, this report places the results in terms of the current context and explores some implications for demand and employment in the domestic economy. The analysis did not include a scenario specifically examining the 25% reduction target agreed by Government in July 2022, but it did include two scenarios – a 20% reduction and a 33% reduction – which are close to the agreed target. Under these scenarios, agricultural output and income would be 7-19% and 9-25% lower at 2030, respectively, compared to a 2030 baseline scenario A; the model estimates total cattle would be 9-28% lower at 2030 under these scenarios; and Milk (Cattle) output volumes would be 12-26% (5-33%) lower at 2030 compared to the baseline. These estimates reflect the potential gross economic implications, in the absence of the development of alternative income streams and where GHG mitigation shortfalls are effectively bridged through reduced agricultural activity levels (i.e. livestock reductions). It is important to note that these estimates assume there is no policy response to mitigate economic effects; realised economic outcomes will depend on policies put in place, as well as farm-level responses and individual circumstances.



This report estimates, based on the Teagasc FAPRI estimates of output value impacts, and using a methodology based on multiplier coefficients, that there would be between 5,750 – 12,820 fewer domestic jobs as a result of the gross Milk and Cattle output value shocks under the 20% mitigation scenario, compared to the baseline; and 16,650 – 35,450 fewer jobs under the 33% mitigation scenario at 2030. The lower- and upper-bounds of these employment effect estimates reflect the use of marginal (lower) and average (higher) employment multiplier coefficients for the ranges, highlighting the uncertainty around such estimates due to the significant nature of the output shocks. Again, it is important to note that this analysis does not take any potential policy responses into account; while the abatement burden could also be distributed differently within the agriculture sector than it was in this modelling, which would likely lead to different second-round economic effects.

Employment Effect (Difference in No. Jobs vs. 2030 Scenario A)	Scenario C -20% GHG vs. 2018		Scenario D -33% GHG vs. 2018	
Multiplier Coefficient Type	*Average*	*Marginal*	*Average*	*Marginal*
Milk Output Shock	-7,518	-2,878	-16,069	-6,152
Cattle Output Shock	-5,300	-2,871	-19,386	-10,502
Gross Sum of Milk and Cattle Output Shocks	-12,819	-5,749	-35,455	-16,654

Author's calculations of gross differences in domestic economy-wide employment, versus 2030 Scenario A, arising from differences in the value of agricultural output – implied by average and marginal multiplier coefficients from Miller et al (2014).

Many other considerations are fundamental to understanding the wider implications and the challenges ahead with regard to the transition of the sector. While these are not within the scope of this report, an overview of current evidence on such considerations is provided in the appendix. This includes carbon leakage and food price Inflation; land-use change; measurement of methane warming effects; Just Transition; abatement distribution mechanisms such as cap-and-trade; and non-monetary factors which can affect farmer decision-making. Such factors will be important to consider when designing transitional policies and measures, and further analysis on these issues is warranted.

The report concludes by reiterating the scale of the challenge for the sector to transition to a lower carbon model, with significant changes to management practices and production required. Appropriate incentives will therefore be needed to achieve sectoral targets. Food Vision 2030 can guide the Agri-Food sector toward greater holistic sustainability, as it adopts a Food Systems approach. Knowledge transfer, developing human capital and ensuring access to technology will be important to facilitate a Just Transition as well as adaptation to climate change.

The report makes five recommendations:

1. Ongoing review of transition implications to meet policy objectives and to adapt to scientific developments as they materialise – particularly around feed additives, genetics and management practices.

2. Adopt a holistic and integrated Natural Capital and Sustainable Circular Bioeconomy framework to shape incentives and innovation toward maximising co-benefits for biodiversity, water quality and other eco-system services. Cooperative approaches could align natural capital, primary production and circular bioeconomy value chains for the sustainable mobilisation and valorisation of bioresources.

3. Continued research into the wider socio-economic value of agricultural production on issues such as employment, household income, wellbeing and rural development. Further insights into behavioural factors that influence decision-making will inform policy making to facilitate transition.

4. Further develop transition opportunities to create effective incentives for diversification – that balance the three pillars of sustainability – whilst offering farmers sufficient reward for implementing actions to enhance ecosystem services and provide additional public goods.

5. Implement sectoral plans under the Food Vision 2030 framework to ensure a more sustainable environmental footprint for the beef and dairy sectors in particular. By co-designing measures with stakeholders through a collaborative process, the transition can be managed in a solutions-focused manner.

This report is an initial step in highlighting the scale of the challenge ahead for the agri-food sector and the various complex considerations that will be important in assisting the sector in achieving its climate action targets.

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Note on Data and Methodology

This report was compiled primarily using statistics from the below sources. Where applicable, author's calculations based on figures from these sources are highlighted and the methodology for these estimates are explained; any errors are the author's own.

1) CSO (2022) *Census of Agriculture 2020*
2) CSO (2022) *June and December Livestock Surveys*; *Domestic Milk Intake Statistics*
3) CSO (2022) *Labour Force Survey* (Various Years)
4) CSO (2022) *Agricultural Output, Input and Income*
5) DAFM (2019, 2020 and 2021) *Annual Review and Outlook 2019-2021*
6) EPA (2020) *Ireland's Environment 2020 - An Integrated Assessment*
7) Duffy, P., Black, K., Hyde, B., Ryan, AM and Ponzi, J. (EPA 2022) *National Inventory Report 1990-2020*.
8) Teagasc (2015-2022) *National Farm Surveys 2014-2021*.
9) Teagasc (2022) *National Farm Survey Sustainability Report*

The National Farm Survey is conducted annually by Teagasc in conjunction with the Central Statistics Office (CSO), sampling approx. 900 farms with a Standard Output of more than €8,000 per annum. This is representative of c. 85,000 farms nationally, with farms classified based on enterprise shares in farm Standard Output. Teagasc NFS Sustainability Reports present joint assessments of Cattle Rearing and Cattle Other farms under the heading of 'Cattle' farms, while they are differentiated into Cattle Rearing and Cattle Other in NFS reports. For simplicity, these farms are sometimes referred to as Beef farms in this report. 'Dry-stock' systems generally refers to Cattle (Beef) and Sheep farms. Tables and figures using NFS data are updated to 2021 where possible; the 2021 NFS results and NFS trends over time, by system and region, can be explored in this interactive Teagasc presentation. The bi-annual CSO Livestock Surveys (June and December) measure the total number and type of cattle farmed domestically, with the June Survey being referenced in this report; livestock number trends are analysed on a regional basis here, however data is only available to 2021 on the regional breakdown.

All emissions data presented in this report are shown in Carbon-Dioxide Equivalent Emissions. Under Intergovernmental Panel on Climate Change (IPCC) AR4 methodologies, Greenhouse Gas (GHG) emissions are calculated on a standardised basis, where carbon dioxide has a reference value of one, methane has a reference value of 25, etc. Emissions are measured under a 100-year horizon in terms of their Global Warming Potential (GWP), reflecting the radiative forcing intensity of respective gases. Carbon Dioxide Equivalent emissions are measured on the supply-side and do not account for full life-cycle effects, such as transportation of goods or services. MT refers to Million/Mega Tonnes, while KT refers to Kilo (Thousand) Tonnes and T refers to Tonnes of CO_2e. IPCC AR5 accounting is used in National Climate Action Plan 2021, giving higher Agriculture sector emissions as the carbon equivalence factor for methane (the main source of agricultural emissions in Ireland) is increased to 28. Emissions from Fishing in the agriculture sector are excluded, and reference year emissions are from the EPA National Inventory Report. While the EPA have provisionally reported an increase in agriculture sector emissions in 2021, this report uses final 2020 figures as reported by the EPA.

Regions reflect the CSO Nomenclature of Territorial Units for Statistics (NUTS) at levels two (region) and three (sub-region) as follows:

NUTS 2	NUTS 3	County
Northern & Western	Border	Donegal Sligo Leitrim Cavan Monaghan
	West	Galway Mayo Roscommon
Southern	Mid-West	Clare Tipperary Limerick
	South-East	Waterford Kilkenny Carlow Wexford
	South-West	Cork Kerry
Eastern & Midland	Dublin and Mid-East	Dublin Wicklow Kildare Meath Louth
	Midlands	Longford Westmeath Offaly Laois

Introduction

This report summarises the socio-economic implications of the transition to a low-carbon model of Irish agriculture for the sector, primary producers and the wider rural economy. The present structure and trends in the Irish agriculture sector are established, providing the socio-economic, environmental and policy context. Evidence of sustainability challenges under the present model, across the three pillars, illustrates the need for a transition to a lower environmental footprint for the sector. Findings from the current literature are presented, highlighting areas of vulnerability as well as opportunities to improve farm viability via diversification and capturing possible sustainability dividends. The implications of the transition are likely to reflect existing structural variation within the sector, leading to concentration of effects in certain systems and, by extension, regions. This, in turn, will have implications for rural development due to the integration of agriculture in local economies, as changes in output are exacerbated by upstream and downstream effects. Constraints on agricultural production may also give rise to unintended effects.

While heightened climate ambition can support Ireland in achieving our commitments under the Effort Sharing Regulation (ESR) as well as meeting the national legally binding GHG emissions reduction target, the social and economic costs associated with any restrictions on, or modifications to, production will require a Just Transition[1] approach. This can support those displaced and improve access to alternative opportunities for income and employment on existing farm enterprises, such as carbon farming[2], production of renewable energy and other diversification opportunities, alongside existing efforts to improve the environmental footprint of the sector through the Food Vision Dairy and Beef & Sheep Groups. While the transition could heighten existing structural vulnerabilities without sector supports, it also provides an opportunity to ensure greater socio-economic sustainability of farming. Protecting the extensive public goods provided by primary producers, while reducing the harmful environmental externalities, will require policy and supports to re-shape producer incentives. The adoption of a Natural Capital framework alongside sector supports can therefore help Irish agri-food to transition to a more sustainable model. Co-benefits can also be realised, such as improved water and air quality, as well as greater economic efficiency and resilience. While there is considerable uncertainty around national and international agricultural mitigation pathways, the areas of socio-economic vulnerability and likely distribution of impacts are presented here to reflect the current context for Irish agriculture.

The paper is structured as follows:

- Section One outlines recent socio-economic and environmental trends in Irish agriculture, exploring the structure of farming systems and their relative impacts on nature. The policy context is then explored with respect to national and EU policies aimed at climate mitigation and adaptation of relevance to agriculture.
- Section Two builds highlights areas of risk and opportunity as the sector transitions toward a more environmentally and socio-economically sustainable future. This recognises the different weaknesses of farming systems in terms of economic viability, geographies and environmental pressures.
- Section Three provides estimates of the quantitative effect of emissions reduction targets for possible socio-economic outcomes in Irish agriculture to 2030. This analysis, completed by Teagasc, illustrates the possible constraining effects of such targets under specific scenarios, all else being equal.
- Section Four concludes by recapping the implications of structural strengths and weaknesses of the agriculture sector, before evaluating the current evidence on the likely effects of the transition. Finally, recommendations are provided for an effective and holistically sustainable transition.

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[1] Applying the principles of Just Transition can ensure that no one cohort of citizens, workers, communities or enterprises is disproportionately impacted by any changes or disruption arising from decarbonisation of the economy.

[2] Carbon farming refers to "the farm-level management of carbon pools and flows with the purpose of mitigating against Climate Change", as recognised in DAFM (2020) *Ag-Climatise: A Roadmap towards Climate Neutrality*, p.21

Section One: Sector Structure, Socio-Economic Sustainability and Policy Context

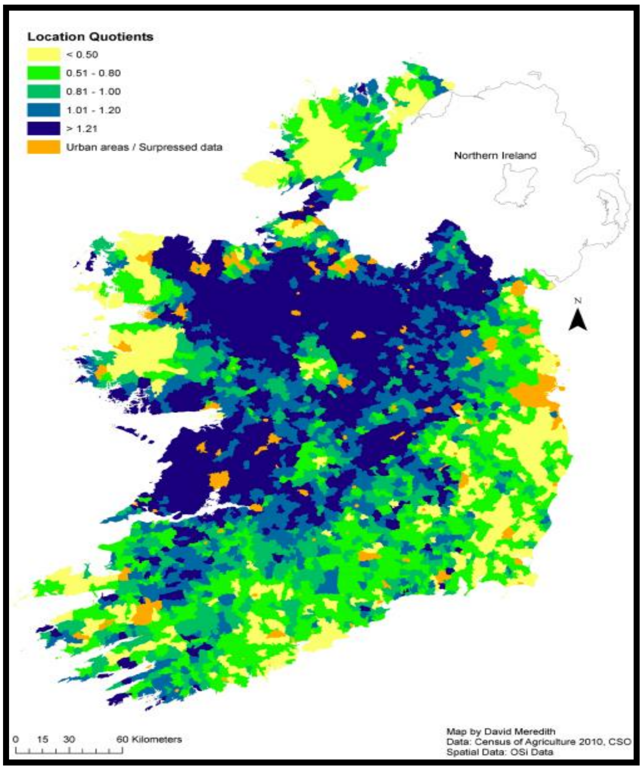
1.1 Sector Structure

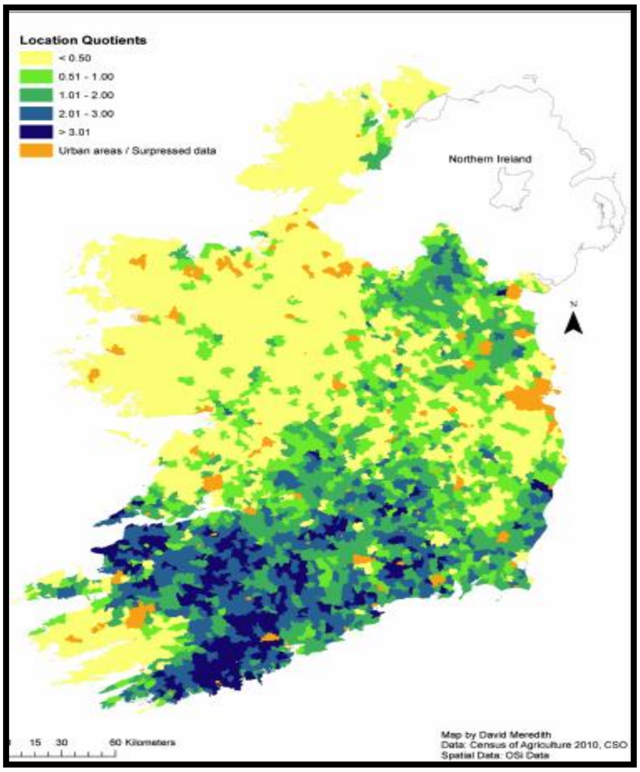
The primary agriculture sector is comprised of circa (c.) 135,000 farms, almost all of which are family farms, supporting rural households and wider communities. Over 170,000 people, including 107,000 in the primary sector, were employed in Agri-Food in 2021. This corresponds to 7.1% of total employment, while the sector contributed over 6% of Modified Domestic Income (GNI*) in 2020. Almost 90% of food produced in Ireland is exported, meaning the sector is heavily reliant on the general macro-economic context internationally and other exogenous supply and demand factors. Systems vary by number, size and location (Northern/Western or Southern/Eastern regions) of farms.

Farming System	Number of Farms (000s)		Average Size (UAA in Hectares)		Mean Age of Holder (Years)		System % Share of Farms (Census of Agriculture)		
Source / Region	*Census*	*NFS*	*Census*	*NFS*	*Census*	*NFS*	*State (Overall)*	*Relative (%) Regional Split N/W vs. S/SE*	
Beef	74.16	48.16	26.9	34.8	58.3	58.6	55	57	43
Dairy	15.32	15.26	65.1	64.2	52	54.1	11	22	78
Sheep	17.46	13.99	28.9	44.6	56.2	59.4	13	67	33
Tillage	4.57	6.24	63.6	67.9	56.6	58.4	3	14	86
Other	23.56	1.15	30.7	N/A	58	N/A	17	51	49
Overall	135.04	84.54	33.4	44.9	57.2	57.9	100	52	48

Number of Farms, Average Land Use and Economic Size by System in the CSO Census of Agriculture 2020 and Teagasc NFS 2021.[3]

Below, 2010 CSO Census of Agriculture data for the spatial concentration of beef (left-hand side) and dairy (right-hand side)[4] enterprises are mapped – with blue colouring representing higher concentrations of each – illustrating a key distinction between the two largest systems in terms of both economic significance and the number of farms.



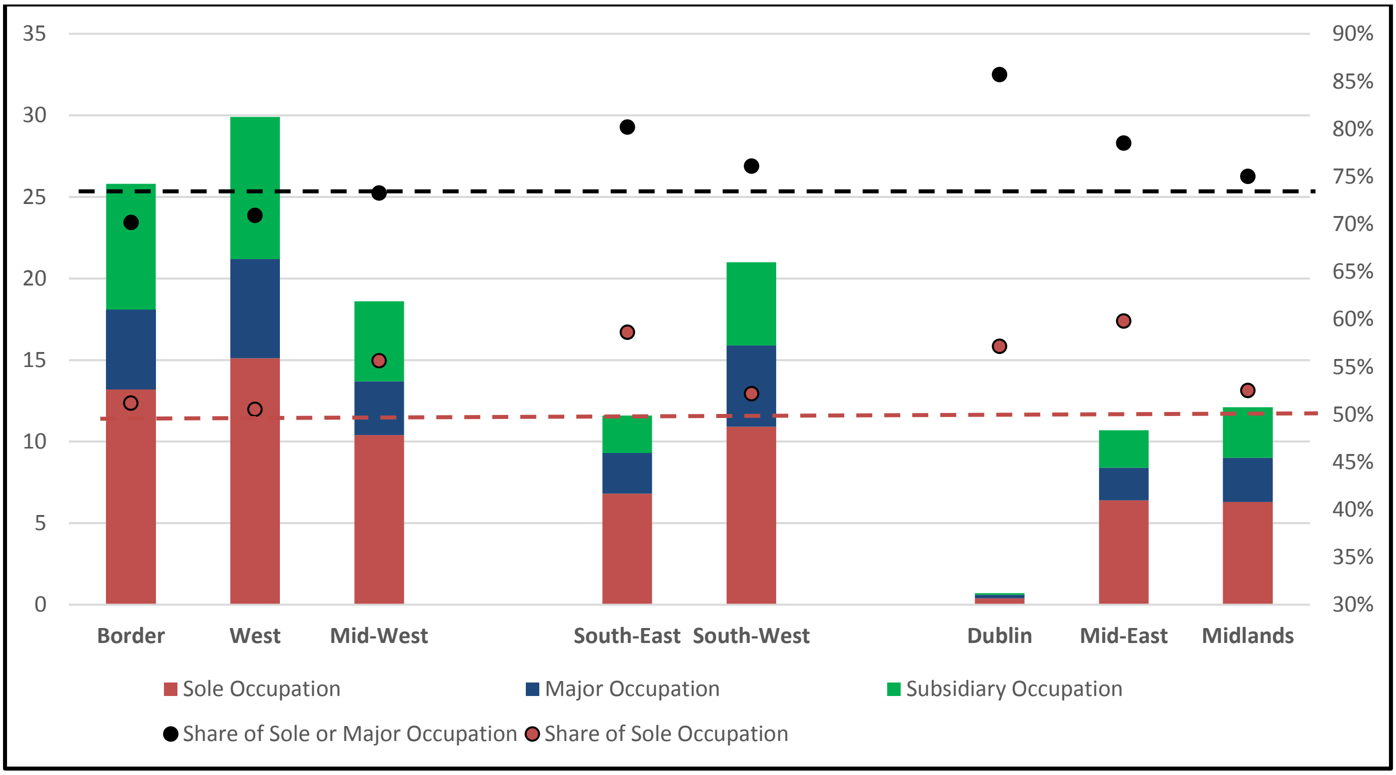


[3] Data for 'All Farms' refer to the results of the CSO Census of Agriculture 2020; 'NFS Farms' refer to those represented in the Teagasc National Farm Survey 2020, i.e. those with a Standard Output of > €8,0000 per annum. NFS 'Beef' is the sum of Cattle Rearing and Cattle Other farms and average values are weighted averages of all farms categorised in these systems in the NFS.
[4] Meredith, D. And Crowley, C. (2018) *Continuity and Change: The Geo-Demographic Structure of Population of Farmers* in Irish Geography, Vol. 52, Issue 2, pp.111-136, Figures Seven and Nine. These maps use 2010 data, but 2020 Census Maps 2.2 – 2.3 indicate heightened concentration due to suckler declines and dairy increases in the Southwest and Mid-West regions since.

The occupational significance of agriculture for a given farm holder also varies significantly by region, with farming being the sole occupation among 53% of Irish farm holders in the 2020 CSO Census of Agriculture – but only 51% in the Mid-West and almost 60% in the Mid-East; this figure rises to 74% when those farm holders for which farming is either the sole or major occupation is taken into account at the national level, but again this varies by region, at 70% in the Border area but nearly 79% in the Mid-East. Farming is the sole or major occupation of holders at a higher level in Southern and Eastern areas – where dairy farming is concentrated – compared to the Northern and Western areas. This corresponds to farm-level NFS figures, which show part-time farming is more common among drystock farms.

Another indicator of the differences in the profile of farm holders by region is age; 33% of farm holders were over the age of 65 nationally in 2020, with this falling to 28% in the South-West and rising to 37% in the West. As such, the profile of farming varies geographically in terms of farming system, age and the relative importance of farming as an occupation, with these factors inter-related. Women comprise just 13% of farm holders as of 2020, with little regional variation (rising to 14.1% in the West and falling to 12.4% in the South-East); with women comprising a higher (but still minority) share of farm labour, at 27% of overall labour (persons[5]), rising above 30% in the South-West and falling to 24% in the Border region. Non-Holder Family labour comprised 41% of a total 278,580 farm workers in Ireland in 2020, while 12% of farm workers (34,096) came from non-family sources and the remainder (130,216) were farm holders.

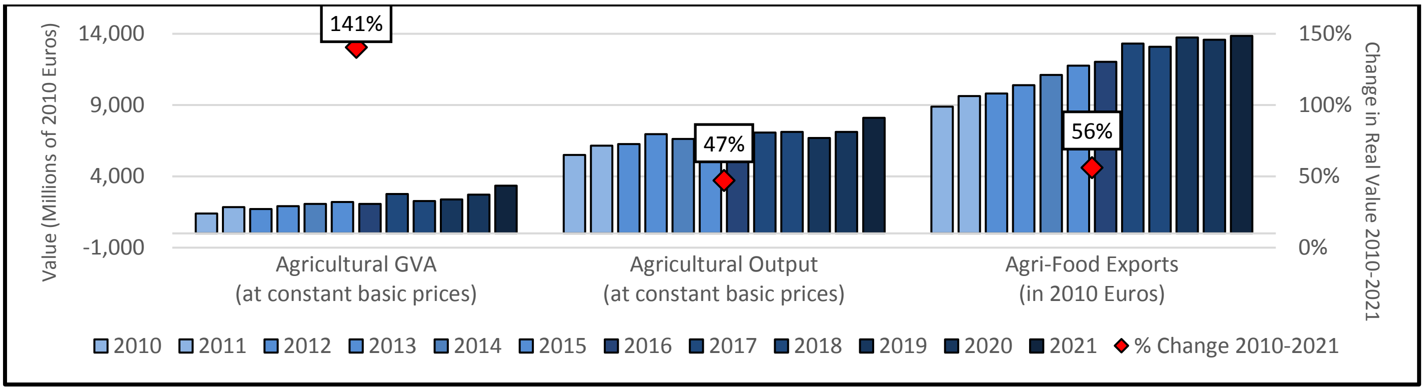
The graph below shows the number (thousands) of farm holders by region and relative occupational significance, as detailed in the 2020 Census of Agriculture, with the dotted lines indicating the national-level shares of sole and sole/major occupation among Irish farm holders. The absolute prevalence of drystock farms, and their concentration in the Border-Midland-West region, is reflected in these figures; while the more labour-intensive and more remunerative nature of dairy is shown in the lower rate of subsidiary employment in Southern/Eastern areas.



Number (Thousands) of Farms in 2020 Census of Agriculture, by Region and Relative Occupational Significance of Farming. Author's Calculations based on CSO (2022) PxStat *Table AVA50 Family Farms by Region and Significance of Farm Work in 2020.*

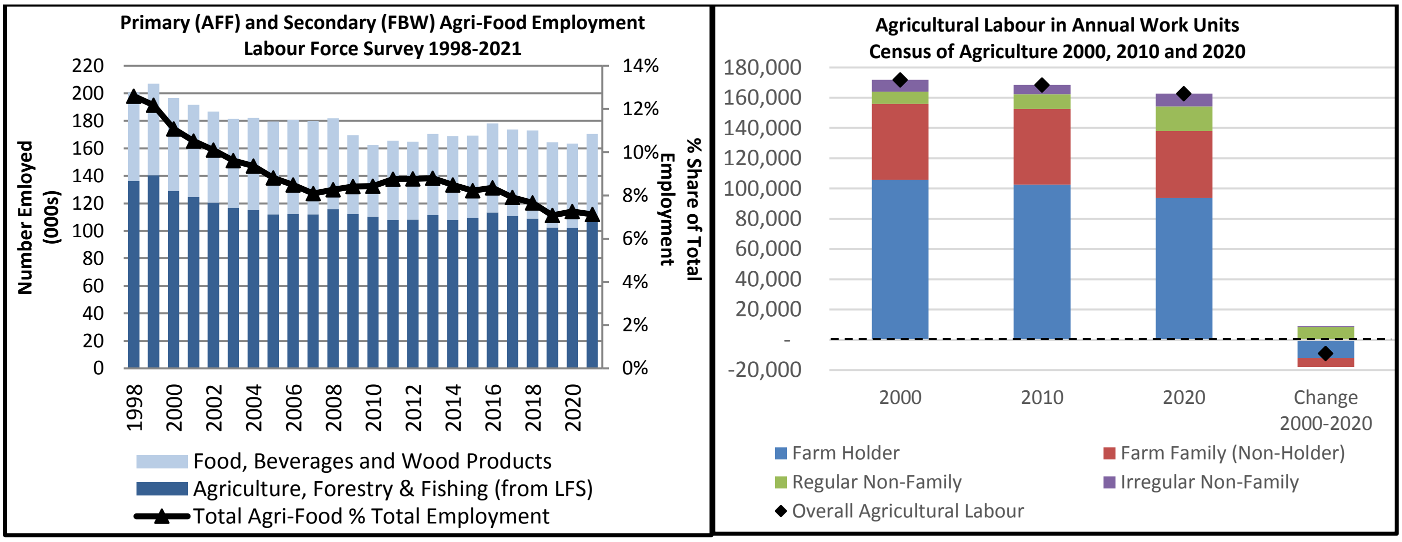
[5] Women comprise closer to 20% of the farm workforce in Annual Worker Unit (AWU) terms, which takes account of time worked. This is illustrated in Table 2.3 on the Agriculture Labour Force Detailed Results of the 2020 Census.

There has been a €2.59bn or 47% increase in the value of primary agricultural output at constant basic prices, i.e. in real terms, over 2010-2021; while Gross Value Added (GVA) and Operating Surplus in the sector have grown 141% and 79% in the same period, respectively. The nominal value of total agri-food exports also grew by 73% (€6.48bn) between 2010-2021, from €8.89bn to €15.37bn. The value of cattle and milk output averaged €2.3bn and €2.5bn within 2016-2020, respectively, or 29% and 31% of total sector output value at producer prices. The dairy sector has expanded significantly since the ending of milk quotas in 2015, increasing milk output volume by 69% over 2010-2021 and representing €5.17bn in exports in 2021, one third of total agri-food exports. The sector, at aggregate level, has proven generally resilient to disruption arising from the Covid-19 pandemic, including milk output worth €2.75bn in 2020. The full implications of the Trade and Co-Operation Agreement (TCA) between the UK and EU are still emerging, however the UK represented 38% of total agri-food exports from Ireland in 2020; agriculture is therefore particularly exposed to any disruption to EU-UK trade arising from adjustments, with beef being likely to be disproportionately affected.



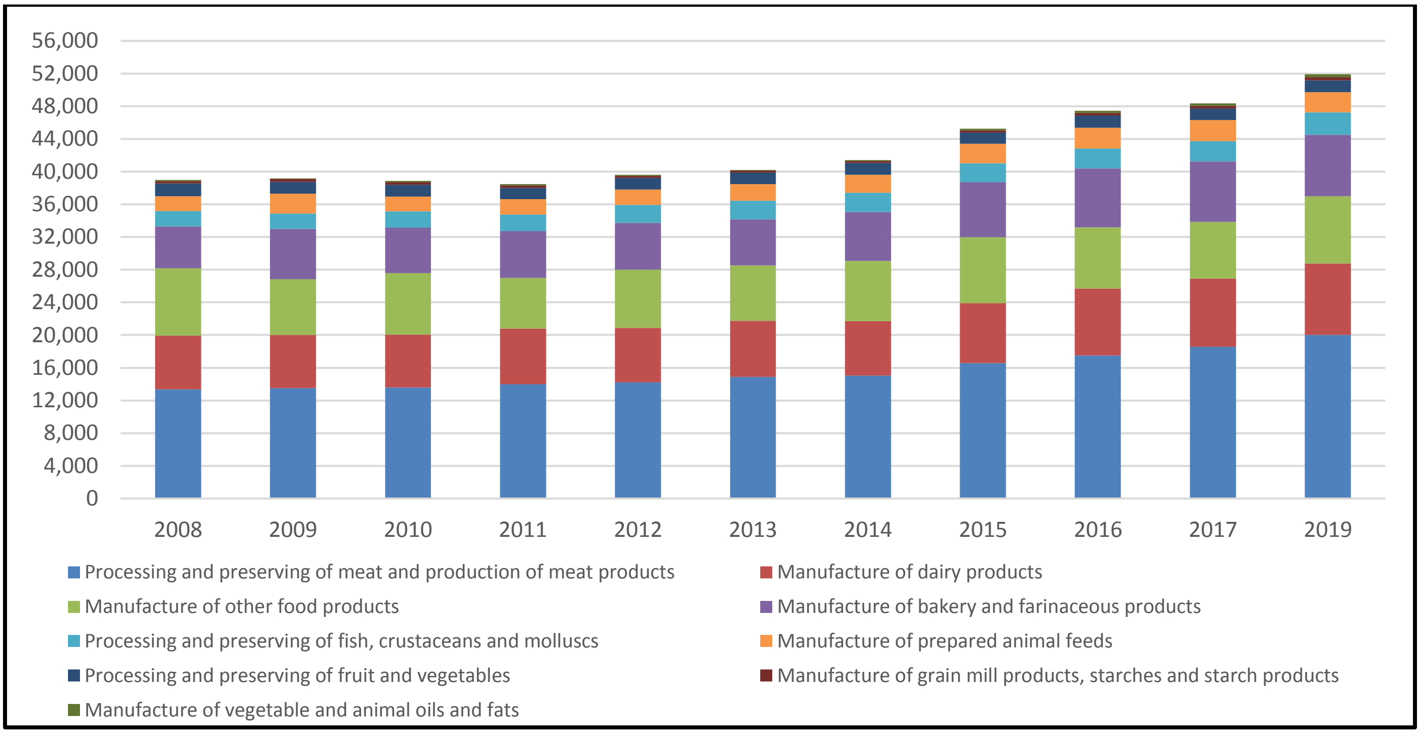
Value of Primary Output/GVA and Agri-Food Exports 2010-2021 (Millions of 2010 Euros). Source: Eurostat Economic Accounts for Agriculture (Table aact_eaa04); Author's calculations of exports in 2010 prices using CSO inflation calculator tool at December 2010 and DAFM estimates.

The number of people employed in primary agriculture has been generally in decline over the long-term; primary employment (in agriculture, forestry and fishing) fell 21% over 1998-2021, while total agri-food employment (i.e. including secondary employment in food, beverages and wood products) has fallen 15%. Employment outside agri-food (the wider economy) has grown 59% over the same period. Primary employment as a share of total domestic employment has almost halved, from 8.6% to 4.5%; agri-food represented 7.1% of 2021 total employment overall. CSO Censuses of Agriculture estimate a more moderate decline in agricultural labour of 5% between 2000-2020.



Left-Hand Side: Primary (AFF) and Secondary (FBW) Agri-Food Employment. Source: Author's Calculations based on CSO Labour Force Surveys (1999-2022) – quarterly average. **Right-Hand Side: Annual Work Units (AWUs) in Censuses of Agriculture 2000-2020.** Source: CSO Censuses.

Agri-Food employment is most significant as a share of total regional employment in Border, Midland and Western counties, representing 14.2% of total employment in the Border region in 2016 compared to 7.8% in the Mid-East[6]. In the figure below, the 2008-2019 trend in employment in food manufacturing employment is graphed using available Eurostat NACE-3 Rev. 2 data. This shows that manufacture of meat and dairy products accounted for c. 20,000 and 8,740 jobs, respectively, in 2019. Together, dairy and meat processing/manufacturing therefore employed c. 55.4% of the jobs supported by food manufacturing overall in 2019. Employment in the manufacture of beverages is not included here but accounted for almost 4,000 jobs in the latest year for which data is available, 2014. Of the net 13,440 jobs added to the sectors graphed below between the nadir (2011) to the most recent year (2019), 45% (c. 6,000) are accounted for by 'Processing and preserving of meat and production of meat products', while 14% (c. 1,920) accrue to 'Manufacture of dairy products'.



Disaggregated Agri-Food Employment level by activity type 2008-2017. Source: Eurostat *Annual detailed enterprise statistics for industry (NACE 3 Rev. 2)* data for 2008-2019. Data for 2020 incomplete and provisional, and data for 2018 withheld, at time of writing.

Combining employment in agriculture and food manufacturing, agri-food employment stood at c. 140,000 persons as of Q1 2021, or 6.6% of total employment, accounting for nearly 20% of employment in manufacturing industry. Employment in these sectors is directly dependent on domestic agricultural output levels and is relatively less import-intensive than other sectors of the economy. As Teagasc also note, the key inputs for Irish food manufacturing industry are sourced domestically, with modest live cattle imports for breeding purposes and some fresh milk imports from Northern Ireland which are generally for direct consumption. Therefore, these areas of employment are sensitive to fluctuations in the level of primary production activity, as well as the domestic economy more broadly; as a result, changes in agricultural activity are likely to lead to proportionately larger employment effects than would arise in other sectors of the economy more generally.[7] Any changes to agricultural activity would therefore have significant secondary consequences for employment and output from the food manufacturing industry. This would, in turn, lead to changes in employment and activity in other areas of the economy (such as transport or agricultural input manufacturing and distribution) and spending in local areas closely linked to agri-food employment.

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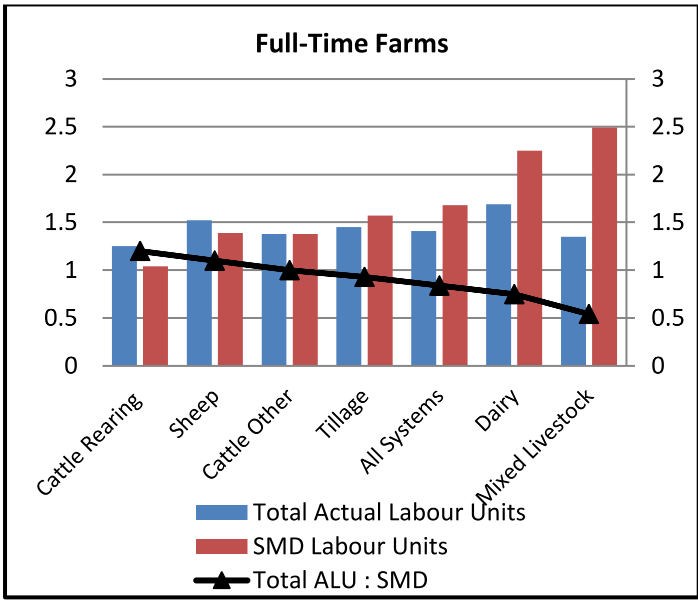
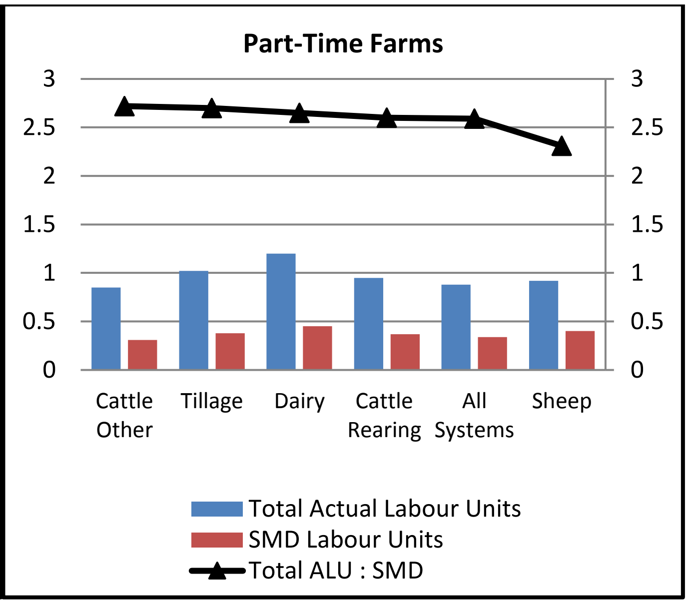
[6] Conefrey, T. (2018) *Irish Agriculture: Economic Impact and Current Challenges*, Central Bank of Ireland Economic Letters, Vol. 2018, No. 8

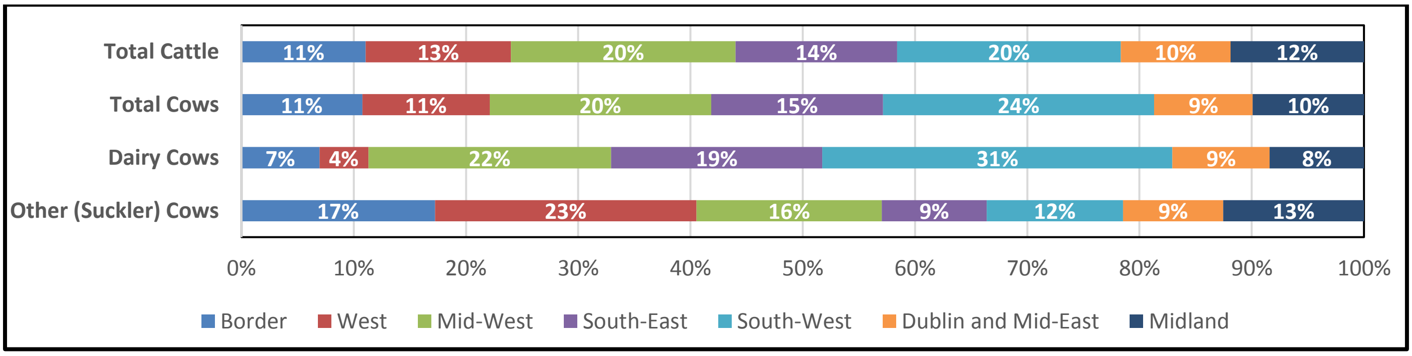
[7] Ibid, p.9.

The gap between the number of people and annual work units illustrates the part-time nature of a significant number of farms. Off-farm employment has increased from 45% to 53.5% of farm holders and/or spouses over 2002-2020, according to NFS data[8]. Further, 88% of small farms (those with an SO of < €8,000) had off-farm employment or other non-farm income in 2017. Using 2019 NFS data, we can see the variation in labour below, with values (Actual Labour Units and Standard Mean Days[9]) and the ratios (between these values) for part- and full-time farms. This evidences the gap between labour necessary to maintain the farm and number of people engaged in on-farm activity, reflecting the varying significance of off-farm economic activity for farm households. This also highlights the distinction between those who primarily farm for economic or other reasons. This difference in motivations for farming could have policy implications, as some farmers may be less responsive to economic/market signals in their behavioural choices. For example, off-farm employment income can contribute to sustaining low-margin farming activities, particularly amid a strong labour market in general in recent years. Similarly, non-pecuniary and/or social factors are also influential.





The regional concentration of farm system types is also reflected in the regional distribution of livestock, with half of Dairy Cows held on farms in the South (South-East and South-West) in 2021 but just 21% of Other (Suckler) Cows located in the same region; meanwhile, 41% of Other (Suckler) Cows were located in Northern and Western counties, but just 11% of Dairy Cows were held in this region in 2021. The majority (61%) of all cows are held outside the South-East and South-West, however, with 42% of all cows held in the Mid-West, Border or West regions.



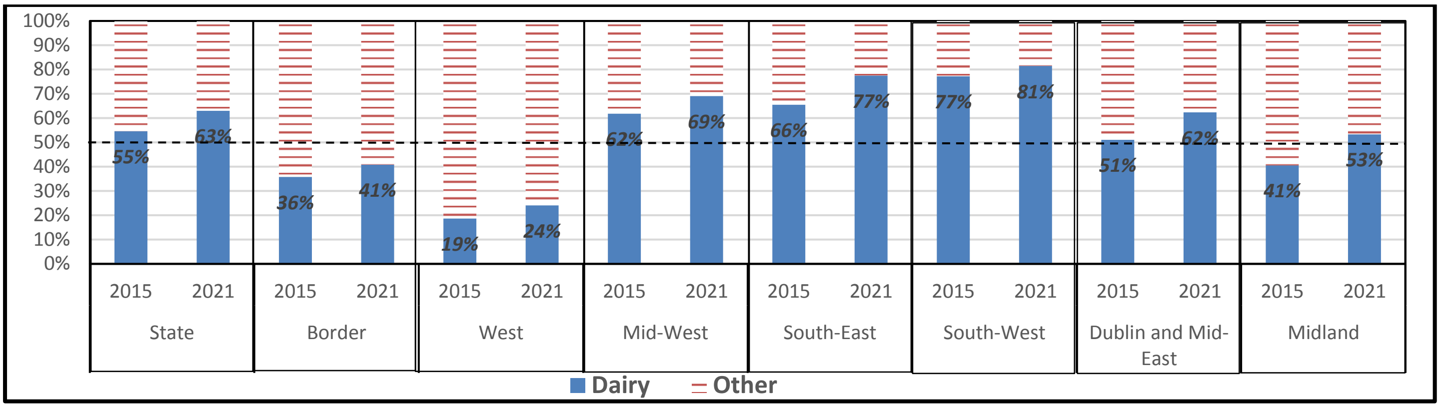
Region Shares (%) of Cattle and Cows, by Type, in 2021. Source: Author's Calculations based on CSO June Livestock Survey

[8] The increase in the estimate of off-farm employment has likely been affected by the re-weighting of the NFS sample over time, excluding more small farms (with Standard Output below €8,000).
[9] One Actual Labour Unit is defined as 1,800 hours worked by an adult on a farm per year. One Standard Mean Day is eight hours of work supplied by an adult, with total SMDs required to maintain a farm varying by farm type and size.

The number of dairy cows has increased in each region in 2015-2021, but increases have been mainly concentrated in Southern/Eastern areas, where declines in other cows have been largest and capacity for dairy expansion seems strongest; for example, the South-East saw a 37% increase in dairy cows and a 24% decline in Other (Suckler) Cows.

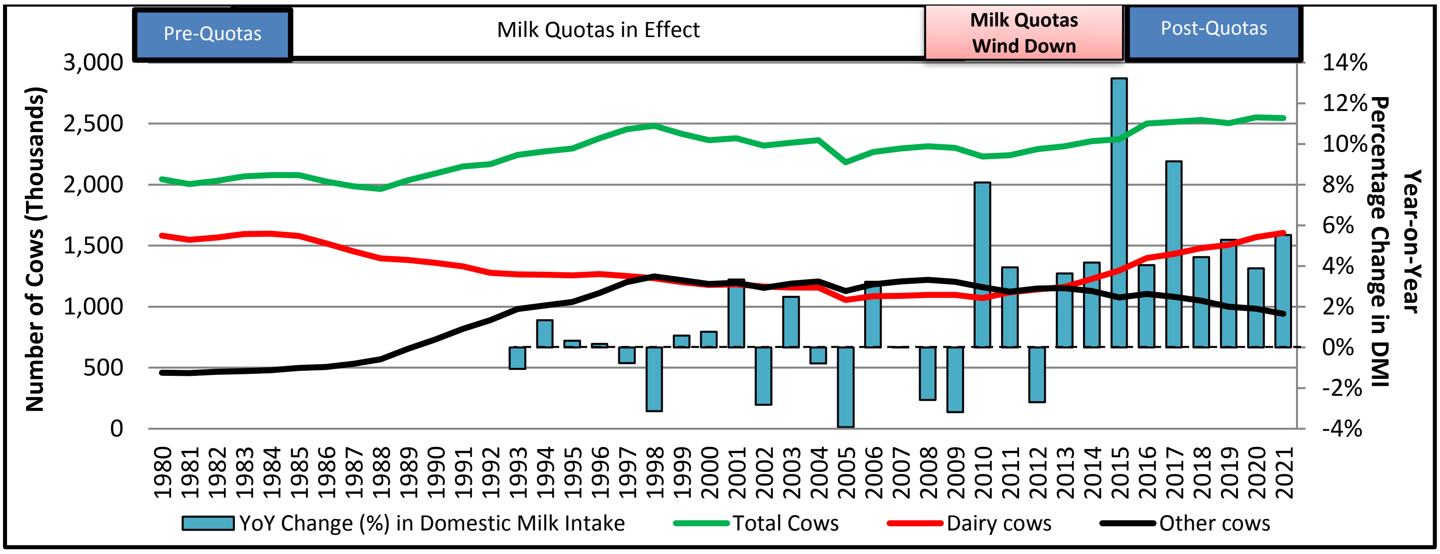
Region	Dairy Cows			Other (Suckler) Cows			Total Cows		
Year / Change	*2015*	*2021*	*% Change*	*2015*	*2021*	*% Change*	*2015*	*2021*	*% Change*
State	1,296	1,605	24	1,076	940	-13	2,372	2,545	7
Border	99	112	13	178	162	-9	277	274	-1
West	56	70	25	242	219	-9	298	289	-3
Mid-West	287	347	21	177	155	-12	463	502	8
South-East	220	302	37	115	88	-24	335	390	16
South-West	437	501	14	129	114	-11	566	615	9
Dublin and Mid-East	104	139	34	99	84	-15	203	223	10
Midland	93	135	44	137	118	-14	230	253	10

Number of Cows (Thousands) by Type & Region and percentage change 2015-2021. Source: Author's Calculations using June Livestock Survey



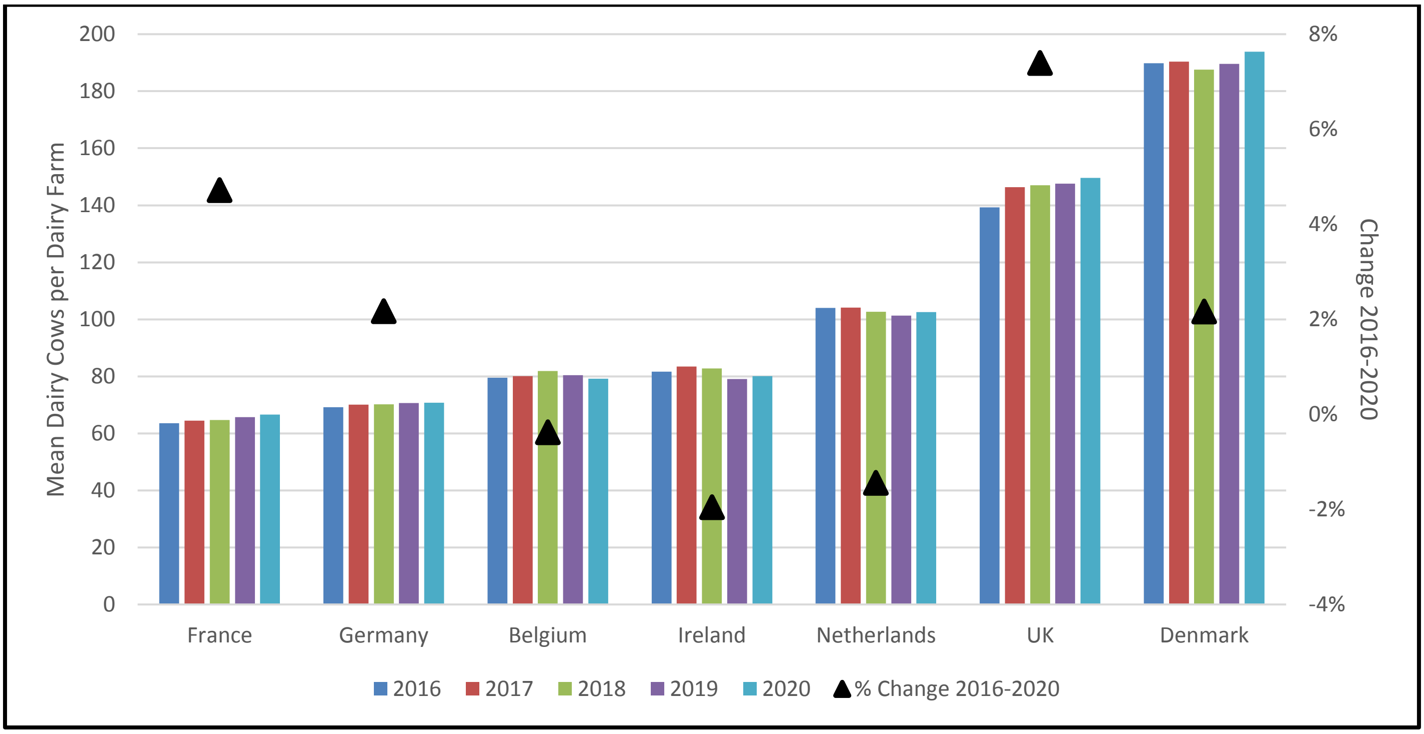
Dairy as a Percentage (%) Share of Total Cows (Dairy & Other) in each Region. Source: Author's Calculations using CSO June Livestock Survey

The above changes reflect an overall swing from beef to dairy farming at the national level since the ending of milk quotas at EU level. If a long-term horizon is adopted, we can see the current level of dairy cow numbers has trended toward the level of approx. 1.6 million which was seen before milk quotas were implemented, shaping incentives for decades. Suckler cows have not fallen as quickly as dairy cows have increased, however, resulting in an elevated level of total cows. Milk production rose 69% over 2010-21; June Dairy cow numbers grew 50% from 1.071m to 1.605m.



Number of Cows (000s) by Type, versus Year-on-Year Percentage (%) Change in Domestic Milk Intake (DMI) 1980-2020. Source: Author's calculations based on CSO (2021) data from June Livestock Survey and Milk Statistics. Milk Quotas 'wind down' announced March 2008. The number of dairy cows increased again in the provisional June 2022 Livestock survey, by approx. 22,800 additional head (1.4%) compared to June 2021 – a slower pace of year-on-year increase but one which continues to add to the agricultural emissions profile.

The family-farm structure predominant in Ireland translates to a large volume of relatively small farms nationally. Similarly, even though dairy farms tend to be larger when compared to other systems domestically, the family farm model translates to relatively low average herd sizes when compared to many countries. The below illustrates the mean dairy cows per farm in Europe, showing the relatively smaller size of dairy farms in Ireland compared to some countries, and herd size changes being generally consistent with dairy cow farm-level trends in recent years in the EU.



Mean Average Number of Dairy Cows & UAA (ha.) per Dairy Farm and percentage change in cows in selected countries during 2016-2020. Source: Farm Accountancy Data Network (FADN) Farm Economy Focus by Sector – Livestock (Dairy) Data Dashboard at June 2022.

Regional dependence on agriculture also varies significantly. Taking the contribution of each region to agriculture sector GVA (Gross Value Added, i.e. output less intermediate consumption), and comparing this to a region's share of national GVA from CSO data, we can assess the relative dependence of a given region on agriculture in 2019. The Border and Midlands are each more than four times as dependent on agricultural GVA relative to what would be expected if it was regionally distributed in proportion to the distribution of national GVA. While these figures are skewed by Dublin, they still show the variation in regional dependence on the agriculture sector.

Region	% Contribution to National Overall GVA	% Contribution to Agricultural GVA	Regional Dependence on Agriculture
(Key)	*(A)*	*(B)*	*(C = B/A)*
Border	3	13	4.62
West	3	7	1.99
Dublin	41	2	0.05
Mid-East	9	14	1.50
Midland	2	7	4.14
Mid-West	10	15	1.59
South- East	7	18	2.57
South- West	25	24	0.95
State	*100*	*100*	*1.00*

Gross Value Added relative contribution of each Region in 2019. Source: Author's Calculations based on CSO data on *County Incomes and Regional GDP,* Table 9D.

The inter-dependent variation in farm type, mode and location outlined here significantly shapes socio-economic and environmental outcomes and sustainability at both the farm and aggregate level.

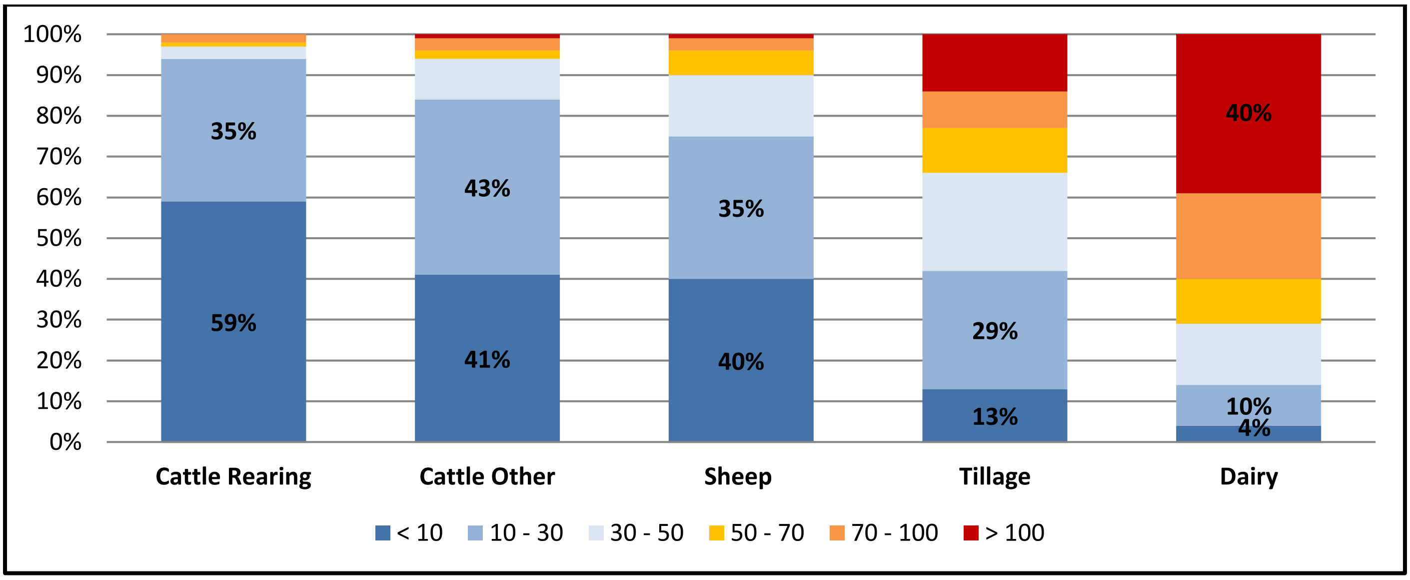
1.2 Socio-Economic Sustainability

Family Farm Income (FFI)[10], the main indicator of farming income in the NFS, is measured as gross output less total costs. This does not, however, include information on off-farm income sources, so it cannot be used as a metric of total household income. Mean FFI outcomes are unevenly distributed across farm systems; full- and part-time farms and regions; as is well evidenced in recent Teagasc *National Farm Survey* and *NFS Sustainability Report* publications. In general, drystock farm households are more likely to operate on a part-time basis, rely to a greater extent on off-farm income sources, have higher social vulnerability & isolation rates, and have a higher age profile, particularly when compared to dairy farms. Dairy contributed over half the value of the aggregate Family Farm Income total for NFS farms in the agriculture sector (51%) in the 2021 NFS, despite comprising less than 18% of the population of farms represented. Meanwhile, Cattle Rearing and Cattle Other contributed a combined 25% in aggregate FFI from 56% of the total number of farms represented. Below, author's calculations of three-year rolling average FFI per farm reported in the NFS over 2014-2021 is shown, by system and adjusted to real values (in 2021 Euro terms).

Real Mean FFI (2021 Euros)	2016	2017	2018	2019	2020	2021	Change 2016-21 (€)	Change 2016-21 (%)
Dairy	50,820	57,258	56,768	75,181	72,394	83,631	32,810	65
Tillage	33,590	36,390	38,494	38,884	37,457	42,429	8,839	26
Overall (Weighted Average)	*27,402*	*29,047*	*27,896*	*27,602*	*26,026*	*29,367*	*1,966*	*7*
Sheep	16,738	17,251	16,186	15,731	16,128	18,368	1,630	10
Cattle Other	16,589	17,942	17,257	16,039	15,390	15,998	- 591	-4
Cattle Rearing	12,683	13,431	11,847	10,520	9,034	9,723	- 2,959	-23

Average Family Farm Income, Three-Year Rolling Averages, for 2016-2021, by System. Values expressed in 2021 Euros. Source: Author's Calculations based on NFS Reports (2014-2019; 2021) Table 8A; values deflated using CSO Inflation Calculator tool.

The above averages cloud underlying variation within systems. FFI per farm is concentrated (more than 75%) below €30,000 within dry-stock systems; within dairy farming, more than 87% of farms earned above €30,000 in 2021.



Family Farm Income Distribution by System and Income Bracket (€ 000). Source: Teagasc *National Farm Survey 2021,* Table 8 (E)

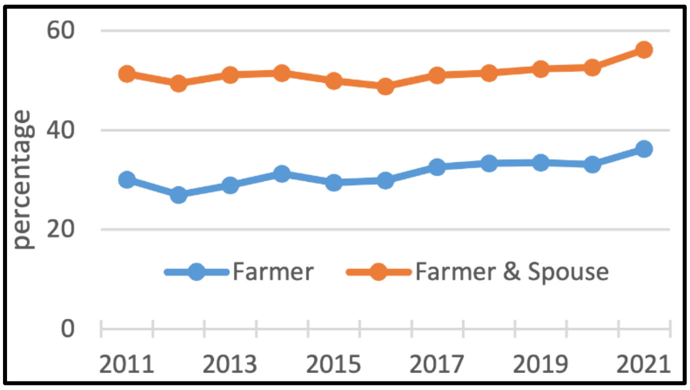
These distinctions between systems' economic sustainability hold if we control for land use, due to smaller farm sizes as well as lower capital and labour use among drystock farms resulting in smaller output and therefore incomes:

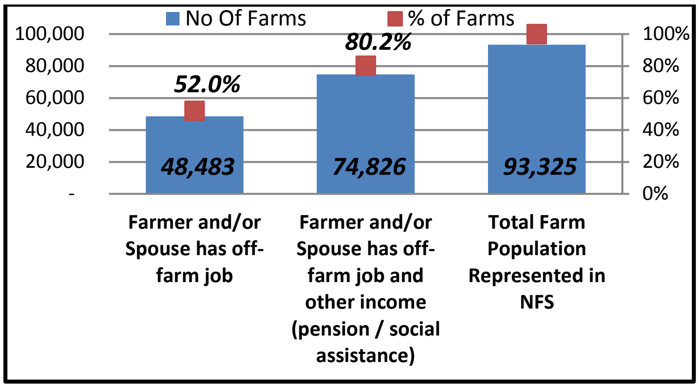
[10] Family Farm Income (FFI) is the income that remunerates the unpaid family labour provided other farm business and to remunerate the family owned capital used in the business.

2019-21 Three-Year Average	Average Size (ha)	Gross Output	Gross Output per Ha	Gross Margin	Gross Margin per Ha	FFI	FFI per Ha	Direct Payments	Direct Payments per Ha (€)	FFI from Direct Payments (%)
Dairy	62.9	246,330	3,918	148,842	2,368	81,525	1,297	21,124	336	26
Tillage	63.9	127,291	1,991	84,680	1,325	41,326	646	26,416	413	64
Cattle Other	36.8	56,633	1,457	34,518	938	15,506	421	17,111	465	110
Sheep	45.7	54,666	1,197	35,467	777	17,818	390	19,015	416	107
Cattle Rearing	31.4	37,794	1,202	24,926	793	9,433	300	14,412	458	153

2019-2021 Three-Year Nominal Average for Gross Output, Gross Margin and Family Farm Income relative to Land Use (Utilised Agricultural Area in Hectares), by Farm System. Source: Author's Calculations based on NFS Reports 2019 and 2021, Table 8 (A-B).

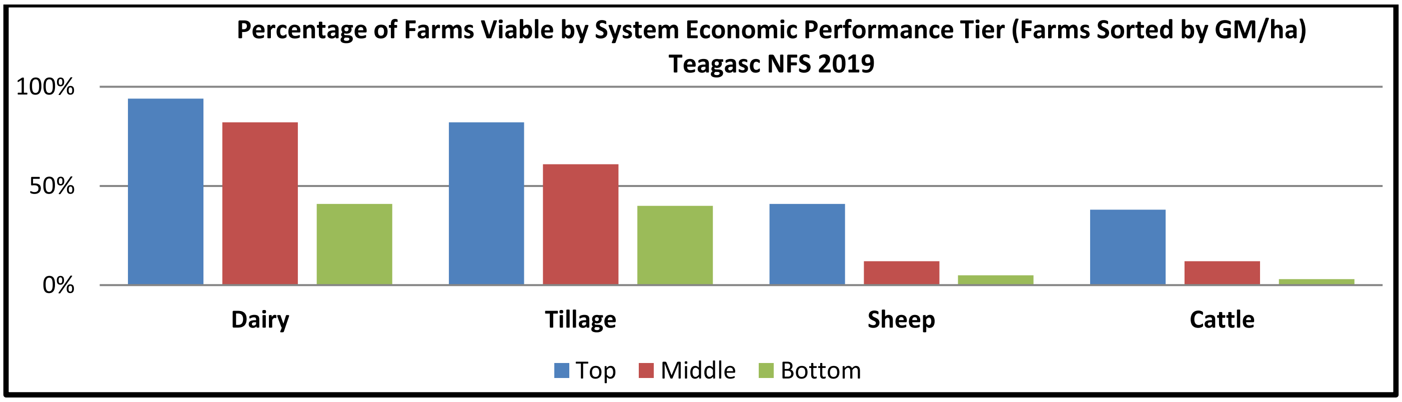
This translates to variation in viability for farms within and across systems. A farm business is defined as viable if income (FFI) is sufficient to remunerate farm labour supplied at the minimum wage and to provide an additional five percent return to non-land based assets employed on the farm. A farm household is sustainable if the farm business is economically unviable but has an off-farm labour income and the household is defined as vulnerable if the farm is not economically viable and there is no off-farm household income. The figure below illustrates the growing number of farming households where the holder and/or spouse have off-farm employment since 2012 – reflecting wider trends in labour force participation, only falling slightly (0.6%) in 2020 in spite of the general labour market shock during the Covid-19 pandemic. Further, approx. 80% of farm households represented in NFS 2020 had income from a) off-farm employment or b) pensions or social assistance.





Left-Hand Side: Percentage of farm holders and holders & spouses engaged in off-farm employment 2008-2021 (Teagasc NFS 2021, p.29, Fig.31)**; Right-Hand Side:** Number of Farms represented in NFS 2020 with non-farm income from employment, pensions or social assistance (Teagasc NFS 2020 data).

Consistently, only one third of the NFS farm population can be described as viable, a further third as sustainable (due to off-farm employment income sources in the farm household) and a final third as vulnerable due to economic unviability and the absence of a source of labour income in the farm household. In terms of economic performance (Gross Margin per hectare), top and middle farms have significantly higher viability when compared to the lowest tier; meanwhile, top-performing dry-stock farms have similar viability ratings to the lowest tier of dairy and tillage farms.



Percentage of Farms Viable by System and Economic Performance Tier. Source: *2019 NFS Sustainability Report* – Figures 6, 37, 63 and 88.

Over the medium-to-long run, dairy farming appears to offer relatively high but more volatile FFI, while other sectors earn lower incomes at a relatively stable level due to their lower level of activity, lower input expenditure and reliance on stable subsidy support. This has implications for investment planning and debt sustainability. Dairy farms are more likely to have debt, most probably reflecting post-quotas expansion investment; however, debt levels are sustainable compared to farms with debt in other systems, in terms of debt relative to income.

Farm System	Share of Farms with Borrowings (%)	Average Debt if > 0 (€)	Average FFI if Debt > 0 (€)	Debt : FFI Ratio
Cattle Other	29	46,703	20,645	2.76
Cattle Rearing	34	28,984	14,299	2.03
All	*40*	*70,788*	*53,468*	*1.32*
Dairy	66	139,031	108,551	1.28
Tillage	48	64,570	82,470	0.78
Sheep	37	21,263	27,984	0.76

Percentage of Farms with Borrowings and Average Debt in 2021. Source: 2021 NFS, p.xvi.

Finally, it is important to acknowledge the significance of Direct Payments (DPs), which totalled more than €1.17bn in 2019; the aggregate value of Direct Payments and Subsidies was €1.54bn among NFS farms in 2021, averaging €18,129 across the more than 84,500 farms represented in the survey. While the absolute value of DPs/Subsidies is low on dry-stock system farms, they are large relative to FFI; while absolute payments are largest for dairy or tillage farms on average but comprise a relatively smaller share of FFI. This reflects smaller scale, lower levels of production per hectare and lower market returns for drystock farms compared to dairy or tillage farms. Following from the regional distribution of farm system types, mean Pillar One direct payments are highest in Southern and Eastern counties.

System Averages	Dairy	Cattle Rearing	Cattle Other	Sheep	Tillage	*Overall*
Direct Payments and Subsidies as a Share of FFI (%)	21	133	99	91	46	*64*
Direct Payments and Subsidies (€)	21,124	14,412	17,111	19,015	26,416	*18,319*
FFI (€)	98,745	10,865	17,233	20,794	57,939	*28,513*

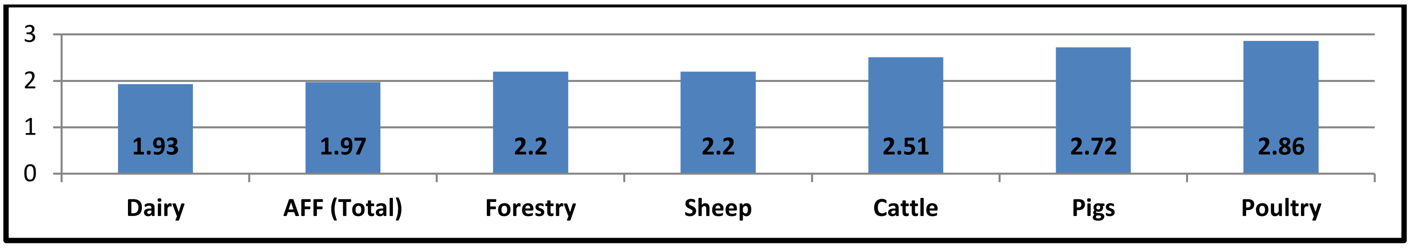
2019-21 Average Direct Payments per Farm (Euros) and Contribution of Direct Payments to Farm Income. Source: NFS 2019-21 Table 8A.

Pillar one direct payments supports farm incomes which helps to ensure the security of food supply provided by primary producers, whist adhering to conditionality including environmental, good farming practice and eligible area. Pillar two supports rural development through the European Agricultural Fund for Rural Development. This funding is important given the extent to which agriculture is socio-economically embedded, and the specific social challenges faced by rural communities and farm households.

The multiplier[11] effect of agricultural output is relatively high compared to other domestic sectors due to its integral ties to the wider domestic economy. The CSO multiplier estimate for Agriculture, Forestry and Fishing (AFF) in Ireland is 1.45, compared to 1.4 for the wider economy and 1.2 for foreign-owned firms. Other studies such as Grealis and O'Donoghue[12] have accounted for wider impacts and have estimated a higher multiplier for Agriculture, Forestry and Fishing at 1.97, but this is higher for dry-stock farm systems in particular – as seen in the chart below.

[11] According to Tsakiridis, A. et al (2020) *A Comparison of Environmental and Economic Sustainability across Seafood and Livestock Product Value Chains* in Marine Policy Vol. 117, "*An output multiplier for sector i is the total value of production in all sectors of the economy that is necessary in order to satisfy €1 worth of final demand for sector i's output*"

[12] Grealls, E. and O'Donoghue, C. (2015) *The Bio-Economy Input-Output Model: Development and Uses*, p.55, Table 5.6.



Multiplier Coefficient Estimates for Sectors of Irish Agriculture. Source: Grealis and O'Donoghue (2015)

Social challenges for farm households have been illustrated by successive Teagasc NFS Sustainability Reports. While DPs are high relative to FFI on dry-stock systems, these same households have higher age profiles and face elevated risks of isolation and vulnerability. Meanwhile, dairy farm holders work significantly more hours, on average, with larger average household sizes. Financial, infrastructural and other supports can help to alleviate these challenges.

It is therefore important, in the context of the transition to a low carbon agriculture sector, to be cognisant of the underlying variation, nuance and complexity in the structure, demography and spatial distribution of Irish agriculture. The social and economic sustainability of agriculture varies widely – with several drivers of trends across systems, time and geography – and there are diverse challenges within the sector to be taken into account.

1.3 Environmental Trends

Alongside economic considerations of ensuring security of food supply, sustainable family farm income and access to affordable food, environmental sustainability is imperative for the sector's future development. Taking a Natural Capital[13] perspective emphasises the significant impacts of agriculture on the environment; the necessity to protect and enhance existing environmental assets; and the role of agriculture in climate action, including adaptation. This is important given that grass- and crop-land together account for c. 70% of land use in Ireland as of 2019, and forestry a further 11%[14]. Environmental pressures have increased in recent years across biodiversity, water and air quality, and climate-warming impacts. EPA figures show Irish agriculture contributed 48.2% of national non-ETS (European Trading System) carbon-equivalent GHG emissions[15] and c. 37.1% of total Irish GHG emissions overall in 2020. This reflects savings in other industries and concurrent output expansion in agriculture, which saw emission increases in seven of the eight years to 2018 (EPA 2019). The seemingly disproportionate level of emissions for agriculture, relative to other sectors, stems from: (i) the scale agricultural production relative to the human population as reflected in our share of produce exported driven by the comparative advantage of production from extensive grasslands; (ii) the relative lack of historical development of heavy industry in Ireland; and (iii) the emissions-intensive nature of ruminant livestock farming.

Total emissions from the agriculture sector were 21.41 million tonnes (MT) CO2e in 2020, 12% higher than 2009 but down 3% from the 22.05 MT emitted by the sector in 2018. Emissions intensity fell 14% on a GHG/kcal food output basis over 2005-2013; projections are for a 35% reduction within 2005-2035 for emissions intensity when measured against gross output[16]. Absolute agricultural emissions have increased significantly, however, reflecting supply growth in response to export demand. Emissions were trending downward between 1998-2011 but have generally trended upwards since. The EPA cites increased dairy herd numbers and milk production (up 25% and 40%, respectively, over 2013-18 alone) as primary drivers of the upward trend, capturing the effect of the ending of milk quotas in 2015[17].

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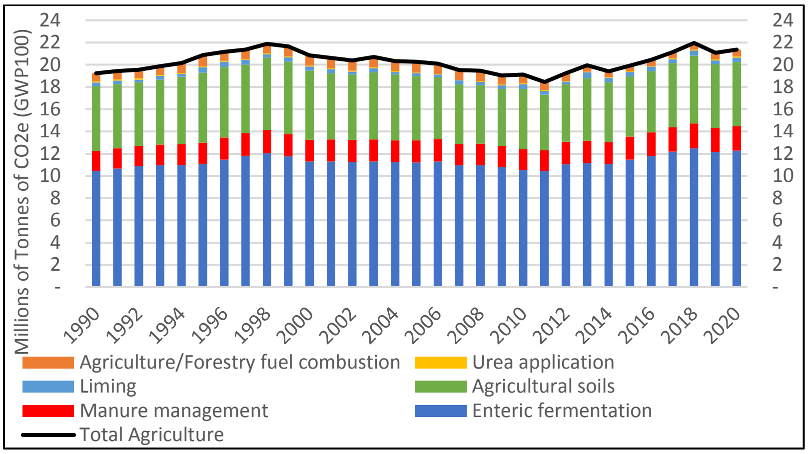
[13] Natural Capital is defined in Dasgupta, P. (2021) *The Economics of Biodiversity: The Dasgupta Review.* UK: HM Treasury as "*The stock of renewable and non-renewable natural assets (e.g. ecosystems) that yield a flow of benefits to people (i.e. ecosystem services). The term 'natural capital' is used to emphasise it is a capital asset, like produced and human capital.*"
[14] CSO (2021) Land Use (Table 6.1); DAFM (2020) *Forest Statistics Ireland 2020.*
[15] Carbon-Equivalent (CO2e) emissions are standardised units of GHG emissions, where carbon-dioxide is the reference value – while methane has a value of approx. 25-28 – to reflect their relative Global Warming Potential under IPCC reporting requirements.
[16] National Mitigation Plan 2017, p.122
[17] Duffy, P., Black, K., Hyde, B., Ryan, AM and Ponzi, J. (EPA 2022) *National Inventory Report 1990-2020.*

Enteric Fermentation accounted for 12.30 MT (57%) of the overall total of 21.47 MT CO2e in average agriculture sector emissions per annum in 2018-2020; Manure Management (2.21 MT or 10%) and Agricultural Soils (5.86 MT or 27%) were also significant.



Emissions Source (3-Year Average; MT AR4 CO2e)	2008-2010	2018-2020	% Change 2010-2020
Total Agriculture	*19.20*	*21.47*	*12*
Enteric Fermentation	10.77	12.30	14
Manure Management	1.91	2.21	16
Agricultural Soils	5.28	5.86	11
Liming	0.33	0.40	21
Urea Application	0.08	0.10	14
Agriculture/Forestry Fuel Combustion	0.83	0.60	-28

Non-CO2 Agricultural Emissions in MT CO2e (1990-2020, AR4 Accounting). Source: EPA (2022) *Final 2020 National GHG Emissions*. 'Fishing' CO2 emissions from the sector (less than 0.1 MT CO2e) are excluded from the analysis in this graph/table.

The three main sources of GHG emissions from the Irish agriculture sector are[18]:

- Biogenic Methane (CH_4) from ruminant livestock
- Nitrous Oxide (N_2O) and Methane (CH_4) from the production and storage of manure, as well as synthetic fertilisers used to treat soils.
- Carbon Dioxide (CO_2) emitted by farm machinery and fishing vessels, as well as CO_2 associated with liming and urea application.

Methane generally accounts for approx. 70% of annual GHG emissions from agriculture in Ireland when measured in CO2 equivalents (AR5 accounting); a further quarter derive from Nitrous Oxide, and approx. 5% arise from Carbon Dioxide. Ammonia, a non-GHG emission, is also emitted through agricultural production, with negative implications for air quality. Agriculture is responsible for approx. 99% of ammonia emissions in Ireland and there were 122.68 Kilotonnes of ammonia generated by agriculture in 2020, although this is 8.7% lower than the 2018 peak primarily due to the adoption of Low Emission Slurry Spreading (LESS) techniques at farm level; Teagasc estimate 74% of aggregate slurry was spread using Low Emissions Slurry Spreading (LESS) equipment in 2021, compared to only 6% in 2018, reflecting accelerated uptake which can reduce N loss and therefore ammonia emissions. Agriculture is also the largest source of pressure on water quality in Ireland at present, across all water body types except coastal waters. This is largely linked to nutrient losses to water bodies through groundwater and run-off. Further, although farmers are key agents of environmental protection and enhancement as land managers – particularly within extensive systems – some agricultural production practices have placed significant pressures on biodiversity and ecosystem function[19].

Teagasc Sustainability Reports[20], covering NFS data for 2014-2021, have provided estimates of the environmental pressures of agricultural systems over time. Agricultural GHG emissions – when measured relative to quantity of output, land use or monetary value – have improved at the farm level as improved technologies and management practices have been adopted over time. Ammonia emissions, predominantly from dairy farm trends, have expanded

[18] Ibid.

[19] EPA (2020) *Ireland's Environment 2020 - An Integrated Assessment,* Figure 13.2 https://www.epa.ie/pubs/reports/indicators/irelandsenvironment2020.html

[20] https://www.teagasc.ie/rural-economy/rural-economy/national-farm-survey/sustainability-reports/. IPCC AR5 method used.

significantly at farm level; while energy efficiency has improved across all systems. There are persistent gaps between systems, however, due to differences in farm scale, farming intensity and the differences in emissions factors associated with types of livestock[21]. It should be noted that a kg of milk is not directly comparable with a kg of meat, given the water content in milk, and also to recognise the dependence of milk production on beef production.

System	Emissions (Tonnes C02e)	Emissions from Cattle (T CO2e)	Emissions from Dairy (T CO2e)	Share (%) of Emissions from Cattle/Dairy Sources	Emissions per Ha. (T CO2e)	Emissions per Kg Output (KG CO2e)
Dairy	596.2	159.3	435.8	99.8	9.4	0.89
Cattle	151.3	146.3	0.1	96.7	4.5	11.80
Sheep	158.1	73.4	0.0	46.4	3.9	11.13
Tillage	168.5	105.9	0.0	62.9	2.5	N/A

2019-2021 Average Agricultural Emissions per Farm: Gross and Relative to Land Use and Output. Source: Author's Calculations using NFS Sustainability Report 2021, Tables A1-A5, pp.78-86

By scaling these farm-level emissions estimates by the number of farms represented for each system in the 2021 NFS, the relative contribution of systems to total agricultural emissions can be estimated. The number of farms in each system was calculated by multiplying the sample size by an aggregation factor, as outlined in Table B of Appendix Two of the 2021 NFS, giving 83,640 farms represented among these four systems. Under these estimates, aggregate dairy and cattle farm agricultural GHG emissions, combined, comprise 82.3% of overall GHG emissions from just under three quarters (74.8%) of the farms represented in the NFS; while cattle and dairy GHG emissions sources account for c. 89.5% of the aggregate agricultural GHG emissions estimate for farms represented from these four NFS systems. The implied total emissions from NFS farms across these four systems – of approx. 19.65 MT CO2e – is equivalent to circa 82% of the 22.37 MT CO2e in total GHGs emitted by agriculture in 2020.

System	No. of Farms Represented in 2020 NFS (000s)	Average UAA per Farm (Ha.)	Aggregate UAA (000 Ha.)	Average Emissions per Farm (T CO2e)	Aggregate Emissions (KT CO2e)
Dairy	15.26	64.9	990	596.2	9,101
Cattle	48.16	34.9	1,683	151.3	7,289
Sheep	13.99	45.1	630	158.1	2,212
Tillage	6.24	66.2	413	168.5	1,052
Overall	*83.65*	*44.42*	*3,716*	*234.8*	*19,653*

System	Relative Share (%) of Total NFS Farms	Relative Share (%) of Total NFS UAA	Relative Share (%) of Aggregate NFS Farm Ag. Emissions
Dairy	18.2	26.6	46.3
Cattle	57.6	45.3	37.1
Sheep	16.7	17.0	11.3
Tillage	7.5	11.1	5.4
Overall	*100*	*100*	*100*

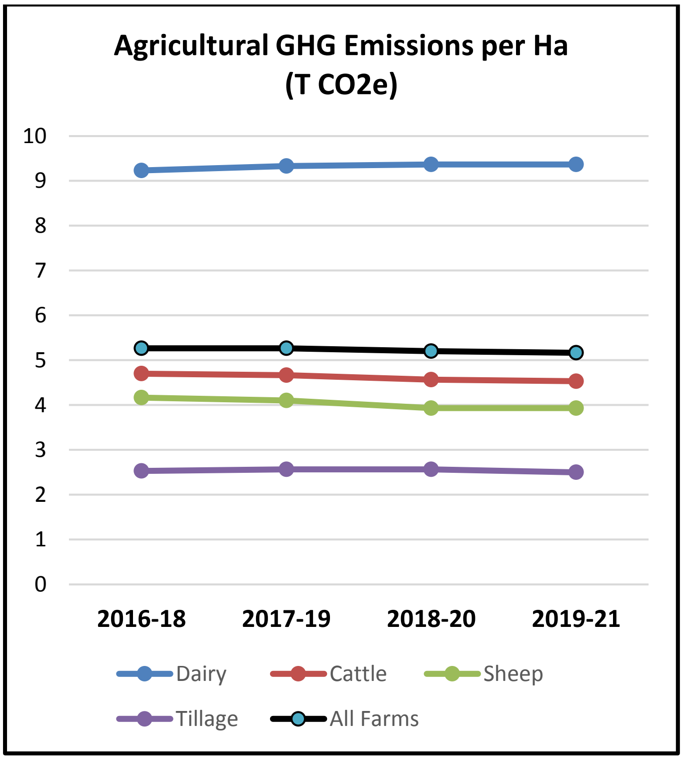
Farms, Land Use and Agricultural GHG Emissions: Gross Aggregate Levels and Relative Shares of Main systems. Source: Author's Calculations of 2019-2021 Three-Year Average UAA and Emissions per farm – using 2021 NFS Sustainability Report Tables A1-A4 – aggregated by the number of farms represented in the 2021 NFS. '*Overall*' averages are aggregate sum value divided by total number of farms (91,100). Values rounded. N.B.: Farm emissions estimates use IPCC AR5 emissions methodology.

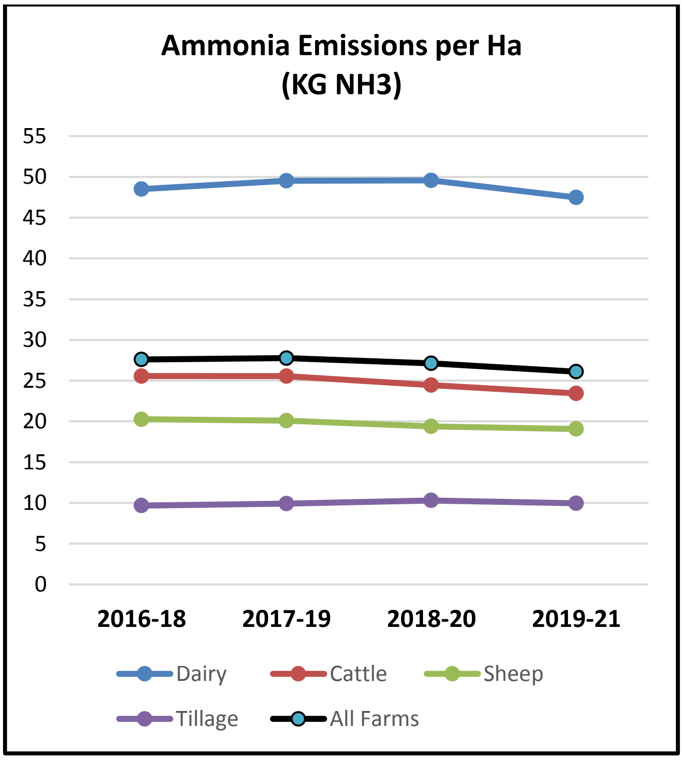
[21] EPA (2022) *National Emissions Inventory Report*, Tables 5.4 and 5.5, pp.156-162, show the methane output of two dairy cows is approx. equivalent to three suckler cows – at a GHG output ratio of 1.64 – at 3.34 T CO2e output per annum per dairy cow to 2.03 T CO2e output per annum per suckler cow. A carbon equivalence factor of 25 is used for these estimates, as per IPCC AR4, to convert the methane output from Tier 2 Enteric Fermentation and Manure Management to (tonnes of) CO2e. See appendix two of this paper for tables showing estimates using AR4, AR5 and AR6 emissions factors and a 20- and 100-year GWP timeframe.

At a per unit of output level, economic efficiency is associated with emissions efficiency. There are, though, persistent gaps between systems in terms of average environmental indicators, linked to economic factors such as stocking rates. Efficiency improvements at farm level have limited, rather than prevented, growth in absolute emissions at the aggregate sector level due to output expansion. GHG emissions generated per KG FPCM (Fat- and Protein-Corrected unit of Milk) have fallen 5.5% from 0.9 to 0.85 on the average dairy farm during 2016-2021, for example; however, total dairy farm agricultural GHG emissions have grown almost 96 Tonnes (18.4%) from 518.8 to 614.1 Tonnes CO2e during that five-year period to 2021; the same figure for Cattle farms is 9.6 Tonnes (6.5%) from 147 to 156.6 T CO2e. Again, it's worth noting here the interrelationship between dairy and beef, with any change in beef emissions likely to echo changes in dairy farms in terms of increased supply of animals born on dairy herds transferring to beef farms.

Trends in rolling three-year averages for mean system values of agricultural GHGs – absolute and relative to land-use and output – and ammonia emissions are illustrated below[22]. While dairy farms place higher absolute pressures on the environment in terms of GHG and ammonia emissions, and emissions are higher relative to land use due to the more intensive nature of the system in general, dry-stock farms have higher emissions intensities relative to their economic output. Dairy farm emission increases in recent years were driven by higher livestock numbers and milk yields per cow, while average Cattle, Tillage and Sheep system farm emissions have been generally stable or falling[23].

Finally, it is important to note that 2021 tillage farm agricultural emissions were 57.4 T CO2e per farm when cattle (104.5 T CO2e) and sheep (15 T CO2e) emissions sources are excluded, or approx. 67.6% lower than total emissions per tillage farm when all agricultural sources are included. If cattle and sheep emissions are excluded, tillage farm agricultural emissions per hectare would be 0.81 T CO2e, or less than 10% of dairy farm agricultural emissions per hectare. This reflects the multi-enterprise nature of such farms, as many tillage farms also carry these other enterprises and apply animal manure from external sources to their crops; this highlights the nuances in terms of the relative environmental performance of systems and often their interlinkages, emphasising the need for a whole-of-system approach.





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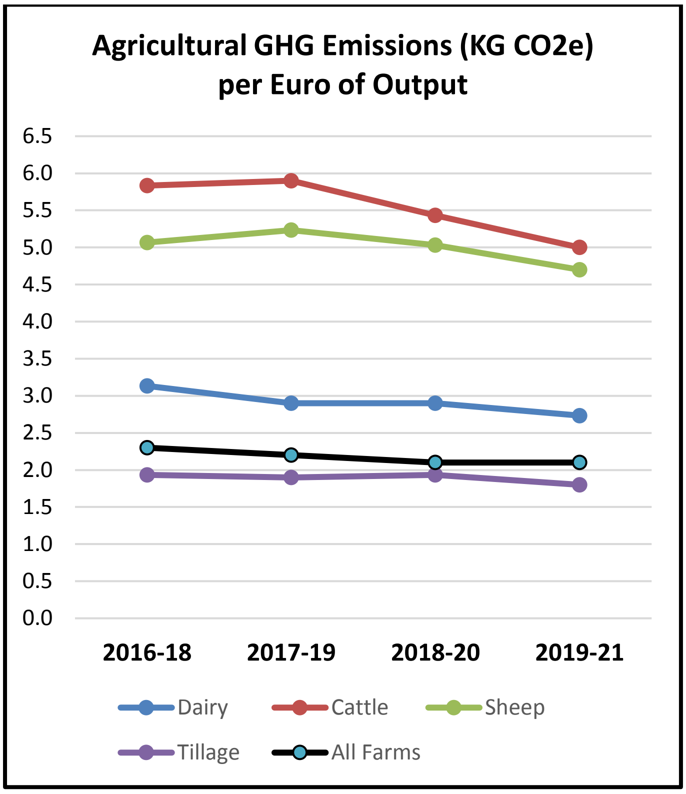
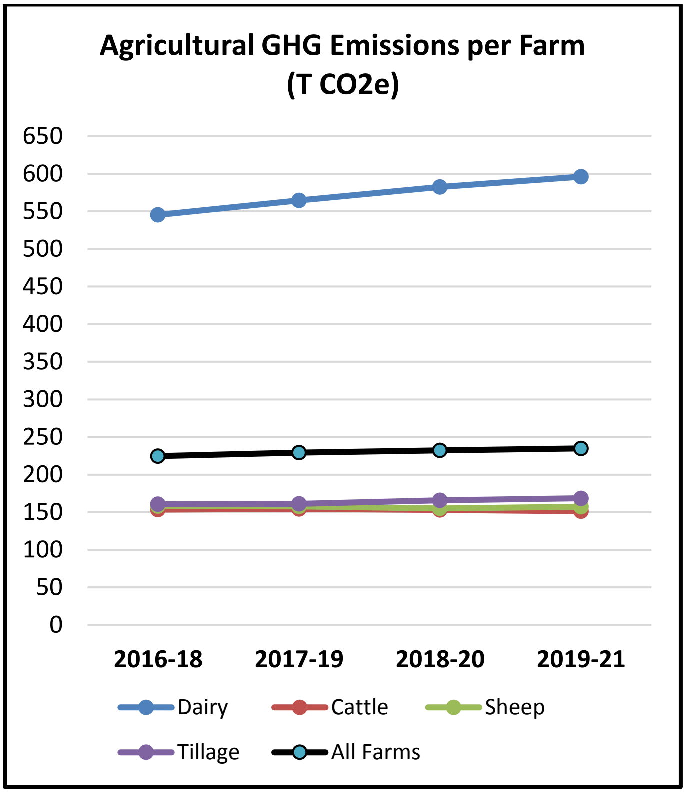
[22]Author's calculations of three-year averages of sustainability indicators, based on figures in: Buckley, C. and Donnellan, T. (2022) *Teagasc NFS Sustainability Report 2021*, pp.78-86, Sustainability Indicator Tables A1-A5.
[23] Buckley, C. et al (2021) *Outlook 2022: Economic Prospects for Agriculture*, pp. 93-95, Figures 2-6. Teagasc.





1.4 Policy Context

At the EU level, overall GHG emissions must be reduced by 55% by 2030 compared to 1990, while net zero emissions is the target by 2050. Under the Effort Sharing Regulation, Ireland must reduce its overall non-ETS emissions by 30% by 2030, although this is expected to rise when the *Fit for 55* package is adopted. The EU Green Deal, launched in 2020, established a framework toward 2050 net neutrality in terms of the plans to decouple growth from resource use. Of particular relevance to the Irish agri-food sector, this included the Farm-to-Fork and Biodiversity Strategies for 2030. These aim to promote a sustainable life-cycle approach to the food supply chain; protect & restore natural capital; "shift the fiscal burden from labour to pollution"; provide statutory protections for at least 30% of EU land & sea areas; and ensure 25% of UAA is under organics in the EU by 2030. The Farm to Fork strategy makes clear that "improving the incomes of primary producers and reinforcing the EU's competitiveness" are key objectives incorporated into the policy, as well as improving food security and food system resilience[24]. This will inform mechanisms included in the new Common Agricultural Policy from 2023.

The EU Commission Methane Strategy notes that heightened general climate ambition will "*require an accelerated effort to tackle methane emissions"* through technology and innovation, as well as improved granularity of emissions measurement, reporting and tracking. Such data, with verification, could create opportunities for primary producer income diversification. The Strategy recognises the *"inherent complexities involved in achieving methane emissions reductions in agriculture [...] Trade-offs in mitigation actions must be minimised [and] benefits from grazing ruminants* [protected] *in terms of carbon sequestration and biodiversity".* The main technologies available "*have the potential to deliver emission reductions decoupled from production. These are mainly related to improvement of animal diets, herd management, manure management (notably its use in fertilisers and biogas generation), breeding, herd health and animal welfare."* A digital carbon navigator template will also support carbon farming. The Methane and Farm-to-Fork Strategies emphasise "*rewarding farmers for applying farming practices that remove CO2 from the atmosphere and contribute to the climate neutrality objective";* commit to analysing methane life-cycle effects; and will consider "*targeted research on the different factors that effectively lead to methane emissions reductions*". These strategies at

[24] EU Commission (2020) *A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system.*

EU level are particularly relevant for Irish agriculture due to the overwhelming dominance of ruminant livestock production systems in Irish agriculture.

Domestic policies are integrating this focus on viable agricultural sustainability. The Climate Action and Low Carbon Development (Amendment) Act (2021) establishes a statutory commitment to pursuing the transition to a climate-resilient, biodiversity-rich and climate-neutral economy by 2050; to reduce emissions by 51% by 2030; provides for five-year sectoral carbon budget cycles informed by the independent advice of the Climate Action Council; and ensures parliamentary oversight from an Oireachtas Committee. The CCAC must also retain at least one member with specialist knowledge of agricultural policy. Notably, the Act gives mention to the *"special economic and social role of agriculture"* and the *"distinct characteristics of biogenic methane".*[25] Ag-Climatise, a climate roadmap for the agriculture sector, was launched in 2020 and provided a holistic set of 29 actions to meet the 2019 National Climate Action Plan targets. The roadmap was informed by the Teagasc Marginal Abatement Cost Curve, which outlined mitigation actions in terms of unit and aggregate abatement potential and cost if scaled up with high uptake at farm-level. Ag-Climatise is a living document to be amended based on changes in ambition in terms of identified measures or new scientific evidence.

The Climate Action Plan 2021 was launched in November 2021. This provided a detailed plan to achieve a 51% reduction in overall national Greenhouse Gas (GHG) emissions by 2030 compared to 2018 and sets Ireland on a path to reach net-zero emissions by no later than 2050, as set out in the Climate Action and Low Carbon Development (Amendment) Act 2021. The Agriculture sector has a target under the CAP21 2021 of a 22-30% reduction in GHG emissions, compared to 2018 output of approx. 23 MT CO2eq (in IPCC AR5 emissions accounting terms), to between 16 and 18 MT CO2eq by 2030[26].

Climate Action Plan 2021 builds on the *AgClimatise* climate action roadmap for the sector[27], and commits to:

- **Increasing the pace and depth of change in an enhanced *AgClimatise* climate action roadmap** for the sector, by furthering targets and bringing forward measures to be consistent with sectoral emissions ceilings.
- **Reducing the amount of chemical nitrogen used on farms** through a significant shift toward greater use of nitrogen fertilisers containing inhibitors (Protected Urea) that will mitigate Nitrous Oxide and Ammonia emissions. Further mitigation of these emissions will be achieved through the inclusion of legumes in swards, sowing multi-species swards, and optimising soil pH levels. A revised nitrates programme will be implemented, and a national fertiliser register will be established also.
- **Accelerating animal breeding improvements,** through Economic Breeding Indices, funding relevant research and assimilating data. This will include a focus on the selection for traits that lead to lower methane production in the beef breeding programme.
- **Optimising the crude protein levels in livestock feeding stuffs**, as well as testing new feed additives under local conditions to establish best available technologies to deliver methane mitigation, animal welfare and food safety during the winter housing period.
- **Increasing the area farmed organically** to at least 350,000 hectares by 2030 through the provision of capital grants and access to the Organic Farming Scheme.

[25] Climate Action and Low Carbon Development (Amendment) Act 2020, p. 11. The distinct characteristics of biogenic methane are "*referred to in the Special Report on Global Warming published by the Intergovernmental Panel on Climate Change".*

[26] Emissions expressed in terms of the IPCC AR5 accounting methodology, which increases the 2018 baseline emissions from the Agriculture sector from 22.03 MT CO2eq to approx. 23 MT CO2eq when compared with the IPCC AR4 emissions accounting methodology used in the National Inventory Report (NIR) to date. This is due to a higher methane and lower nitrous oxide carbon equivalence factors leading to a higher estimate in net terms.

[27] AgClimatise incorporated mitigation measures identified in the Teagasc Marginal Abatement Cost Curve, which provided for up to 2.9 MT CO2eq abatement to reach the 10-15% reduction in GHGs by 2030 targeted in the 2019 Climate Action Plan. Climate Action Plan 2021 commits to update the MACC to reflect heightened climate ambition.

- **Improving the animal health of beef and dairy herds** to increase productivity and reduce emissions per unit of output through this greater efficiency.
- **Increasing the volume and quality of grazed grass consumed by animals** through the rollout of agri-advisory programmes, as well as the Teagasc Signpost Programme to promote best practice.
- **Developing plans to manage the sustainable environmental footprint of the beef and dairy sectors by Q2 2022** as part of the implementation of Food Vision 2030 for the Agri-Food sector.
- **Finalising the Common Agriculture Policy Strategic Plan (CSP) for 2023-2027** as a delivery mechanism for achieving climate ambition. This will include actions via the new 'Green Architecture', incorporating:

  - Enhanced environmental conditionality for payments;
  - New annual Pillar One voluntary agri-environmental Eco-Schemes, which will provide payments for actions which contribute to improved environmental and climate outcomes above the baseline requirements under conditionality; and
  - Focused Pillar Two agri-environmental and climate interventions to deliver long-term environmental improvements, particularly for biodiversity and water quality, including a flagship Agri-Environmental and Climate Scheme (AECM).

Specific GHG mitigation measures included in Climate Action Plan 2021 for the agriculture sector, to be implemented to achieve the target emissions reduction by 2030, include:

1. **Reductions in Nitrous Oxide emissions by changing farm management practices** (1.5-2 MT CO2eq Mitigation):

- Chemical nitrogen use on Irish farms must be reduced to less than 350,000 tonnes by 2025, and less than 325,000 tonnes by 2030;
- 65% of straight Calcium Ammonium Nitrate (CAN) to be replaced by protected urea (or other protected nitrogen products); and
- 90% uptake of Low Emission Slurry Spreading (LESS) equipment use.

2. **Improved animal breeding and management** (0.3 MT CO2eq Mitigation)

- Number of dairy herds carrying out milk recording to increase from 50% to 90%, and suckler beef herd weight recording from 30% to 70%.

3. **Improved animal feeding** (0.7 MT CO2eq Mitigation)

- Reduce crude protein content of livestock feeding stuffs to minimise nitrous oxide and ammonia loss, while utilising feed additives during housing period.

4. **Early finishing age of cattle** (0.7 MT CO2eq Mitigation)

- Reduce the average age of slaughter of prime animals from 27 to 24 months by 2030.

5. **Increased organic farming** (0.3 MT CO2eq Mitigation)

- Increase the area farmed organically in Ireland from 74,000 hectares to 350,000 hectares by 2030.

6. Use of agricultural feedstocks to produce biomethane (0.1-0.2 MT CO2eq Mitigation[28])

- Contribute agricultural feedstocks toward the production of 1.6 TWh per annum of indigenous sustainably-produced biomethane for injection into the gas grid by 2030.

Other measures with a mitigation potential yet to be determined include greater diversification (e.g. agroforestry, significantly increased biomethane production and afforestation); developing a carbon farming model[29]; and exploring technological solutions that deliver pasture-based methane-reducing technologies such as 3-NOP. Other measures within the CAP21 with relevance to the food system more widely include a renewed focus on the Circular Economy and the Bioeconomy, improving resource use across value chains. In support of these ambitions, the establishment of the National Agricultural Soil Carbon Observatory (NASCO) will help in quantifying carbon sequestration in Irish agricultural soils. Similarly, a Teagasc Agricultural GHG Centre of Excellence was opened in 2021 for innovation in climate smart agriculture and land-use for the agri-food sector; and an exemplar network of Teagasc SignPost farms has been established to demonstrate best climate practice under real-world conditions and to facilitate Knowledge Transfer.

In addition, within Climate Action Plan 2021, there is to be a separate contribution from the **Land Use, Land Use Change and Forestry (LULUCF) and the Marine** sectors to reduce emissions by 37-58%, from 4.6 MT CO2eq in 2018 to 2-3 MT CO2eq, by 2030. The LULUCF sector action plan has a number of measures which, although they may not be directly related to the agricultural emissions inventory, the agriculture sector will make a significant contribution to in terms of implementation. The Climate Action Plan 2021 commits to achieve this headline target by:

- Increasing the annual afforestation rate, including promoting forest management initiatives.
- Reducing the management intensity on 80,000 ha of grasslands on drained organic soils.
- Improving management of carbon sequestration on at least 450,000 ha of grasslands on mineral soils.
- Increasing the inclusion of cover crops in tillage to at least 50,000 ha by 2030.
- Increasing the incorporation of straw to at least 10% of tillage areas[30].
- Rehabilitating 65,000 ha of peatlands across numerous landowners and projects.
- Designating 30% of Ireland's marine area as a Marine Protected Area.

The European Commission also adopted its new EU strategy on adaptation to climate change in February 2021, setting out how the European Union can adapt to the unavoidable impacts of climate change and become climate resilient by 2050. The Strategy has four principal objectives: to make adaptation smarter, swifter and more systemic, and to step up international action on adaptation to climate change. It will be important for adaptation policies to be effectively implemented to limit socio-economic losses arising from increasingly significant climate impacts. Where proper adaptation planning is in place, costs will likely be lower over the long-term in spite of near-term costs, with possible synergies between mitigation and adaptation actions, which could be explored further to foster food system resilience.

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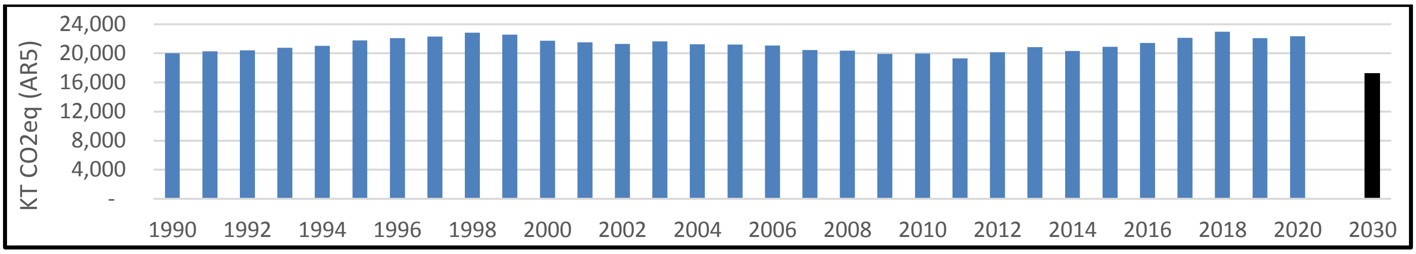
[28] This will also deliver a further 0.4 MT CO2eq Mitigation in the Energy sector.

[29] The Department of Agriculture Food and the Marine (DAFM) is exploring the development of a carbon farming model with the potential for trading – one which rewards farmers for emissions reductions and removals, including through potential private sector investment. Such an approach will require the establishment of baseline data, auditing, the development of voluntary carbon codes, leveraging of private financing through public/private partnerships, and putting governance structures in place.

[30] In 2021, the Straw Incorporation Measure provided an aggregate approx. €10m to tillage farmers to chop straw from cereal crops in-situ. This is a means to return organic matter to soils, thereby reducing GHG emissions by increasing Soil Organic Carbon (SOC) levels via increased carbon sequestration. There are further potential environmental benefits to this measure via improved soil biology and reduced application of imported manures.

In July 2022, specific GHG emissions mitigation targets for each sector were agreed under the sectoral emissions ceiling process – with the exception of LULUCF, the inclusion of which has been temporarily delayed, to coincide with the completion of a Land Use Review (committed to in the Programme for Government). The Agriculture sector has been set a 25% target, compared to the 2018 baseline, meaning a reduction from approx. 23 MT CO2e to 17.25 MT CO2e (AR5) by 2030. The targets agreed for emissions reduction across each sector reflects the Government response to the climate crisis, but also recognises the importance of sustainable food production. There is also a recognition of the key role agriculture will play in relation to decarbonising our energy system; this can be realised through significant opportunities such as Anaerobic Digestion (AD), Solar and Forestry, which will provide opportunities for farmers to access additional income sources whilst contributing to national energy systems. The 2022 National Climate Action Plan will reflect the new sectoral targets; and Ag-Climatise will also be updated.



Agricultural Emissions 1990-2020 and the 2030 mitigation target of approx. 17.25 MT CO2eq at 2030 (-25% from circa 22.9 MT in 2018).

The international and national context of policy objectives are aligned under Food Vision 2030[31] for sector development, shaped through stakeholder engagement. The Strategy develops a coherent vision toward greater economic, social and environmental sustainability using a Food Systems approach. For the environment, the overarching aim is to develop a climate-neutral food system by 2050, with verifiable progress achieved by 2030 – encompassing ambition to reduce GHG and ammonia emissions, increase carbon sequestration, and improve biodiversity and water quality. The Strategy focuses on opportunities for sustainability premia which could add value throughout the supply chain – with resilience built around Agricultural Knowledge and Innovation Systems, diversification and product differentiation. The Strategy also emphasises the need for Just Transition principles and provisions to "minimise hardship for workers and their communities", acknowledging some trade-offs exist across the three dimensions of sustainability and the need to reach "realistic compromises on the direction of change and the speed at which it can take place". Acknowledging that targets will increasingly be set by legislation, Food Vision 2030 environmental targets include:

- A minimum 10% reduction in biogenic methane by 2030 (which has already been overtaken by the Climate Action Plan);
- Emissions associated with chemical fertiliser use to reduce by more than 50% by 2030;
- Ammonia emissions 5% below 2005 levels by 2030; and a 50% reduction in Nutrient losses to water by 2030;
- 10% of farmed area prioritised for biodiversity, spread across farms throughout the country by 2030; and
- 7.5% of UAA under Organic production; and a halving of per-capita food waste by 2030.

Food Vision 2030 also commits to "*determine the sustainable environmental footprint of the dairy and beef sectors*" in 2022. Several measures have been identified in the final report of the Food Vision Dairy Group, with the aim of stabilising and reducing emissions associated with the dairy sector. This demonstrates the capacity of stakeholders to work collaboratively and constructively to find feasible and implementable measures to address the challenges facing the sector, and this significant progress can be replicated in the Beef and Sheep Food Vision Groups. This evolving policy context emphasises a sustained focus on climate action as part of holistic sector sustainability.

[31] DAFM (2021) *Food Vision 2030: A World Leader in Sustainable Food Systems*.

Section Two: Considerations for Transition

2.1 Spatial Concentration of Agricultural Systems

As noted at the outset, ruminant livestock systems are the predominant source of agricultural emissions in Ireland, either directly (e.g. biogenic methane) or indirectly (e.g. through chemical fertiliser use). Farm systems tend to be geographically concentrated, which implies uneven regional effects from changes in specific agricultural production systems. If technical measures prove insufficient and/or technologies do not rapidly develop – or climate ambitions are increased – further changes in agricultural production activity could be required in the sector. The distribution of the adjustment burden between agricultural systems would determine which regions are disproportionately affected. Non-dairy (suckler) cows are more concentrated in the Border-Midlands-West region, while dairy cows are mainly clustered in Southern and Eastern counties, as established at the outset.

Spatially differentiated socio-economic consequences of reduced agricultural output from either specialist beef or dairy systems would follow from the spatial concentration of beef and dairy systems. Alternative economic opportunities – including diversified activities (e.g. agro-forestry, bio-energy production or agro-tourism) – could help to mitigate negative socio-economic effects from reduced ruminant agriculture activity. The differing levels of socio-economic dependence on agriculture across regions should also be taken into account, with different multiplier effects from changes in primary economic value across regions. If abatement were distributed on a least-cost[32] basis, previous economic modelling has estimated that specialist beef (cattle) farms would be disproportionately affected due to low direct economic returns, on average. Cattle farms are also the most numerous system, however, and they also have the highest economic multiplier effects due to their embedded nature in local rural communities, as well as the greater labour intensity of beef as opposed to milk processing. This implies significant indirect localised socio-economic effects which could also reduce household income and economic value in the wider economy (ibid). This assumes no compensation of direct losses or changes in domestic policy but illustrates the significant implications of abatement and its asymmetric effects depending on how burdens are distributed.

2.2 Asymmetric Demographic Effects

A key issue in the transition to a low-carbon economy is knowledge transfer, education and re- or up-skilling of labour displaced by the effects of decarbonisation policies. Targeted supports for cohorts at elevated risk from any negative socio-economic effects of climate change policy actions may therefore be required. The economic literature generally suggests that:

- Older workers who face displacement, relative to younger peers, likely face heightened challenges in
    - Recouping returns to investment in their re-skilling or education, due to the shorter career time remaining between their re-employment and their retirement; and
    - Face scarring effects such as longer periods of unemployment, difficulties in competing for new employment and more depressed wages when they return to employment[33]
- Lower-skilled labour have higher risks of long-term unemployment, which creates scarring effects via the detrimental impacts on social connectivity and lifetime earnings[34]

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[32] Miller, AC,, Donnellan, T., Matthews, A. and Hanrahan, K. (2014) *Expanding Agri-Food Production and Employment in the Presence of Climate Policy Constraints: Quantifying the Trade-off in Ireland* modelled least-cost abatement for Irish agriculture: "*From an economic perspective, those farms with lower abatement costs should reduce their GHG emissions more than those with higher abatement costs, since otherwise the total cost of achieving the reduced GHG emissions level will be higher than necessary".*

[33] Botta, E. (2018) *A Review of Transition Management Strategies: Lessons for Advancing the Green Low-Carbon Transition.*OECD.

[34] Machin, S. and Manning, A. (1998) *The causes and consequences of long-term unemployment in Europe* in Handbook of Labor Economics. London School of Economics.

- Female labour force participation is generally at a heightened risk to negative economic shocks, requiring additional protections and targeted policy measures[35].

2.3 Indirect and Induced Socio-Economic Effects

As already outlined, indirect or induced output and employment effects would arise from any changes in production. Such production changes would reduce the value of the agriculture sector and farm household income, but also:

- Output and employment related to consumption of intermediate agricultural inputs;
- Secondary processing output and employment; and
- Wider economic output, employment and income in the general domestic economy.

There is little capacity for substitution of agricultural labour, due to sector-specific knowledge and experience. Previous estimates of average and marginal employment multiplier coefficients per million Euros of agricultural output have illustrated the socio-economic significance of beef, sheep and dairy in particular[36]. The overall marginal employment multiplier for primary Irish production has been estimated, using 2012-2014 CSO data, at c. 16 jobs per additional million Euros of Agriculture, Forestry and Fishing output[37]. This relationship between primary production and employment is strongest outside Dublin and the Mid-East.

Most primary sector average elasticity coefficients for employment in agri-food sectors lie within a positive range of 0.23 to 0.28; marginal multipliers – which measure the additional jobs needed for a given million Euro increase in output – also vary and are larger for primary production (between 4-16) than secondary/processing activities (from 0.85 to approx. 3).[38]. There is uncertainty around the direct, indirect and/or induced effects of changes in agricultural output value in terms of employment – particularly due to the generally low value of employment multiplier estimates, which are likely a result of increasing automation and capital-intensity of production, with technical change over time reducing the amount of additional labour required to expand output. Also, as Miller et al (2014) note, "*in general, multipliers tend to be more valid for modelling the impact of small [changes] in production and become less reliable as the scale of the change in the economic activity being modelled becomes larger*"; as such, estimates of up- and down-stream economic implications of changes in sector output will vary in their reliability depending on the size of the initial shock to the sector. Finally, while these are the most recently available employment multiplier estimates for Irish agriculture, they are based on underlying data representative of the sector and its relationship to the wider economy during 1995-2008. As such, actual secondary economic impacts will likely differ from those estimated using these multipliers, but can indicate the level of economic change which might be anticipated in response to shocks.

Studies which have examined the impact of the closure of other sectors, such as the 1980s widespread closures seen in the UK coal mining industry, have shown negative indirect effects for local communities[39]. The cessation of activity was abrupt with little alternative employment opportunity provided in many cases – in contrast to just transition principles. The negative direct and indirect socio-economic impacts from the decline of this structurally significant sector, with regionally concentrated production, created large and persistent negative effects on female employment, population level and labour participation rates. This highlights the scale of the challenge and reinforces the importance of Just Transition principles for contemporary societal shifts.

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[35]Jaumotte, F. (2003) *Female Labour Force Participation: Past Trends and Main Determinants in OECD Countries.* OECD Working Paper No.376

[36] Miller, AC, Matthews, A., Donnellan, T. and O'Donoghue, C. (2014) *The employment effects of Food Harvest 2020 in Ireland.* Irish Journal of Agricultural and Food Research , 2014, Vol. 53, No. 2, pp.149-169.

[37] Hennessy, T., Doran J., Bogue, J. and Repar, L. (2018) *The Economic and Societal Importance of the Irish Suckler Beef Sector*, pp.38-40, Tables Seven and Eight. This peer-reviewed report was published by the Irish Farmers Association.

[38] Miller, AC, Matthews, A., Donnellan, T. and O'Donoghue, C. (2014) *The employment effects of Food Harvest 2020 in Ireland.* Irish Journal of Agricultural and Food Research , 2014, Vol. 53, No. 2, pp.149-169, Table Three.

[39] Aragon, F., Rud, J.P. and Toews, G. (2015) *Mining Closure, Gender and Employment Reallocations: The Case of UK Coal Mines.*

2.4 Opportunities of the Transition

The transition offers co-benefit opportunities to improve socio-economic resilience – for example, through income diversification and cost-neutral or cost-saving measures which can improve production efficiency and animal health while simultaneously reducing environmental pressures[40]. It also provides the chance to further incentivise the provision of public goods on farms through mechanisms such as Payments for Eco-System Services (PES) or Carbon Farming – via public and private finance – compensating farmers for the public goods which may not otherwise be rewarded by the market. Direct payments and subsides already account for a significant proportion of Family Farm Income on many farms; this presents an opportunity to shape incentives which encourage sustainable forms of production or the provision of public goods such as ecosystem services, while continuing to support farm incomes and wider rural development[41].

The transition also represents an opportunity to 'green' agricultural employment, therefore safeguarding jobs as economic development decouples from emissions-intensive activities, limiting displacement. This has already been illustrated in the Just Transition approach to Bord na Móna workers in the midlands in response to the closure of peat harvesting for power generation, where alternative forms of employment and new sources of investment have been developed. However, it should be acknowledged that the scale of peat harvesting was relatively small when compared with the wider agriculture sector. As the International Labour Organisation (ILO) outlines: "[M]*any, and perhaps most, existing jobs will simply be transformed and redefined as day-to-day workplace practices, skill sets, work methods, and job profiles are greened.*" There will also be employment creation generated by the investments required to transition to a more sustainable economic model: "[a]*s the incomes generated are spent across the economy, they create further employment (induced jobs)*." A lack of labour mobility and/or skills deficits may be barriers to greening employment, requiring policy interventions which can ensure existing employment is protected and new green employment is created or induced by transitional investments. As the ILO acknowledges, "*agriculture and forestry open up opportunities to build on traditional knowledge and empower communities that already face several socio-economic vulnerabilities*."[42]

Diversification presents an opportunity to increase resilience to climate and economic shocks. In adapting to the challenges of the transition, alongside the efforts being undertaken through the Food Vision Dairy and Beef & Sheep Groups, there could be opportunities to convert to organic production and forestry; conversion to alternative, relatively lower-emissions systems such as tillage or sheep farming[43]; and to capitalise on emerging innovations in agri-tourism, precision farming and other diversification options – particularly in bioeconomy products, renewable energy generation (from biomass and biomethane) being sold to the national grid, and carbon farming. This would, however, likely require significant investments and re-training to adapt holdings and skillsets.

Ultimately, negative socio-economic effects from a transition requiring reductions in emissions-intensive agricultural output can be limited or negated by capitalising on co-benefit opportunities such as dividends from verifiable sustainability, enabling product differentiation in export markets; or food price premia for producers in the event of greater scarcity of output, outweighing negative quantity effects, although this would likely be associated with food

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[40] Antón, J. (2021) *Dynamics of Farm Performance and Policy Impacts.* OECD Food, Agriculture and Fisheries Paper no.164.

[41] Both social and economic considerations have been recognised as contributing to farmer decision-making around participation in agri-environmental schemes. Extensive drystock systems (cattle and sheep) have historically been more likely to participate in such schemes than generally more intensive systems such as dairy due to the opportunity costs of participation being higher for more profitable systems in general. Similarly, schemes with higher existing subsidy levels are more likely to participate.
See: Cullen et al (2021) *More than two decades of Agri-Environmental schemes: Has the profile of participating farms changed?* In Journal of Environmental Management, Vol. 292.

[42] "*A study of 1,144 organic farms in the United Kingdom and the Republic of Ireland concluded that organic farms employ 135 per cent more full-time equivalent (FTE) jobs per farm than conventional farms (Morison et al., 2005)".*

[43] The impacts of such conversion would need to be taken into account, e.g. increased soil emissions from tillage; it is also not clear that a sufficient market opportunity exists or that this would be compatible with commitments to reduce fertiliser use.

security and consumer price inflation risks. Furthermore, a portion of carbon tax revenue will be ringfenced for agri-environmental projects and social protection measures. These opportunities have been emphasised by sector stakeholders and are central components of Food Vision 2030.

2.5 Further Considerations

Other aspects which will be important in achieving transition are provided in the appendix of this report. These include land use; Global emissions (carbon leakage) and food price inflation; emerging technologies; options for how abatement burdens can be distributed; Just Transition; non-monetary factors which influence decision making; and demand-side factors, particularly consumer preferences. The evidence on these issues continues to develop, but their importance to the transition for the sector will be considerable.

Further research into the wider dynamic context is required to determine the nature and to what extent such factors will be important or can play a role in mitigation efforts during the transition.

Section Three: Estimates of Socio-Economic Transition Effects

Existing estimates suggest the shape and extent of changes in agricultural value and farm income will likely depend on which of the price or quantity effects dominate. The existing economic literature has, to date, suggested the price effect of increased scarcity of output should generally outweigh any reduced production output in the transition in developed economies. Overall employment should also be relatively unchanged under this framework, with job losses limited by shifts toward low-carbon economic activities, although there could be structural changes in agricultural labour[44]. While aggregate changes may be marginal in these estimates, employment and output effects are expected to be concentrated in local areas, occupations and sectors most dependent on carbon-intensive inputs and outputs.

Existing modelling of the impact of higher carbon taxation levels suggests the agriculture sector can convert to lower-emissions energy use at relatively marginal costs. For instance, aggregate agricultural employment in developed economies is estimated to fall 2% relative to a 2011 baseline, with possible downward pressure on income, at a carbon tax rate of $50 (USD) per tonne of CO2e[45]. ESRI research[46] has suggested increases in the carbon tax rate to €80 could reduce energy emissions from agriculture by 8-40%, driven by a transfer of intermediate inputs towards non-energy commodities and farm energy demand toward renewable sources. The recording of these emissions savings in the energy or transport inventories – rather than agriculture – should be borne in mind, however. Primary sector value-added and employment would both be relatively unchanged, increasing marginally by 0.1-0.3% (ibid.). The effect of carbon pricing would drive down demand for carbon-intensive goods and energy, stimulating demand for sustainable substitutes and energy-saving technologies. Recycling carbon tax revenue would enable transitional supports and increased technological efficiency from transitional investment, with positive indirect and induced effects on employment and output value (ibid). This ties to international findings that transitioning to low- or zero-carbon energy sources and economic activities can provide economic co-benefits such as productivity improvements[47]. Such modelling, however, reflects the alternatives available to reduce energy emissions in a cost-effective manner using renewables and other innovations, while reducing agricultural emissions at such a scale is more challenging without changes in activity levels.

Some recent economic modelling has been undertaken of the possible effects of reducing agricultural emissions and other environmental impacts – in the EU, in the context of the Green Deal, and in Ireland, in the context of Climate Action Plan targets. At present, the available economic assessments of the Farm-to-Fork and Biodiversity Strategies have generally shown that, at an aggregate EU level, the policies required to achieve their objectives would likely lead to reduced crop yields, lower output and income value, and reduced exports, with probable gross carbon leakage to less environmentally efficient food producers in third countries, although net Global emissions would still be reduced[48]. Estimated effects vary by methodology, assumptions, sector and region. Such studies also generally note the need for further refinement to: a) better account for the potential production and societal benefits which can arise from reduced environmental impacts, such as for soil health, biodiversity, air and water quality; and b) capture the

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[44] National Economic and Social Council (2020) *Addressing Employment Vulnerability as Part of a Just Transition in Ireland.*

[45] Chateau, J. Et al (2017) OECD Working Party on Integrating Environmental and Economic Policies *Impacts of green growth policies on labour markets and wage income distribution: a general equilibrium application to climate and energy policies.*

[46] De Bruin, K. And Yakut, AM (2019) *The Effects of an Incremental Increase in the Irish Carbon Tax towards 2030.* ESRI Working Paper No. 619 pp.11-12.

[47] Botta, E. (2018) *A Review of Transition Management Strategies: Lessons for Advancing the Green Low-Carbon Transition.* OECD

[48] Bremmer, J. et al (2021) *Impact Assessment Study on EC 2030 Green Deal Targets for Sustainable Food Production: Effects of Farm-to-Fork and Biodiversity Strategies at farm, national and EU level.* Wageningen University.

dynamic response of both producers in third countries to reduced EU agricultural output (supply-side), as well as possible changes in consumer behaviour in seeking greater sustainability in their food choices (demand-side)[49].

Economic impact assessment modelling of domestic emissions reduction scenarios has included some scenario analyses undertaken by private consultancy firms, commissioned by sector stakeholders. The methodologies employed in these studies differ in their assumptions and design, and their estimates are therefore not directly comparable to the Teagasc FAPRI modelling estimates that are presented in this report below.

3.1 Summary of Teagasc FAPRI Economic Modelling of Agricultural GHG Mitigation Scenarios

Economic modelling of changes in agricultural emissions in the Irish context is required, to assess the implications of the transition for the sector. This section presents estimates generated by Teagasc for changes to output, income, cattle numbers and emissions which could evolve under hypothetical scenarios of emissions reduction targets for 2030. A summary of the main findings of this analysis was published in the CCAC Technical Report on Carbon Budgets in 2021, and informed the Climate Action Plan and carbon budgets process; here, the results of the analysis are explored to highlight some key findings and implications. The analysis is intended to illustrate the types and levels of changes which could be required to meet emissions reduction targets at varying levels of climate ambition for the sector and the associated socio-economic ramifications. These estimates were generated using the FAPRI model of the agriculture sector which is a Structural Partial Equilibrium Model, which estimates parameters induced by relative changes while all other parts of the economy, such as price levels, remain constant. Initially, the scenarios modelled do not require changes in agricultural production (quantity), as technical mitigation measures can reduce absolute emissions. Once the mitigation capacity consistent with *Ag-Climatise* is exhausted, a progressively larger effect is introduced onto the relevant model parameters to induce the necessary changes in absolute emissions levels. The two main agents of change to create these adjustments are reducing beef subsidies and reducing real milk prices. These changes alter the incentives facing producers and their simulated production behaviour. Policies, including the Common Agricultural Policy, are assumed to remain unchanged from 2020, while 2018 is the base year for emissions to align with targets under the Climate Action Plan.

It is important to note that the analysis is intended to illustrate the scale of changes required to meet specified emissions reduction levels, rather than to predict how the parameters will evolve in reality, in the absence of further technical measures to reduce emissions without reducing livestock numbers. The model presents data examining one of an infinite number of possible combinations of changes in relative dairy and beef incentives, and as such the analysis is not intended as a policy preference. Analysis focused on altering incentives faced by farmers of beef and dairy cows since as earlier discussions highlighted, most agricultural GHG emissions in Ireland are ultimately driven by the evolution of the dairy and beef sectors. The model, as calibrated for this analysis, prioritises initial reductions in activity levels in the beef sector due to the lower direct economic costs of abatement as compared to those in the dairy sector. However, alternative estimates of changes would be possible through differing incentives between the dairy and beef sector, which would lead to different primary and secondary effects, both economic and environmental.

Furthermore, the scenarios do not consider the implementation of any policies which might mitigate against the estimated economic losses or foregone economic gains. Therefore, additional analysis would be required to account for such factors, particularly in relation to the potential to compensate for some losses in terms of diversification or bio-economy opportunities. Farm-level effects are not estimated but would depend on circumstances at the individual farm level. There could also be land use change emissions induced, for example, by converting grassland to cropland for tillage. Carbon leakage effects are not considered in the modelling and Irish agricultural commodity prices are assumed to continue to be determined on EU markets where no change in policy is assumed to occur relative to the Baseline. Irrespective of these caveats, the estimates provide an indication of the challenge facing the agriculture

[49] Barreiro-Hurle, J. et al (2021) *Modelling environmental and climate ambition in the agricultural sector with the CAPRI model.* EU Joint Research Centre (JRC) Technical Report.

sector of varying climate change policy ambition. The scenarios are summarised below. The scale of the challenge and lack of an historical precedent provide a unique challenge for the FAPRI model, particularly for the higher levels of ambition beyond c. 40% abatement, with associated uncertainties. An additional Scenario (F) of over 50% emissions mitigation was included in the CCAC Technical Report on Carbon Budgets, but is not included here. This level of mitigation was judged to be unfeasible given its economic costs, and deemed unnecessary given the technical mitigation options available in other sectors, such as energy/transport, which would incur lower economic costs.

2030 Scenario	Scenario Target Design Description
Business as Usual	Business as Usual (Baseline) without measures. Assumes TCA (Brexit).
Scenario A:	Business as Usual with measures – consistent with *Ag-Climatise* but otherwise unconstrained. GHG emissions are reduced by 14% vs. 2018 at 2030.
Scenario B:	Consistent with *Ag-Climatise* and dairy sector is constrained at its 2019 level. GHG emissions are reduced by 15% vs. 2018 at 2030.
Scenario C:	GHG emissions are reduced by 20% vs. 2018 at 2030.
Scenario D:	GHG emissions are reduced by 33% vs. 2018 at 2030.
Scenario E:	GHG emissions are reduced by 40% vs. 2018 at 2030.

Nomenclature describing scenarios and their emissions levels at 2030. Source: Teagasc, as developed for FAPRI modelling.

It should be noted that the estimates of emissions reductions for all scenarios, other than BAU, assume all absolute emissions mitigation measures from the Teagasc MACC are implemented. These measures are distinct from efficiency measures, which could lead to higher emissions if farmers responded by expanding their production, or lower emissions if farmers produced the same level of output from less inputs. The distribution of changes in cow numbers between Dairy and Beef (sucklers) varies across scenarios as presented in the table below[50].

Scenario	Percentage (%) Split of Reduction in Total Cow Numbers versus 2030 BAU (A)		Number of Cows (Millions)			Percentage (%) Change in Cows Versus 2018		
Sector	*Dairy*	*Beef*	*Dairy*	*Beef*	*Total Cows*	*Dairy*	*Beef*	*Total Cows*
2018	N/A	N/A	1.48	1.05	2.53	-	-	-
2021	N/A	N/A	1.60	0.94	2.54	8	-10	1
2030 BAU	-	-	1.65	0.78	2.43	11	-26	-4
2030 A	-	-	1.65	0.78	2.43	11	-26	-4
2030 B	164	- 64	1.47	0.85	2.32	0	-19	-8
2030 C	62	38	1.45	0.66	2.11	-2	-37	-16
2030 D	44	56	1.22	0.23	1.45	-18	-78	-43
2030 E	49	51	1.06	0.17	1.23	-29	-84	-51

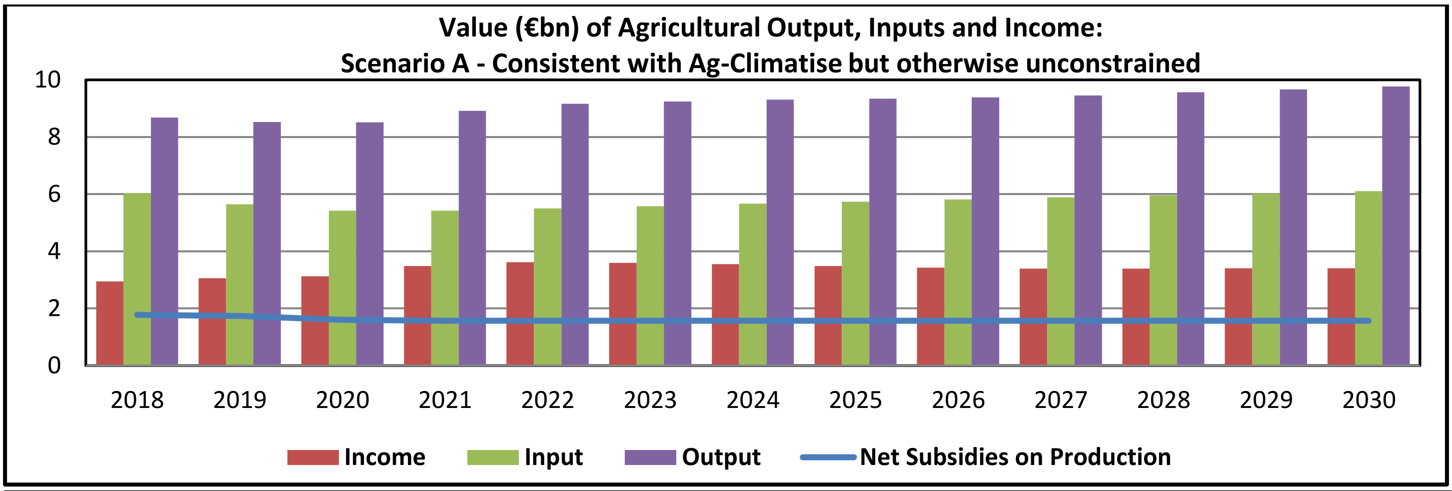
Sector Percentage (%) Shares of the Change in Total Cows relative to 2030 Scenario A; and rounded Number of Cows by Type (Millions of dairy & non-dairy cows). 2018 and 2021 data are from the CSO; 2030 Scenarios from Teagasc FAPRI estimates. 2018 used as baseline for sector split in relative shares of change in cows under scenarios.

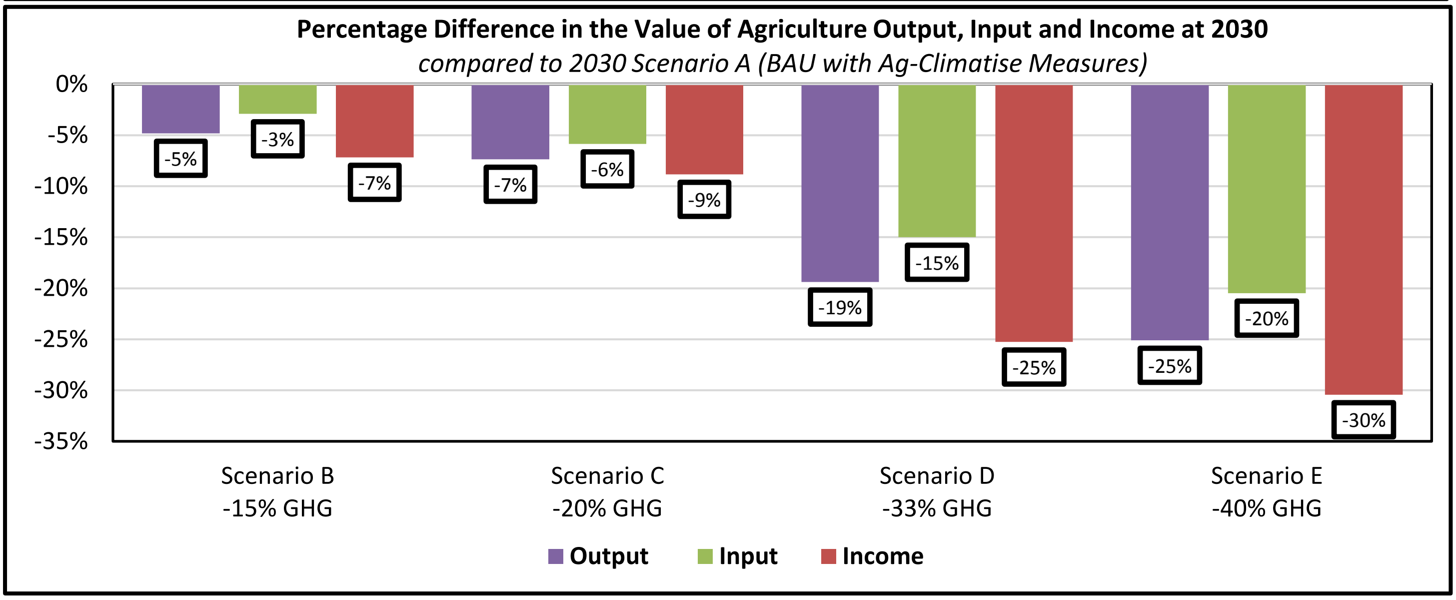
2030 Scenario	Total Cattle (Million Head)		Agricultural Output (€bn at Basic Prices)		Agriculture Income (€ bn Operating Surplus)	
	2030	**% Change vs. A**	**2030**	**% Change vs. A**	**2030**	**% Change vs. A**
BAU	7.098	-	9.77	-	3.41	-
Scenario A	7.10	-	9.77	-	3.41	-
Scenario B	6.866	-3	9.30	-5	3.17	-7
Scenario C	6.429	-9	9.05	-7	3.11	-9
Scenario D	5.095	-28	7.87	-19	2.55	-25
Scenario E	4.662	-34	7.32	-25	2.37	-30

Total Cattle, Output Value and Income (Operating Surplus) Value under FAPRI scenarios modelled, by 2030 Scenario, in millions of head and Euros where applicable and in percentage change terms compared to Scenario A.

[50] Compared to 2018 instead, Dairy would account for 3/7/24/33% of the total cow number reduction for Scenarios B/C/D/E.

At the overall sector level, aggregate nominal economic output (at basic prices) and income (operating surplus[51]) are relatively resilient to changes in emissions abatement ambition across the scenarios, reflecting the likely dynamic changes in farm-level behaviour as relative economic incentives change. This is due to the initial adjustment falling principally on the suckler beef herd, where there is relatively little GVA generated at the farm level, and therefore reducing cow numbers doesn't necessarily have as large an impact on aggregate GVA. However, for the scenarios with a higher GHG reduction, the dairy cow numbers fall, and the impact on GVA is more pronounced as the marginal dairy cow is creating GVA and once removed it leads to progressively larger reductions in operating surplus doe this loss of GVA. Sector income falls by 7, 9, 25 or 30% when compared to the baseline (scenario A, consistent with *Ag-Climatise* but otherwise unconstrained) under scenarios B-E, respectively; and it is lower than its 2020 level of €3.26bn across scenarios B-E. Meanwhile output at basic prices only falls below its 2020 level of €8.91bn under scenarios 2030 D and E; but again output would be 5, 7, 19 or 25% lower under scenarios B-E, respectively, when compared to what it would be at 2030 under scenario A. Summaries of changes in cattle, emissions, income and output are presented below with 2020 as the reference year[52]. 2018 is the baseline reference year for emissions in the 2021 Climate Action Plan, while 2020 is the latest year for which official final estimates are available for sector GHG emissions at the time of writing[53].





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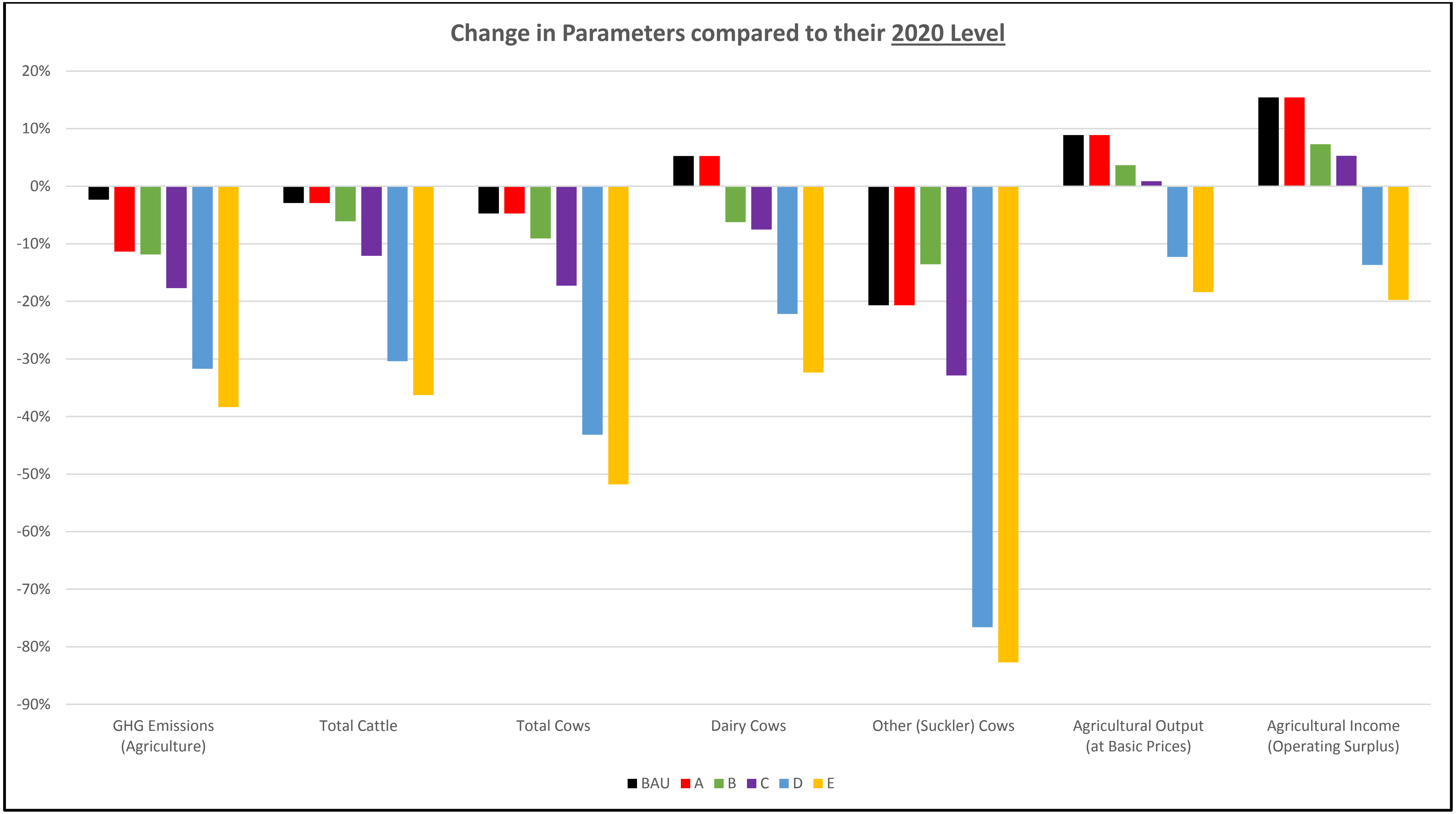
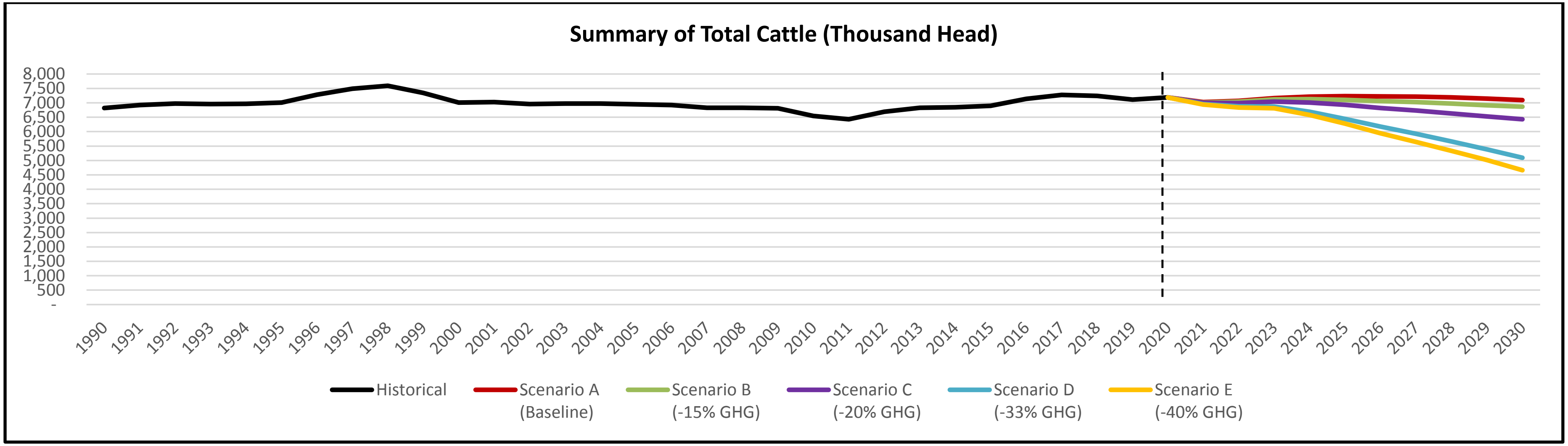
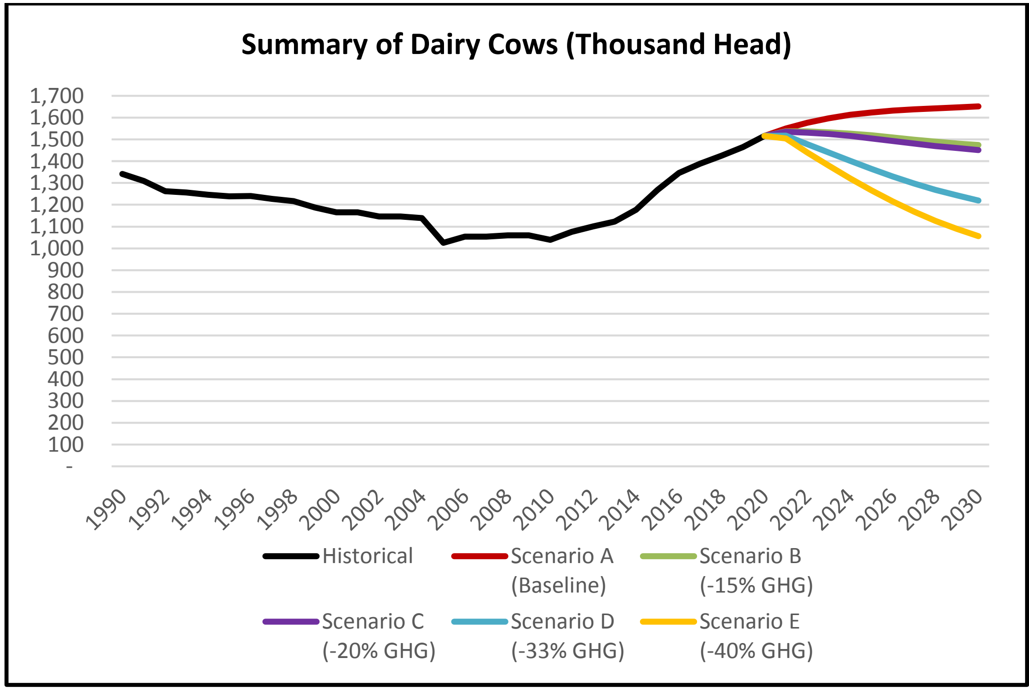
[51] Income here refers to operating surplus of the agriculture sector as a whole at current prices, i.e. total factor income less employee compensation before payments on borrowed capital, land annuities and rent paid to landowners are deducted.
[52] The 2018 emissions baseline of 21.95 MT CO_2e, as reported in the 2021 EPA National Inventory Report, represents agricultural GHG emissions in the Agriculture sector and excludes carbon emissions from fishing in the sector. This same figure was 21.38 MT CO_2e in 2020, which is the reference year in some of the graphs and tables presented here.
[53] Provisional Estimates for 2021 have been published by the CSO, however these remain subject to change, so 2020 is used.



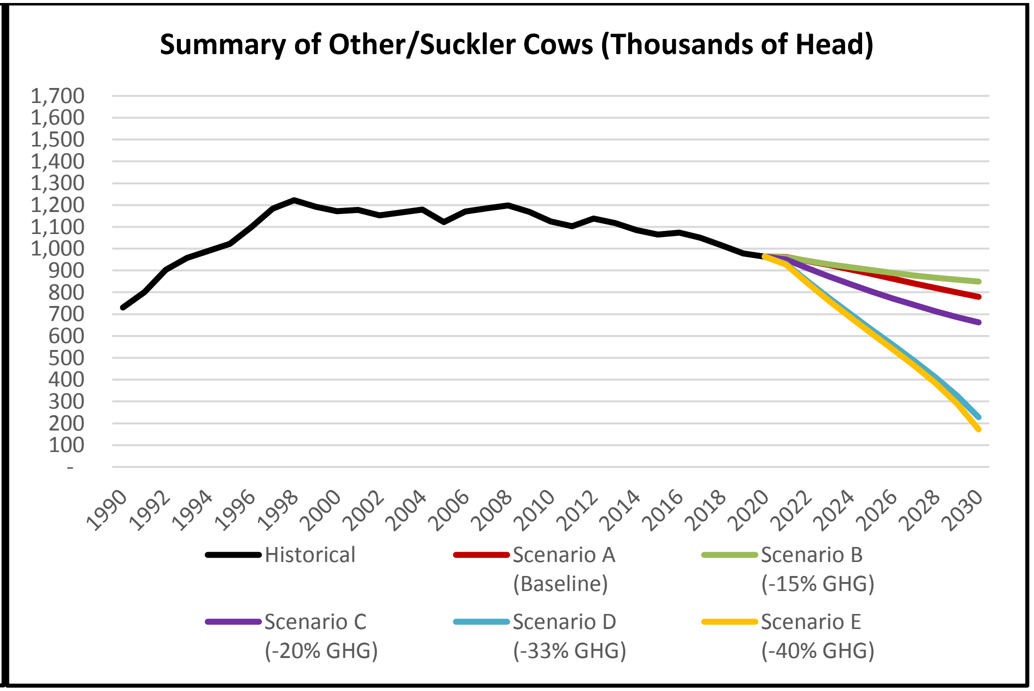
Summary of cattle, cows, output and income by 2030 scenario compared to 2020. Source: Teagasc FAPRI estimates and Author's Calculations. 2020 used as baseline in this graph as this is the most recent year for which final GHG emissions estimates are available.



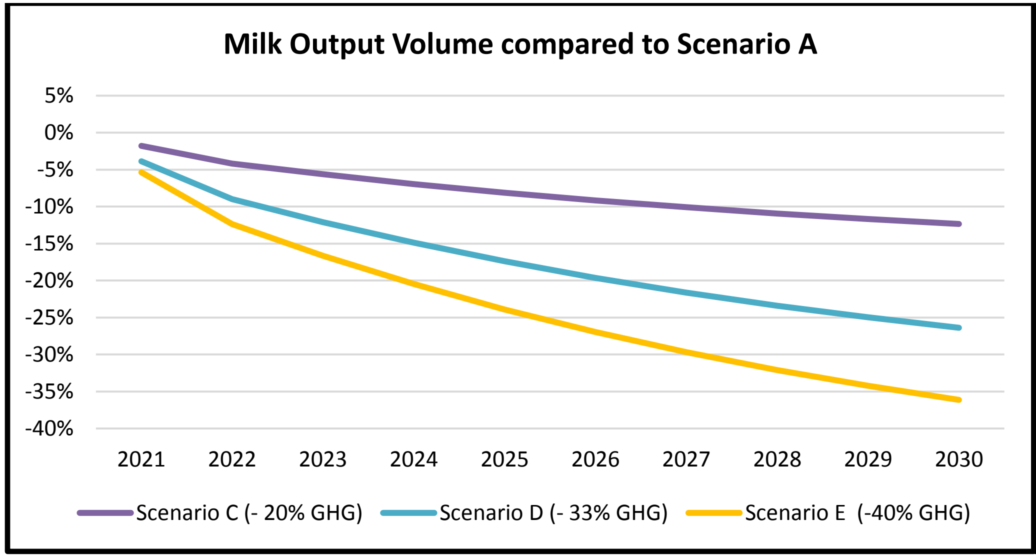
Summary of Total Cattle (Thousand Head)
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Historical
Scenario A (Baseline)
Scenario B (-15% GHG)
Scenario C (-20% GHG)
Scenario D (-33% GHG)
Scenario E (-40% GHG)

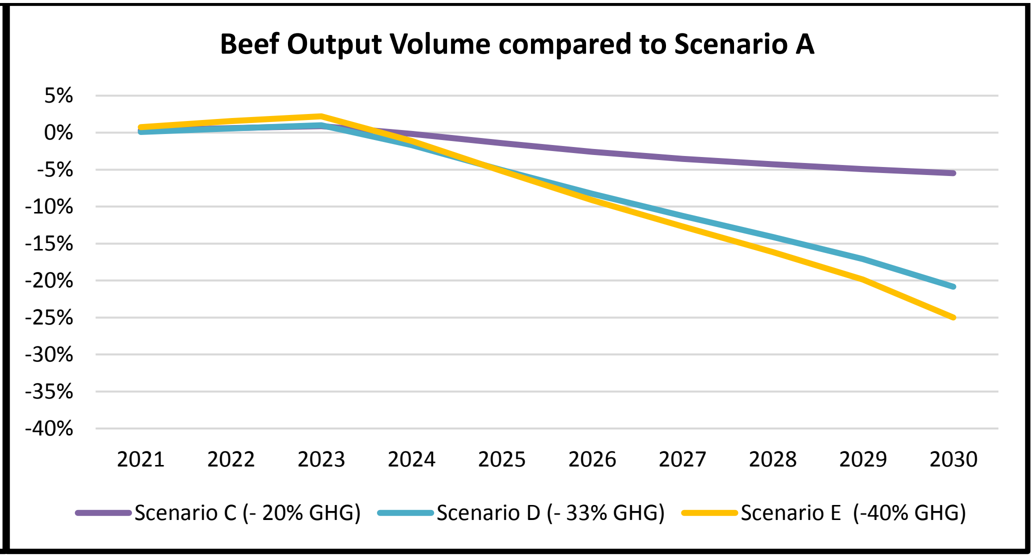


Summary of Dairy Cows (Thousand Head)
1,700
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
-
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030
Historical
Scenario A (Baseline)
Scenario B (-15% GHG)
Scenario C (-20% GHG)
Scenario D (-33% GHG)
Scenario E (-40% GHG)

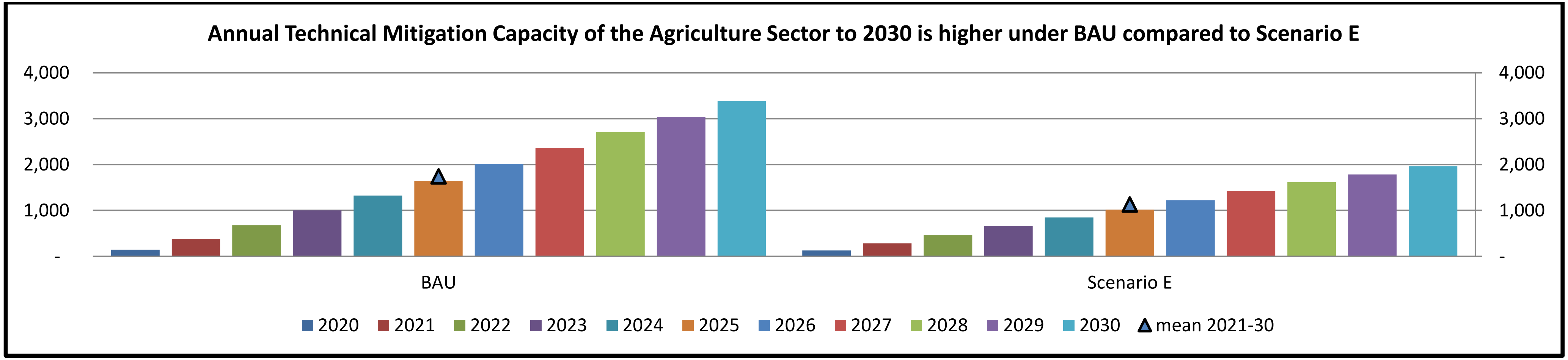


Summary of Other/Suckler Cows (Thousands of Head)
1,700
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
-
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030
Historical
Scenario A (Baseline)
Scenario B (-15% GHG)
Scenario C (-20% GHG)
Scenario D (-33% GHG)
Scenario E (-40% GHG)





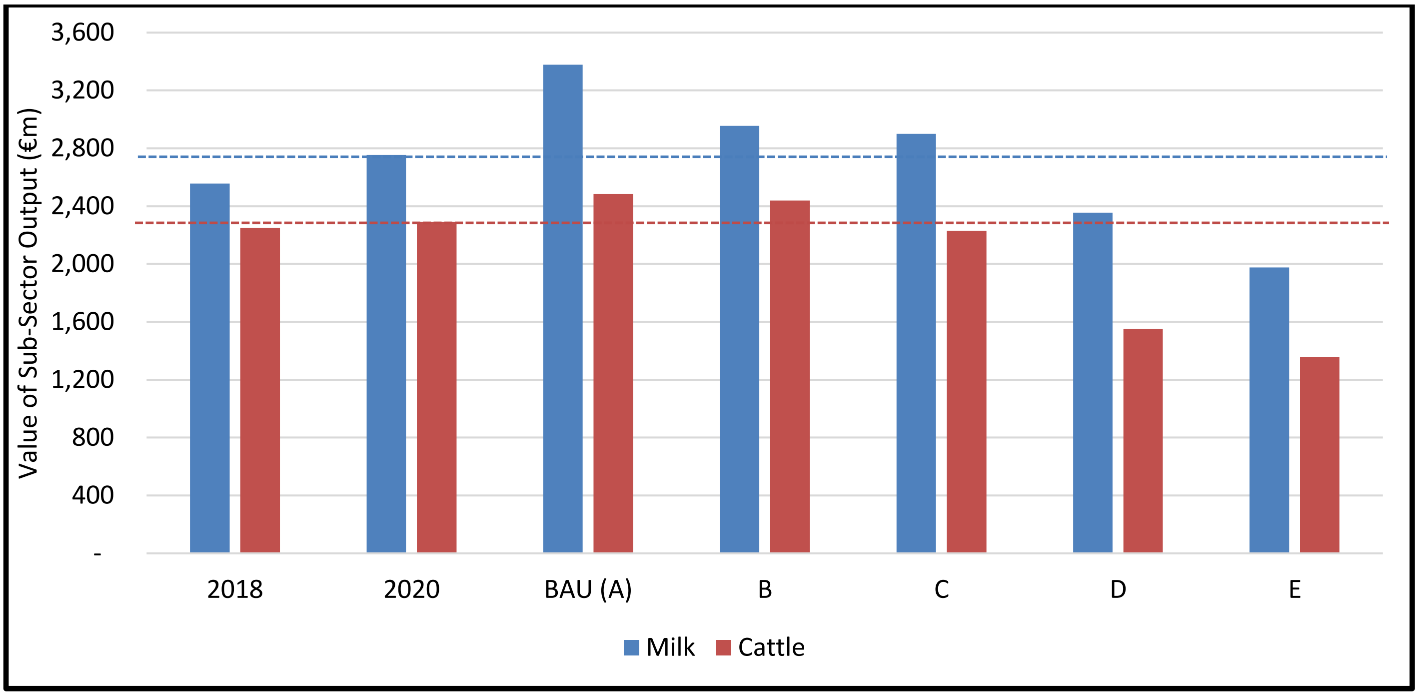
Milk (LHS) and Beef (RHS) Output Volume under Scenarios C/D/E compared to Scenario A for the years 2021-2030. Source: Hanrahan and Donnellan (Forthcoming) *Impact of GHG Scenarios on Agricultural Activity, Output, Input and Income in Agriculture and Employment in the Agriculture and Food Processing Industries*, pp.4-5, Figures Three and Four. Teagasc FAPRI Model.



Note: The large reductions in agricultural activity under more ambitious mitigation scenarios imply lower technical mitigation capacity, meaning sharper declines in production are required to deliver more ambitious emissions reduction targets. This is reflected in the above graph. Source: Teagasc.

3.2 Direct Sectoral Impacts

The changes in milk and cattle output would be most pronounced for scenarios beyond Scenario C, at which point both milk and cattle output can remain above or near their 2018 level. It is important to note that the dairy sector also contributes to the value of cattle output, therefore output value losses in the suckler beef sector could be larger than indicated by changes in cattle output.



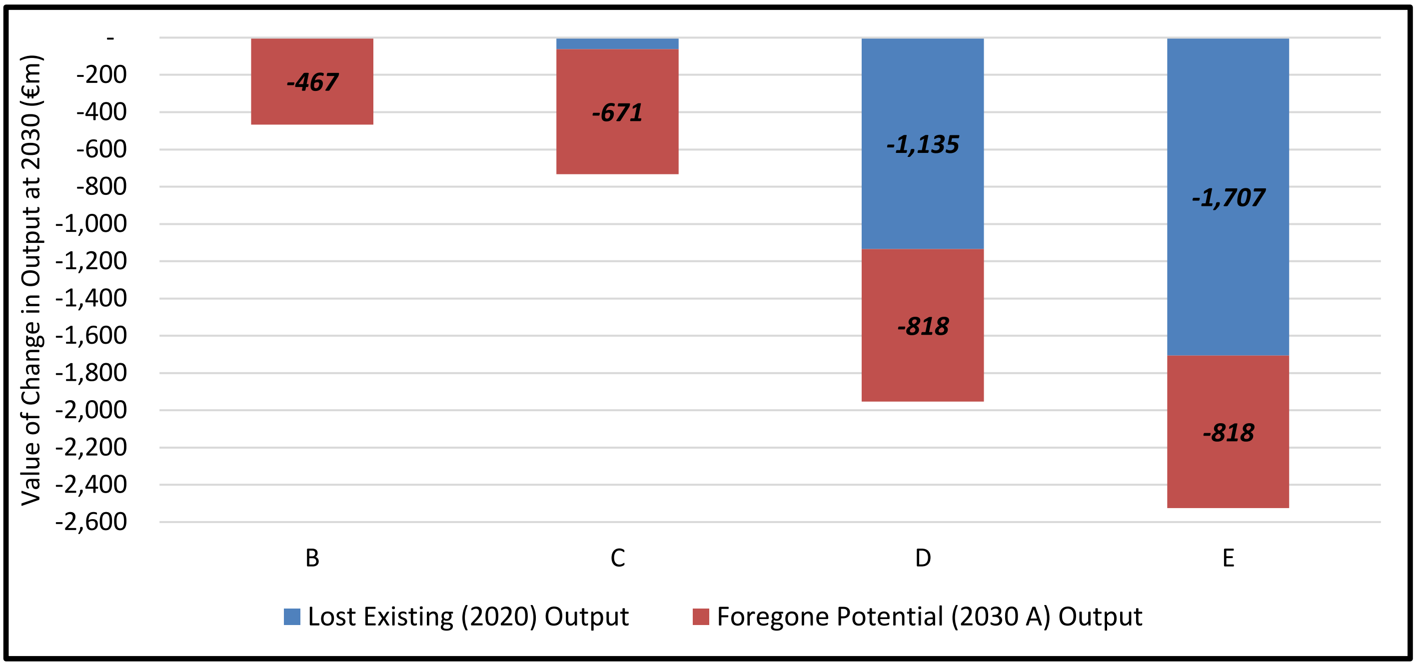
Value of Milk and Cattle Output (€m) by 2030 Scenario. Source: Teagasc FAPRI estimates. Dashed lines represent 2020 output.

The Table below distinguishes between existing output losses under these scenarios from foregone potential output which could be generated under a Business-as-Usual scenario beyond the current output level of the sectors.

Scenario	Milk		Cattle		Sum (Milk and Cattle)	
	Lost Existing (2020) Output	*Foregone Potential (2030 A) Output*	*Lost Existing (2020) Output*	*Foregone Potential (2030 A) Output*	*Lost Existing (2020) Output*	*Foregone Potential (2030 A) Output*
B	0	423	0	44	0	467
C	0	478	61	193	61	671
D	397	625	738	193	1,135	818
E	775	625	931	193	1,707	818

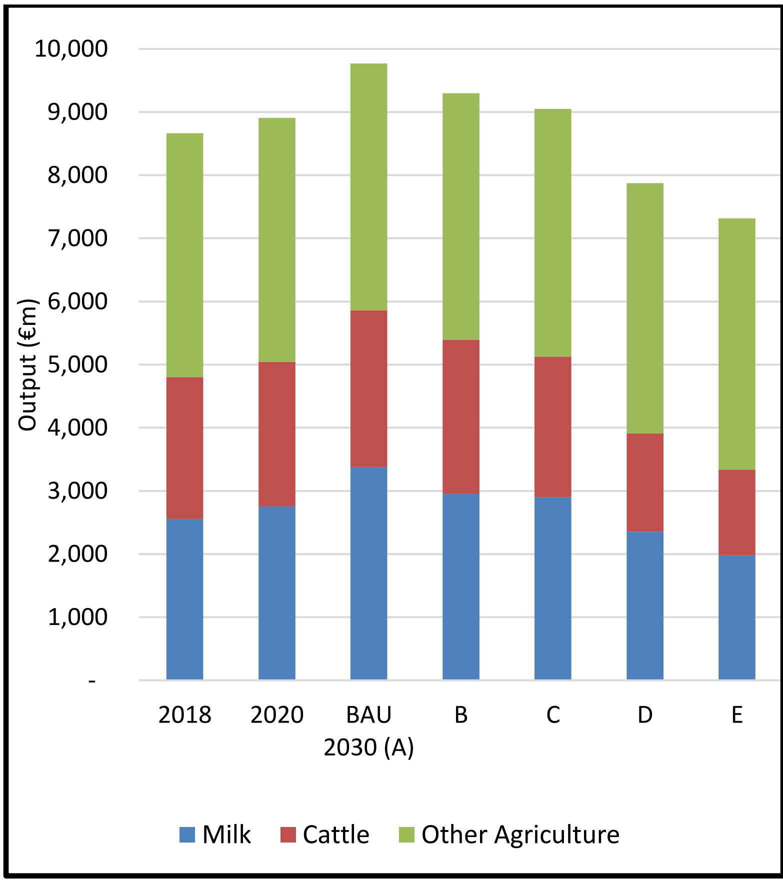
Lost (Existing) Output and Foregone (Potential) Output under FAPRI Scenarios B – E (€m). Source: Author's Calculations based on Teagasc FAPRI estimates. Lost (existing) output derived by deducting output under the scenario from 2020 output; foregone (potential) output is the difference between scenario output compared to output under 2030 BAU (A) net of lost existing output. Note that Scenario A is the same as BAU from an economic and activity level perspective, and is therefore not reported here.

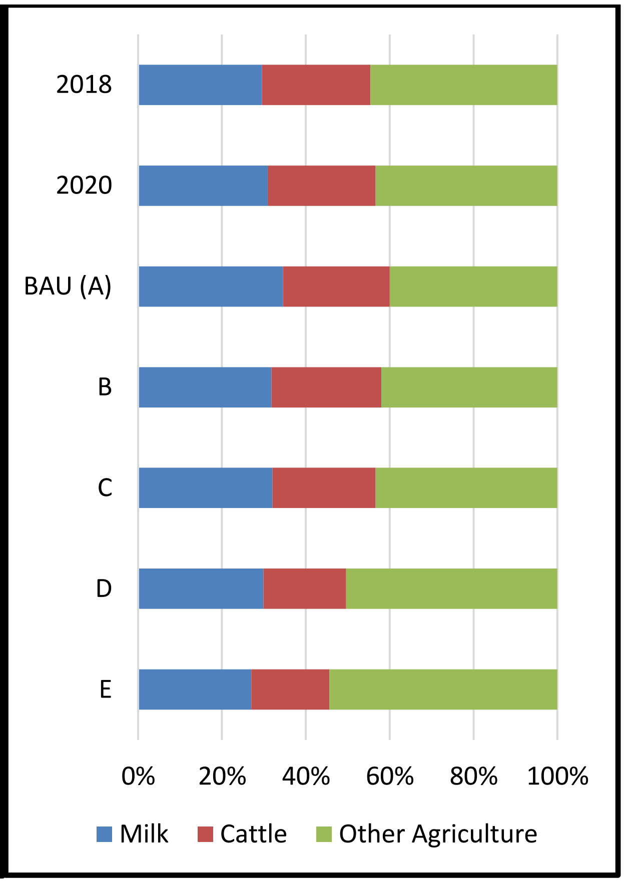
While milk output would grow €625m (22.7%) at 2030 BAU compared to 2020, and cattle output by €193m (8.4%), and both would remain close to or above their 2020 level under scenarios B and C, output value in these sectors would fall significantly below its 2020 level under scenarios D and E. Milk output would be €297m (€775m) below its 2020 level under scenario D (E); cattle output would be €738m (€931m) below its 2020 level under scenario D (E).



Sum of Direct Milk & Cattle Output Losses (€m) by 2030 Scenario. Source: Author's Calculations based on FAPRI estimates.

Marginal increases in the value of other agricultural output outside milk and cattle would offset some losses, however the agriculture sector overall would reduce in economic size under scenarios D and E compared to its 2020 level of output; it would also be smaller under scenarios B and C than it otherwise would be under the BAU (A) scenario overall. The respective shares of sectors in agricultural output are illustrated below.





Left-Hand Side: Value of Agriculture Sector Output at Basic Prices (€m) for 2018, 2020 and 2030 Scenarios by Sub-Sector. Right-Hand Side: Sub-sector Shares of Total Agricultural Output Value. Source: Author’s Calculations based on Teagasc FAPRI Estimates.

3.3 Discussion of Implications of Teagasc FAPRI Model Analysis

Reducing agricultural activity, i.e. cattle numbers, as a means to reduce absolute emissions from the agricultural sector in the short-to-medium term would contribute to mitigation efforts, but would also incur high economic costs and have long-term implications for the sector. The exhaustion of LULUCF mitigation and other excess mitigation capacity could be explored before such reductions in activity levels (production) may be required. While estimated aggregate agricultural income (operating surplus) would be somewhat resilient to reductions in production as modelled, the modelling does not infer distributional effects, i.e. identifying which sectors or farm and household types would be likely to bear disproportionately higher costs due to the shape of the transition under the hypothetical scenarios. Section One of this report did, however, identify those cohorts facing distinct risks arising from the transition; it is also likely that Cattle Rearing farms would typically be affected first by suckler cow number declines, while farms purchasing cattle from such farms such as Cattle Other (or Beef Finishing enterprises) would be affected next if incentives were distributed in a similar fashion to those in the modelling scenarios.

Dairy farming supports a higher proportion of full-time farmers with higher family farm incomes and more viable household demographics, as detailed across NFS Sustainability Reports. Curtailing the dairy sector would significantly impede the overall sustainability of agriculture in socio-economic terms; conversely, if the dairy sector were to continue unconstrained on its current growth path, the resulting environmental degradation would be incompatible with national policy objectives, and therefore the work of the Food Vision 2030 Dairy group will be key to lowering the environmental footprint of the sector. Creating greater sustainability – e.g. through off-setting (carbon sequestration) efforts, such as the integration of forestry on marginal lands – are examples that could provide environmental benefits. Cattle farming, meanwhile, if compared directly with dairy would appear to generate a greater GHG emissions per KG or Euro of market output. However, a direct comparison of meat and milk output can be misleading as the allocation of emissions for dairy typically not accounting for the calves born which become a joint product that is typically allocated in the beef system. A more meaningful comparison would need to convert both products to the same unit basis such as per unit of protein for example. Also it is worth noting Irish beef's relatively high international ranking in terms of emissions efficiency due to the comparative advantage of extensive grasslands.

Cattle farming generally supports less sustainable household demographics and offers low absolute Family Farm Incomes for farmers on average, which is reflected in high levels of part-time farming and off-farm employment. Changes in output value would therefore be spread across a large volume of farms; however, the changes in the value of farm output could be large in relative terms compared to current levels. There is capacity for the tillage sector to grow as a replacement for bovine enterprises; however, such a transformation could be challenging in terms of the existing skill set and capital needs, while the emissions profile of such a change should also be borne in mind. Equally, some land is not suitable for tillage farming, such as marginal or hilly land. Also, EU policy aims to protect permanent pastureland and the conversion of permanent pasture to tillage would result in considerable GHG emission fluxes.

3.4 Estimates of Indirect and Induced Economic Effects Implied by FAPRI Scenario Modelling

Secondary (indirect or induced) changes in output and employment would also take effect. In the following analysis, multiplier coefficients are applied to the direct changes in output relative to Scenario A (BAU with measures) arising from FAPRI scenarios B, C, D and E. The difference between the total economic effect and the direct change in output represents the indirect economic impact of the reductions in agricultural activity which would be necessitated by the respective scenarios' level of GHG reduction. The shocks are disaggregated to the sectoral level for cattle (beef) and milk (dairy), illustrating that the distribution of the abatement burden has varying downstream economic effects due to the different labour intensities and localised effects linked to the different systems.

Caution is urged in interpreting these broad estimates, as the figures presented here are intended to illustrate the scale of the challenge for the sector under these scenarios, but the reality would depend on various factors such as the broader economic and policy environments, or further opportunities for diversification for example. These estimates fall within a relatively wide range with scenarios D and E showing significant reduction compared to the baseline. Below, the multiplier coefficients used to calculate the secondary economic effects of the various scenarios are summarised. Average employment multipliers are generally larger than marginal coefficients, however both are presented to give an indicative range of the anticipated employment effects of the various scenarios. The (lower) marginal employment multiplier coefficient is likely to be give a better indication of the employment effect, as it reflects the change in output rather than the average number of jobs supported by agricultural output in these sectors.

Sector	Output[54]	Employment (Average Coefficient)	Employment (Marginal Coefficient)
Source	*Grealis and O'Donoghue (2015)*	*Millar et al (2014)*	*Millar et al (2014)*
Milk	1.93	15.72	6.018
Cattle	2.51	20.82	11.279
Agriculture (Overall)	1.97	N/A	N/A

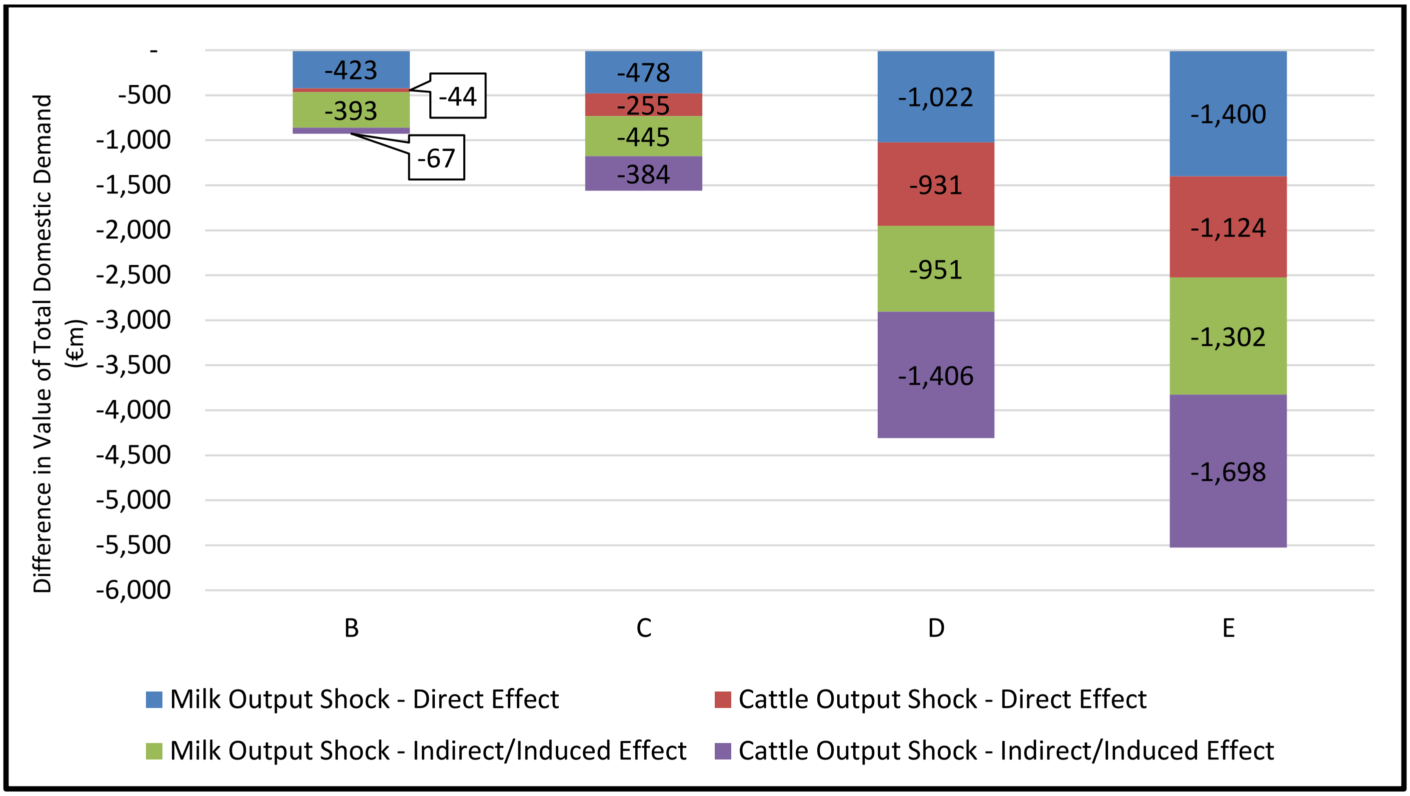
Summary of Multiplier Coefficients per Million Euro of Output, by sector, used to calculate secondary economic effects.

Below, the output and employment effects are summarised, showing a progressively larger total economic effect as the GHG reduction target increases, in keeping with the direct changes in output outlined earlier. The total economic effect is the direct economic agricultural output effect multiplied by the output multiplier coefficient, measuring the additional indirect and induced economic effects in the domestic economy. Under scenario E, as a measure of the impact of such intervention, a total economic effect of €5.52bn corresponds to approx. 2.65% of the value of Modified Domestic Demand in 2020[55]. A proportion of these multiplier effects represent foregone economic output value when compared to a Business-as-Usual 2030 (BAU 2030) scenario, rather than a current baseline level of economic activity.

Sector / Scenario	Scenario B	Scenario C	Scenario D[56]	Scenario E
	Direct Change in Output Value (€m) relative to BAU (Scenario A)			
Milk	- 423	- 478	- 1,022	- 1,400
Cattle	- 44	- 255	- 931	- 1,124
Gross Sum	- 467	- 733	- 1,953	- 2,524
	Implied Total Change in Economy-wide Value (€m) relative to BAU (Scenario A) (Direct, Indirect and Induced Economic Effect)			
Milk Shock	- 816	- 923	- 1,973	- 2,702
Cattle Shock	- 111	- 639	- 2,337	- 2,822
Gross Sum	- 927	- 1,562	- 4,310	- 5,524

Summary of Teagasc FAPRI estimates of direct changes in output compared to Business as Usual (Scenario A) and author's calculations of total change in direct, indirect and induced output implied by Grealis & O'Donoghue (2015) multipliers.

[54] Output multiplier coefficient estimates are calculated from the underlying input-output data from the base year of 2010.
[55] CSO (2021) Annex One Modified Gross National Income at Current Market Prices of €208,178m was reported for 2020 in CSO Table N2024. Modified Domestic Demand is a proxy estimate of the size of the domestic economy by taking account of (stripping out) the distortive effects of Intellectual Property import activity and aircraft leasing on estimates of Gross Domestic Product.
[56] Scenario D estimates differ here to those presented in CCAC Technical Report Tables 3-6/3-7. Multiplier effects are based on estimated changes to sector output value for this scenario, as provided by Teagasc after the publication of the CCAC report.

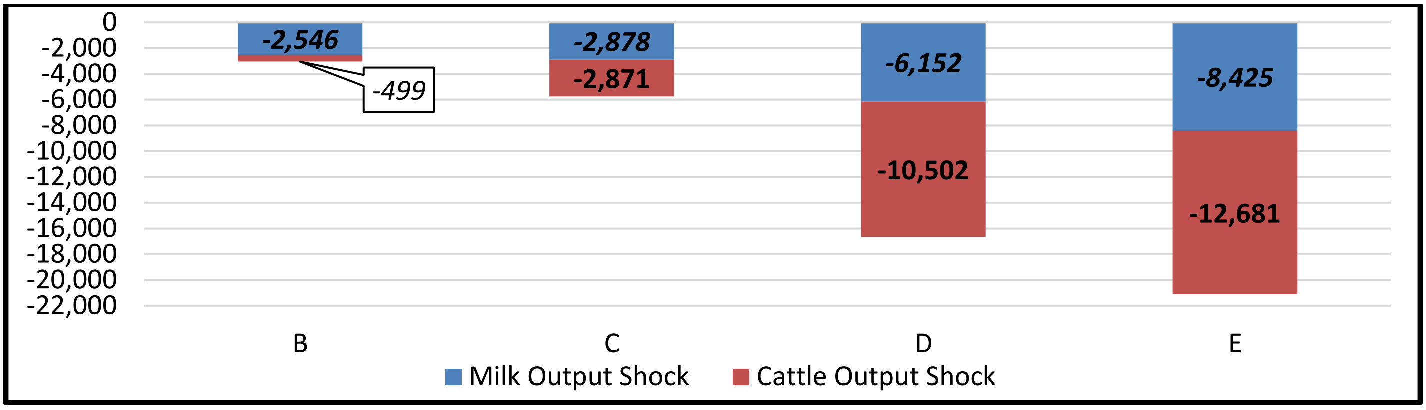


Total Domestic Economic Effect (Direct, Indirect and Induced Domestic Demand Effects) of the milk and cattle output shocks (€m). Source: Author's Calculations applying Grealis and O'Donoghue (2015) disaggregated multipliers to Teagasc FAPRI estimates of cattle and milk sector output level under scenarios as compared to 2030 Scenario A.

In the context of the socio-economic risks outlined in section two of this report – and the asymmetrical impact of these changes for different sectors of Irish agriculture depending on the distribution of the abatement burden – indirect and induced effects would also likely manifest in terms of displacement of employment. The domestic employment effects relative to Scenario A (BAU with measures) are summarised in the table below, with a range presented depending on the multiplier coefficient type used, with the marginal coefficient likely to be a more appropriate measure.

Employment Effect (Difference in No. Jobs vs. Scenario A)	Scenario B		Scenario C		Scenario D		Scenario E	
Multiplier Coefficient Type	*Average*	*Marginal*	*Average*	*Marginal*	*Average*	*Marginal*	*Average*	*Marginal*
Milk Output Shock	-6,650	-2,546	-7,518	-2,878	-16,069	-6,152	-22,009	-8,425
Cattle Output Shock	-921	-499	-5,300	-2,871	-19,386	-10,502	-23,409	-12,681
Gross Sum of Milk and Cattle Output Shocks	-7,570	-3,044	-12,819	-5,749	-35,455	-16,654	-45,418	-21,106

Summary table of author's calculations of differences in domestic economy-wide employment compared to Scenario A, arising from differences in the value of agricultural output, using average and marginal multiplier coefficients from Miller et al (2014).



Gross Difference in Employment from Milk and Cattle Output Shocks. Source: Author's Calculations using Marginal Employment Coefficients from Miller et al (2014) based on difference between 2030 milk & cattle output value under 2030 BAU vs. scenarios.

It is important to note that a portion of these jobs would have been created under the baseline scenario. Using the marginal employment coefficients, the €625m direct increase in milk output value would generate an additional 3,760 jobs compared to the 2020 output level, while the €193m increase in cattle output under the BAU scenario would generate an additional 2,179 jobs compared to the 2020 output level. These c. 6,000 potential jobs could be considered foregone employment creation which may be created elsewhere to compensate for such job losses. Equally, increases in other agricultural output could include some transfer of existing agricultural labour to other systems such as tillage. As a result, net employment destruction would be unlikely to materialise until scenarios in which GHG reduction surpasses the level envisaged under scenario C.

These jobs, or a portion of them, may still be created if alternative output is generated elsewhere in the domestic economy, and can therefore be classified as foregone potential employment. In particular, alternative employment opportunities arising from the low-carbon transition in other sectors such as energy and construction may offset some of the employment effects experienced in the agri-food sector. The estimates presented here are instead intended to illustrate the effects of these scenarios without any mitigatory policy interventions, alternative output generated in the wider economy leading to job creation, or other measures which might reduce such effects. As Teagasc note, *"Some of those who lose jobs in meat and dairy processing may seek and find employment in other sectors of the Irish economy or may emigrate to other countries where demand remains for their skills. Nevertheless, the magnitude of the output shock being considered will almost certainly, at least in the short- to medium-term, lead to large changes in employment levels within agriculture and food manufacturing and related parts of the Irish economy."*[57]

The distribution of total sector abatement between farming systems (largely between dairy and beef) affects the resulting socio-economic effects generated. Regions would be asymmetrically affected by changes in dairy and beef production, all else remaining constant and assuming impacts are proportionate. Northern and Western areas are likely to be most exposed to changes in beef production, while Southern areas are likely to be most vulnerable to changes in dairy production. It is, however, important to acknowledge the likely dynamic nature of effects – meaning impacts are unlikely to be proportionate. This foregone economic value and employment would be concentrated outside urban centres; however, the induced impacts in the wider economy would likely affect rural and urban household income and employment. These estimates illustrate the significance of these shocks; the circa 5,750 – 12,820 (16,650 – 35,450) gross fewer jobs in Scenario C (D) is equivalent to approx. 3.4% – 7.5% (9.8% – 20.8%), respectively, of the 2021 quarterly average Labour Force Survey employment estimate of 170,400 in the agri-food sector. While a proportion of these jobs will be foregone outside the agri-food sector, a significant majority will relate to agri-food itself. The precise implications would, however, depend on various other factors as discussed previously.

[57] Hanrahan, K. and Donnellan, T. (Forthcoming) *Impact of GHG Scenarios on Agricultural Activity, Output, Input and Income in Agriculture and Employment in the Agriculture and Food Processing Industries,* p.12. Teagasc.

Section Four: Conclusions and Recommendations

Irish agriculture, in its current structure and spatial distribution, is concentrated within specialist systems and regions. In the context of the need for reductions in agricultural emissions, this implies that certain systems and regions are more vulnerable to transition risks. This is especially true in the event that technical mitigation measures prove insufficient to reduce emissions to the level required by climate action ambitions for the sector, which would imply the need for changes in production output and planning.

The social and economic consequences of reduced agricultural output, due to direct and up-/down-stream economic effects, could lead to lower aggregate economic value for the wider rural economy; reduced farm income; and possibly reduced farm household income, without alternative employment opportunities or income streams. This could have negative social implications, particularly among vulnerable cohorts where alternative agricultural uses of their land – or alternative economic opportunities in the labour market – are limited. This raises important socio-economic and environmental questions as to what alternative land use might look like, and long-term implications of such changes.

Employment in regions which are more dependent on the agri-food sector is particularly important given a relative lack of alternative opportunities and the high proportion of off-farm employment which is directly or indirectly related to the agriculture sector. Beyond direct socio-economic risks, such changes in production could generate unintended consequences, such as land abandonment, with environmental and rural development implications; and social risks such as increased rural isolation. The extent of such risks is uncertain and will depend on the wider context in which such changes might take place. Equally, failure to achieve sufficient mitigation, and adopt sustainable practices more generally, could reduce sector competitiveness due to reputational damage of failure to achieve climate action targets. However, the true impact of such risks will ultimately be determined by the views of consumers.

Based on current evidence and emissions accounting frameworks – and given existing available mitigation solutions – it is likely that the reductions in GHG emissions and other environmental pressures necessitated by Climate Action Plan commitments will require significant changes to management practices and production in Irish agriculture. It is therefore important, following this analysis, that technical mitigation capacity is maximised and exhausted to limit changes in production levels, particularly those which can simultaneously create greater economic resilience and environmental co-benefits. Similarly, socio-economic and environmental trade-offs must be balanced to promote holistic sustainability. A Just Transition approach will therefore be important, while mitigation measures which are safe and cost-effective or cost-neutral – those identified to date or developed in the medium term – should be advanced and utilised fully. Transition opportunities – particularly in terms of cost-saving environmental efficiency measures, as well as diversification to promote resilience – should also be capitalised on. Research, innovation, demonstration and knowledge transfer will be key to minimising social or economic risks during the transition, and to maximise access to opportunities for improved sustainability across each of the three pillars of sustainability as well.

The opportunity costs of deferring climate action could prove increasingly costly, as the relative value of incentives required to stimulate mitigation could increase over time; equally, the emissions profile associated with agriculture – particularly as the expanding and economically significant dairy sector continues to build – will need to be carefully managed in the immediate term in order to progress toward the targets set out for the sector in line with the Climate Action and Low Carbon Development Act (2021). This may entail significant economic and environmental trade-offs, particularly for cattle-based sectors, given:

a) The relatively intensive nature of the economically viable dairy sector – which places significant strain on air and water quality, as well as emitting larger quantities of GHGs; against
b) The generally extensive nature of beef farming – which is less emissions-efficient in terms of output value per unit of GHG emissions, and which faces severe challenges in terms of profitability.

At the same time, the extensive public goods provided through agriculture must be protected, such as land management services. Internalising the significant externalities in the relative incentives facing primary producers – both positive and negative – can safeguard the valuable goods provided by farmers and reduce harmful environmental and other societal impacts. Developing accessible and cost-effective farm-level emissions and carbon sequestration measurement tools – to operate within a robust Monitoring, Reporting and Verification (MRV) framework – can therefore aid the socio-economic and environmental sustainability of the sector in the medium- to long-term. The policy context and technological capacity are quickly evolving and there is a need to adapt to emerging developments, such as research developments on climate-neutral farming and demonstration developments on biorefining[58]. Significant sector exit would be difficult to reverse, and could have implications for land use and social outcomes.

Ultimately, the effects of the transition will likely be determined by the scale of climate action ambitions; the speed of development of further technical mitigation options; the extent of changes in consumption and production during the transition; the distribution of abatement burdens between systems within the agriculture sector; the policy context; and exogenous factors such as wider domestic economic development and world market (price) developments. Safeguards to protect household income and wider rural development may therefore be required – as well as capitalising on the opportunities to generate greater social, economic and environmental sustainability within the sector – to minimise any potential negative socio-economic effects of the transition. With appropriate safeguards and measures which enable agri-food producers and supply chains to transition to more sustainable systems, economic outcomes can be protected while ensuring national climate action targets are met in the coming years. Further evaluations will be required as socio-economic conditions; mitigation action availability and uptake levels; climate ambition; adaptation planning; diversification opportunities; and scientific knowledge develop.

Following from this, there are five recommendations which could be considered to ensure the sector – and the (largely rural) communities in which it is embedded – can transition in a fair, effective and efficient manner:

4.1 Recommendations

1. Ongoing review of transition implications to meet policy objectives and to adapt to scientific developments as they materialise – particularly around feed additives, genetics and management practices.

2. Adopt a holistic and integrated Natural Capital and Sustainable Circular Bioeconomy framework to shape incentives and innovation toward maximising co-benefits for biodiversity, water quality and other eco-system services. Cooperative approaches could align natural capital, primary production and circular bioeconomy value chains for the sustainable mobilisation and valorisation of bioresources.

3. Continued research into the wider socio-economic value of agricultural production on issues such as employment, household income, wellbeing and rural development. Further insights into behavioural factors that influence decision-making will inform policy making to facilitate transition.

4. Further develop transition opportunities to create effective incentives for diversification – that balance the three pillars of sustainability – whilst offering farmers sufficient reward for implementing actions to enhance ecosystem services and provide additional public goods.

5. Implement sectoral plans under the Food Vision 2030 framework to ensure a more sustainable environmental footprint for the beef and dairy sectors in particular. By co-designing measures with stakeholders through a collaborative process, the transition can be managed in a solutions-focused manner.

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[58] Farm Zero C - Carbery; www.biorefineryglas.eu

Appendix One: Scenarios in 2016 Joint Research Centre Economic Impact Assessment of Agricultural GHG Emissions Mitigation[59]

Scenario Name	Scenario description
Reference Scenario (REF)	- No specific mitigation target for EU-28 agriculture - No subsidy for the application of mitigation technologies - 'Restricted' potential of the mitigation technologies
Non-subsidised Voluntary Adoption of Technologies (HET20)	- Compulsory 20% mitigation target for EU-28 agriculture, allocated to MS according to cost-effectiveness - No subsidy for the application of mitigation technologies - 'Restricted' potential of the mitigation technologies
Subsidised Voluntary Adoption of Technologies (SUB80V_20)	- Compulsory 20% mitigation target for EU-28 agriculture, allocated to MS according to cost-effectiveness - 80% subsidy for the voluntary application of all mitigation technologies - 'Restricted' potential of the mitigation technologies
Subsidised Mandatory/Voluntary Adoption of Technologies (SUB80O_20)	- Compulsory 20% mitigation target for EU-28 agriculture, allocated to MS according to cost-effectiveness - 80% subsidy for the mandatory application of selected* mitigation technologies - 80% subsidy for the voluntary application of the remaining mitigation technologies - 'Restricted' potential of the mitigation technologies
Subsidised Voluntary Adoption of Technologies (with more rapid technological development) (SUB80V_20TD)	- Compulsory 20% mitigation target for EU-28 agriculture, allocated to MS according to cost-effectiveness - 80% subsidy for the voluntary application of all mitigation technologies - 'Unrestricted' potential of the mitigation technologies (i.e. more rapid technological development)
Complementary scenarios	
HET15, HET25	- As HET20, but with a compulsory 15% and 25% mitigation target for EU-28 agriculture, respectively, allocated to MS according to cost-effectiveness
SUB80V_15	- As SUB80V_20, but with a compulsory 15% mitigation target for EU-28 agriculture, allocated to MS according to cost-effectiveness
Subsidised Voluntary Adoption of Technologies, No Mitigation Target (SUB80V_noT)	- No specific mitigation target for EU-28 agriculture - 80% subsidy for the voluntary application of all mitigation technologies - 'Restricted' potential of the mitigation technologies
* Anaerobic digestion, VRT, increasing legume share in temporary grassland.	

[59] Domínguez, I.P. et al (2018) *An Economic Assessment of GHG mitigation policy options for EU agriculture*. EU Commission JRC. Table Five, p.53

Appendix Two: Ratio of GHG Emissions per Dairy to Suckler Cow per annum using Different IPCC Assessment Report Methane Carbon Equivalence Factors

The below tables use EPA National Inventory Report data on kilograms of methane (CH4) emissions per cow per year in 2020, converted to tonnes of carbon equivalent emissions using equivalence factors used in IPCC Assessment Reports Four, Five and Six[60]. This shows that the emissions of two dairy cows is approx. equivalent to three suckler cows, with total enteric fermentation and manure management emissions 64% greater per head among dairy cows compared to sucklers. Given this, the pace of change in dairy and other cows in recent years has led to an elevated emissions level when compared to the pre-quotas period. Equally, this also shows the difference in Global Warming Potential (as measured in carbon equivalents) estimated using a 20- or 100-year timeframe due to the potent nature of methane in the short-term compared to when its warming potential is considered using a longer life-cycle. It should be noted that the emissions factor for dairy cows is anticipated to increase due to a maturing herd, with the composition of the dairy cow population shifting toward higher bands over time.

1) Enteric Fermentation

KG CO2e per Year by Cow Type	Kilograms of CH4 (EPA NIR 2022 Table 5.4)	100-Year GWP Tonnes of CO2e			20-Year GWP Tonnes of CO2e		
IPCC Factor		*AR4*	*AR5*	*AR6*	*AR4*	*AR5*	*AR6*
Dairy Cow	122.21	3,055	3,422	3,324	8,799	10,266	9,875
Suckler	73.66	1,842	2,062	2,004	5,304	6,187	5,952
Ratio	*1.66*	*1.66*	*1.66*	*1.66*	*1.66*	*1.66*	*1.66*

2) Manure Management

KG CO2e per Year by Cow Type	Kilograms of CH4 (EPA NIR 2022 Table 5.5)	100-Year GWP Tonnes of CO2e			20-Year GWP Tonnes of CO2e		
IPCC Factor		*AR4*	*AR5*	*AR6*	*AR4*	*AR5*	*AR6*
Dairy Cow	11.40	0.29	0.32	0.31	0.82	0.96	0.92
Suckler	7.61	0.19	0.21	0.21	0.55	0.64	0.61
Ratio	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*

3) Sum of Enteric Fermentation and Manure Management

KG CO2e per Year by Cow Type	Kilograms of CH4	100-Year GWP Tonnes of CO2e			20-Year GWP Tonnes of CO2e		
IPCC Factor		*AR4*	*AR5*	*AR6*	*AR4*	*AR5*	*AR6*
Dairy Cow	133.61	3.34	3.74	3.63	9.62	11.22	10.80
Suckler	81.27	2.03	2.28	2.21	5.85	6.83	6.57
Ratio	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*

Below, the carbon equivalence factors for methane used for these estimates – by IPCC AR and time-frame – are given, indicating the warming potential of one unit of methane relative to one unit of carbon.

Timeframe	AR4	AR5	AR6
20-Year GWP	25	28	27.2
100-Year GWP	72	84	80.8

[60] AR6 methane conversion factor uses the *Non-Fossil Origin CH4* factor used in the latest IPCC report, to reflect the different behaviours of biogenic and fossil-based methane in terms of Global Warming Potential.

Appendix Three: Overview of Other Considerations

This appendix provides an overview of the existing evidence on further considerations around the transition toward a low carbon agriculture sector. These issues will also be important to consider in planning the transition, but were beyond the scope of this analysis. This includes: Carbon Leakage and Price Inflation; Mitigation Technologies in Development and Difficulties in Reversing Sector Shrinkage; Measurement of the Warming Potential of non-CO2 Greenhouse Gas Emissions; Abatement Distribution Mechanisms; Land Use Effects; Just Transition; and non-Monetary Factors which can Influence Decision-Making.

A3.1 Carbon Leakage and Price Inflation

Delivering gross emissions reductions may not translate to proportionate reductions in net global emissions due to the risk of carbon leakage. This can be defined as the transfer of production from a relatively emissions-efficient region to a less emissions-efficient producer abroad, due to differences in climate ambition or capacity, or the stringency of environmental protection regulations in respective jurisdictions. This is relevant to Irish agriculture, as grass-based Irish dairy and meat production are considered among the most emissions-efficient in the EU[61]; while OECD-FAO projections estimate relatively sustained Global demand for EU beef and dairy produce to 2031[62].

There is uncertainty around the extent of the risk of carbon leakage, as it would depend on the dynamic context, however increased net emissions at a Global level are unlikely, particularly if producers in countries implementing mitigation policies have access to abatement technologies or if regions with similar emissions efficiency can replace foregone supply capacity. The level of carbon leakage (and adverse effects for the export market competitiveness of domestic producers) depends on the scale of emissions mitigation and/or taxation; the availability & accessibility of abatement technologies; and the composition and number of countries implementing the mitigation policy[63]. Studies to date have estimated that a net increase in emissions due to carbon leakage is unlikely, and is more likely to dilute the net effect of gross emissions reductions – although estimates vary within a wide range of net effects dependent on the context in which these reductions materialise; equally, leakage risks can be reduced through consumption incentives and reduced food waste by lowering the need for imports to replace foregone domestic production[64].

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[61] EU Commission Joint Research Centre (JRC) (2010) *Evaluation of the livestock sector's contribution to EU Greenhouse Gas emissions* placed Irish milk as the second-lowest emissions per KG in the EU, while Irish beef had the fifth-lowest emissions per KG. It should be noted this analysis relates to 2004 data, however Ireland's predominantly grass-based production systems are cited as a comparative advantage for emissions efficiency per unit of output. Updated research is needed in this area, however.

For example, the 2021 NFS Sustainability Report estimates that beef production emits 12 KG agricultural CO2eq (AR5) per KG live-weight beef, while this figure is 9.9 KG CO2eq among the most profitable third of Cattle farms; for context, Poore, J. and Nemecek, T. (2018) – *Reducing food's environmental impacts through producers and consumers* in Science, Vol. 360, Issue 6392, pp. 987-992 – estimate that nine KG CO2eq (AR4) per KG beef represented the 10th percentile of Global beef production emissions efficiency, and the global average is 100 KG CO2eq per KG of beef produced from a beef herd.

The KG agricultural CO2eq emitted per KG of Fat- and Protein-Corrected Milk (FPCM) is estimated at 0.85 using the IPCC methodology, according to the 2021 NFS Sustainability Report; this rises to 1.05 under a full life-cycle assessment (LCA) by Teagasc. These figures are lower again among the top third of most profitable dairy farms. This would likely place Ireland among the most emissions-efficient milk producing countries Globally, and is less than half the Global LCA average of > 2 estimated by the FAO.

This leaves Irish producers well-placed to compete on the basis of verifiable relative sustainability for these products, for which demand is projected to continue, and provides a strong basis from which to develop sustainability further.

[62] OECD-FAO (2022) Agricultural Outlook 2022-2031

[63] Henderson, B. and Verma, M. (2021) *Global Assessment Of The Carbon Leakage Implications Of Carbon Taxes On Agricultural Emissions.* OECD Food, Agriculture and Fisheries Paper No. 170. OECD Trade and Agriculture Directorate.

[64] EU Joint Research Centre (2021) *Modelling Environmental and Climate Ambition in the Agricultural Sector with the CAPRI Model.*

More contemporary and comparable data across the EU would be required to fully assess this risk, and the risk would also depend on international policies. For example, if Irish agricultural emissions were unilaterally reduced – compared to a scenario in which each EU Member State would collectively reduce their agricultural emissions by a given amount – the risk of carbon leakage could be lesser. This is because Irish production comprises a relatively small proportion of aggregate EU beef and dairy supply, and it is likely that production could transfer to another territory with similar carbon efficiency of production rather than to a third country in a relatively emissions-inefficient production region, with limited scope for carbon leakage from intra-EU transfers in particular. The higher proportion of national emissions contributed by the primary sector in Ireland, compared to the EU norm, creates greater pressure for mitigation in Irish agriculture in the context of relative Emissions Sharing Regulation (ESR) statutory commitments. Similarly, if other countries are to face similar pressures to reduce emissions, this would lessen the leakage risk.

Studies to date[65] suggest that carbon pricing policies implemented by a single country or small group of countries reduce global emissions, but also affect the international competitiveness of these countries' agricultural sectors and induce carbon leakage to a varying extent:

- While carbon leakage can be somewhat mitigated with trade-related measures that adjust emissions prices at the border, such measures applied in developed countries could potentially lead to welfare losses for developing countries that rely on agricultural exports and would create significant transaction costs.
- The ranges for estimated carbon leakage vary considerably due to uncertainties around relative emissions efficiency levels and the extent to which domestic production can be replaced in other territories.
- Further, the unilateral implementation of a carbon tax in agriculture has been shown to reduce the competitiveness of the implementing countries, as compliance costs reduce net exports and impose economic welfare losses on domestic producers. This finding seems to be especially relevant to the livestock sector, which has higher emission intensities compared to other agricultural products.

Consumer taxes have been shown to be potentially effective in supplementing supply-side emissions mitigation policies. They can be effective in limiting leakage when applied to both domestic and imported food products. Findings suggest, however, that they do not provide producers with the same level of incentives for adopting abating practices as producer-based taxes. Moreover, consumer taxes translating into higher prices for such products are likely to disproportionately affect low-income households, which raises equity issues. Also given that the majority of Irish agri-food produce is exported, the consumers in question would be from other countries, so policy action would need to at the supranational level.

Similarly, funds which are currently allocated through subsidies could be reoriented to address environmental externalities and improve economic welfare. This, in contrast to carbon taxes, could both preserve domestic comparative advantage and prevent carbon leakage in the implementing countries, but existing evidence shows that these abatement payments are less effective in reducing non-CO2 emissions compared to GHG taxes and could transfer significant economic surplus from consumers to producers.

The literature also highlights the potential for multilateral policy co-ordination and for trade-related conditions on importers to minimise the competition and leakage effects. Similarly – as acknowledged in Food Vision 2030 – reputational benefits from evidenced sustainability could lead to price premia for producers and exporters, as consumers are willing to pay a higher price, and could and create market access opportunities[66]. This may compensate for some of the adverse carbon leakage and competitiveness effects induced by domestic emissions mitigation.

[65] Arvanitopoulos, T., Garsous, G. and Agnolucci, P. (2021) *Carbon Leakage and Agriculture: A Literature Review on Emissions Mitigation Policies.* OECD Food, Agriculture and Fisheries Paper No. 169. OECD Trade and Agriculture Directorate.
[66] Henderson, B. and Verma, M. (2021) *Global Assessment Of The Carbon Leakage Implications Of Carbon Taxes On Agricultural Emissions.* OECD Food, Agriculture and Fisheries Paper No. 170. OECD Trade and Agriculture Directorate.

A 2016 EU Commission Assessment concluded an overall 20% reduction in agricultural emissions shared amongst the (then) EU-28 using aggregate least-cost abatement would result in carbon leakage in the absence of changes in meat and dairy consumption patterns, but did not result in net Global leakage under any of the scenarios examined[67]. The level of gross leakage varied significantly by scenario, however, depending on how much of the abatement burden is allocated to production or technical mitigation measures[68]. Subsidising mitigation technologies would minimise both carbon leakage and direct economic losses to producers by limiting the need for reductions in production. Reductions in production at the aggregate level would, however, transfer welfare from consumer to producer economic surplus through greater domestic food scarcity and higher food prices. The development of effective mitigation technologies could therefore alleviate carbon leakage and consumer food price inflation risks. Mitigation subsidies would similarly reduce carbon leakage risks and limit direct economic losses for primary producers as mitigation technologies/subsidies would increase production capacity for a given level of GHG emissions. Any policy which would affect production levels would need to be cognisant of potential food insecurity risks, particularly abroad.

Under the EU Commission assessment, net mitigation was assessed to be highest when mitigation technologies developed more rapidly than anticipated, while it was lowest when higher reductions in the quantity of production were required to achieve the target reductions in emissions. Carbon leakage was estimated at 23/29/35% for the 15/20/25% mitigation scenarios, respectively. EU producer prices for beef (dairy) change by +11% to +26% (-3% to +12%) depending on the scenario – which, it could be assumed, would transfer at least in part, to consumer prices. The development of cost-effective mitigation technologies is therefore imperative and domestic policy should be cognisant of these economic and environmental risks, however further research is required in this area and the level of risk will depend on the wider context in Europe and beyond. These are, therefore, risks to be monitored and do not reduce the need for mitigation; instead, safeguards should be applied to limit carbon leakage and economic harm.

A3.2 Mitigation Technologies in Development

Global research is currently underway into technical mitigation measures which could significantly lower the emissions intensity of ruminant livestock – for example, feed additives such as 3-nitrooxypropanol ('3-NOP'), as well as animal breeding initiatives to improve animal efficiency performance[69]. DAFM are co-funding transnational projects through the ERA-NET Cofund, FACCE ERA-GAS, which was initiated by the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI)[70]. The capacity to roll out novel innovations at scale – such as feed additives – is currently uncertain, however, and their commercial viability is not yet known[71]; similarly, the animal health impacts must be central. The Climate Action Plan 2021 commits to funding a research programme to bring new technologies and feed additives on-stream in the medium term.

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[67] Domínguez, I.P. et al (2018) *An Economic Assessment of GHG mitigation policy options for EU agriculture*. EU Commission JRC.

[68] A table outlining the scenarios examined in the 2016 assessment is available in Appendix A of this report.

[69] Teagasc (2020) *Methane Production: How can we reduce it?.*

3-NOP, branded as 'Bovaer', has received a positive assessment from the European Food Safety Authority for use in dairy cows, indicating the ruminant methane-inhibitor is effective and safe for both animals and consumers. The Dutch company DSM produces Bovaer and claims the feed additive can reduce methane emissions by 20% to 35% in dairy cows and up to 90% in beef cows without affecting production in non-pasture based systems; trials are ongoing to assess whether such mitigation is replicable at pasture. The product received market authorisation from the EU Commission in March 2022; the Teagasc note on Carbon Budgets (2021), p.34, suggests the variant which is being developed for use in pasture-based systems could be available within two years, although its mitigation potential in an Irish agricultural context is yet to be determined.

[70] Examples of projects co-funded by Ireland under ERA-GAS and which include Irish researchers from Teagasc include **RumenPredict**, **SeaSolutions** and **METHLAB**, which are seeking to identify methane-mitigating practices and breeding selection.

[71] Teagasc researchers are evaluating dietary supplements at present – particularly seaweed and extracts – to suppress methane in sheep and cattle rumen as part of Seasolutions, a multinational EU-Canadian collaborative project studying rumen microbiota.

Similarly, it could also be challenging to reverse any shrinkage in the sector in terms of the numbers of cattle and/or farms – alongside changes to the structure of farming, secondary output capacity and secondary employment. Significant reductions in cattle numbers under heightened climate ambitions risks the loss of cumulative genetic efficiency gains made over time from animals removed, and a lower aggregate mitigation potential due to a lower number of animals retained within the national herd. However, improvements in the mitigation potential of animals retained would be expected to continue. It is therefore important to exhaust technical mitigation measures, such as efficiency improvements, before production is constrained due to the significant socio-economic implications and possible unintended effects which may arise from reducing the scale of the sector.

A3.3 Measurement of the Warming Effects of non-CO2 Greenhouse Gas Emissions

Emissions of different GHGs that are harmonised under the Carbon Equivalent (CO2e) metric behave significantly differently to one another. Methane molecules, for instance, are cycled out of the atmosphere after approximately 9-12 years, while stock pollutants such as carbon dioxide have effectively permanent impacts (due to their persistence over very long time horizons – i.e. a near-permanent residual environmental impact). However, methane is relatively more efficient in trapping heat via radiative forcing and is therefore a more potent GHG in the short-term per molecule; each kg emitted has a global warming potential effect over 100 years (GWP100) 28 times greater than each kg of CO2 emitted, or 84 times that of CO2 over 20 years.

There is a recognition of the distinction between the effects of the following in terms of their effects on the climate in terms of warming impacts:

a) Short-Lived Climate Pollutants (flow pollutants, such as methane); and
b) Long-Lived Climate Pollutants (stock pollutants, such as carbon dioxide).

The key issue for climate change and halting atmospheric warming is reaching net-zero stock (e.g. CO2) emissions – i.e. emissions are at least balanced and matched by removals – and declining emissions from flow (e.g. CH_4, N_2O) pollutants. This has been recognised by the IPCC in 2018, stating *"reaching and sustaining net-zero anthropogenic CO2 emissions and declining net non-CO2 radiative forcing*[72] *would halt global warming"*[73]. Climate modelling at the Global level suggests biogenic methane reductions of 24-47% – compared to 2010 – are sufficient to achieve climate stabilisation at a Global Mean Surface Temperature 1.5 Degrees Celsius above pre-industrial levels[74]; however, current modelling also suggests that Global methane emissions are projected to increase by this same range (24-47%) by 2050[75]. While the distinctive characteristics of biogenic methane have been recognised, the gas remains highly effective in terms of trapping heat, therefore consistent growth in methane emissions has a very significant Global warming effect. As such, it is important to emphasise that methane emissions must stabilise and reduce.

The Climate Change Advisory Council (CCAC) has raised imperfections around the use of the Global Warming Potential (GWP) of methane over the standard 100-year timeframe (i.e. GWP^{100}) as under IPCC methodology for national emissions inventory reporting[76]. The CCAC has recognised the difficulties in characterising methane's impact on warming relative to other GHGs under the standardised methodology: *"Treating short-lived climate pollutants (SLCPs) such as methane as carbon-dioxide equivalent (Co2e) using* GWP^{100} *misrepresents their impact on Global Mean Surface*

[72] Methane is considered a non-Co2 radiative forcing gas, i.e. it is very efficient in capturing heat.
[73] IPCC 2018 *Special Report on 1.5 Degrees Celsius*
[74] Rogelj et al. (2018) *Scenarios towards limiting global mean temperature increase below 1.5 C* in Nature Climate Change, Vol. 8, Issue 4, pp. 325-332.
[75] Harmsen et al (2020) *The role of methane in future climate strategies: mitigation potentials and climate impacts* in Climate Change, Vol. 163, pp. 1409-1425.
[76] Emmet-Booth, J., Dekker, S. and O'Brien, P. (2019) *CCAC Working Paper on Climate Change Mitigation and the Irish Agriculture and Land Use Sector*

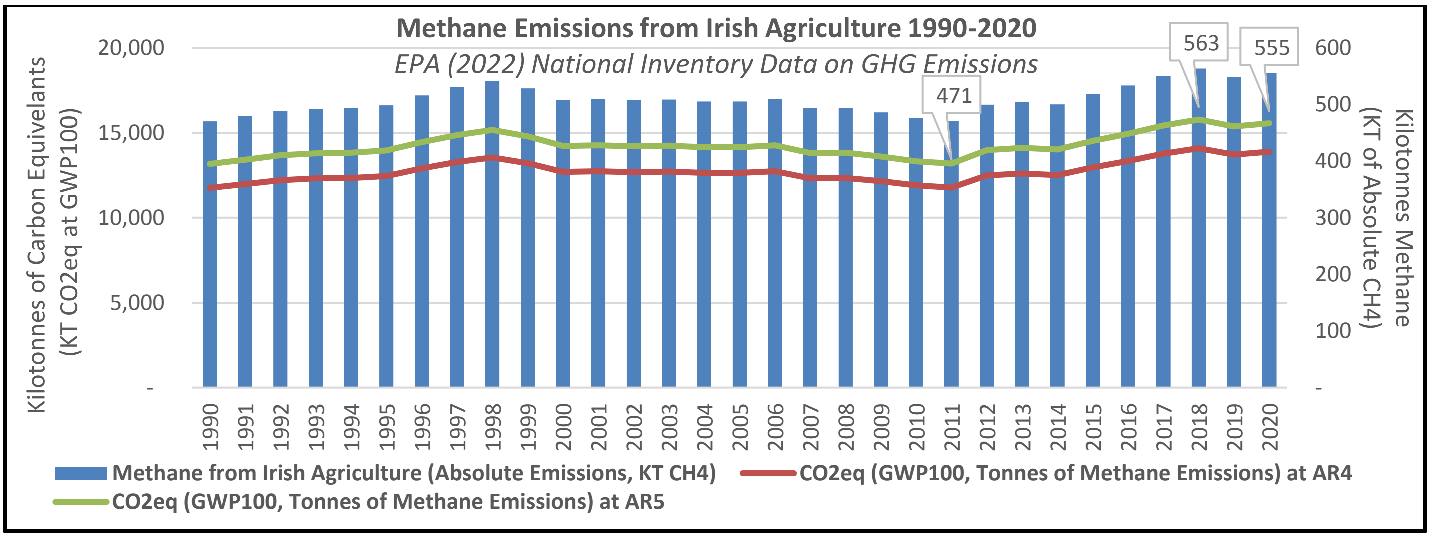
Temperature (GMSP)". Using this metric underestimates the short-term impacts of methane and overestimates its long-term impacts. This is because the 100-year timeframe is used for its good fit for the long-range impacts of carbon dioxide emissions, which is the reference unit for CO2e. This becomes especially challenging in the Irish context due to the much larger proportion of emissions contributed by methane.

The CCAC point to a modified (aggregated) measure which better reflects the distinct behaviour of methane relative to other GHGs, namely GWP*.[77] Using GWP* increases the multiplier factor from c. 28 under GWP^{100} to 84 under GWP*, but reduces the life-cycle reference period from 100 years to a 12-year half-cycle. Under GWP*, measurement is focused on the change in the *rate* of methane emissions, magnifying the relative warming effect from contemporary changes in methane emissions.

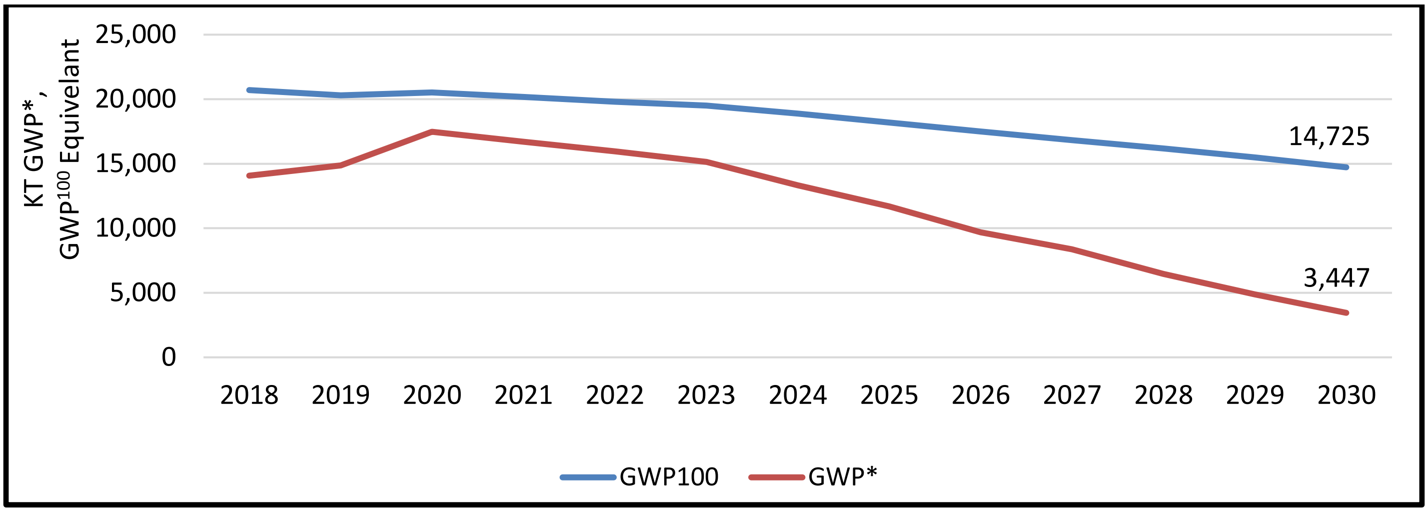
It is important to note that any changes in the method of accounting for methane's global warming effect would not alter the need for reductions in agricultural emissions in Ireland, but emissions levels would be more sensitive to recent/contemporary changes in activity levels.

The nuance around methane measurement is significant in the Irish context because agriculture accounts for a high share of national non-ETS emissions and is responsible for approximately 93% of methane emissions domestically. The distinctive characteristics of biogenic methane have been recognised in the Climate Action and Low Carbon Development Act, while Food Vision 2030 outlines a minimum 10% reduction target for biogenic methane by 2030. Ireland's statutory emissions reductions targets use the standard IPCC methodology for emissions reporting (GWP100), and any changes in measurement would require approval in an international forum. Equally, the derivation of national biogenic methane targets is technically challenging – with implications for international equity in sharing mitigation burdens or national methane budgets/quotas among countries.

In the first chart on the following page, Teagasc estimates compare GWP* to GWP^{100} for scenario D, indicating total emissions c. 77% (11.28 MT) lower at 2030 under GWP* than GWP^{100}. This is a function of the relatively rapid reduction in agricultural emissions under this scenario, as GWP* emphasises the rate of change. While it is possible that 'negative' emissions (effectively cooling) can arise from rapid CH4 reductions in the short term under GWP*, where emissions fall consistently, the climate will eventually tend back toward zero (neutral) emissions as it adapts to lower concentrations of methane. Equally, elevated agricultural emissions in Ireland in recent years would have contributed very significant warming under this metric, with Irish agriculture emissions of methane in 2020 18% above their recent lowest point in 2011. Note that AR5 uses a higher carbon-equivalence factor than AR4 for methane, but lower for N_2O.



[77] Allen, M. et al (2018) *A Solution to the misrepresentation of Co2e emissions of short-lived climate pollutants under ambitious mitigation* in Climate and Atmospheric Science, Issue 1.



Total GHG Emissions (KT Equivalent) under GWP* vs. GWP100: Teagasc FAPRI Analysis Scenario D. Source: Teagasc.

It should also be noted that recent expansions in dairy cows and milk production would have resulted in a more significant increase in emissions under GWP* than would be reflected under GWP^{100}. This is evidenced in the graph below of the measurement of methane under these two indicators over 2010-2020. This illustrates the brief period of climate-cooling effect which would be measured under GWP*, during the period of reduced economic activity around 2008-2011, followed by a sustained period of climate-warming effects since.

Comparison of Methane emissions calculated using GWP^{100} and GWP* (2010-2020). Source: Climate Change Advisory Council (2021) *Technical Report on Carbon Budgets*, p.82, Figure 5-2 (b).

A3.4 Abatement Distribution Mechanisms

If reductions in production were required – as seen in scenarios B-E in the Teagasc FAPRI analysis – specific mechanisms would be required to achieve such changes in economic behaviour to achieve emissions reductions. Mechanisms would vary in terms of the administrative and regulatory burden associated with them, as well as the possible secondary effects they could induce as farmers and suppliers respond to changes in the relative incentives they face. If reductions in production are required, therefore, consideration would need to be given to the type of mechanism which could distribute abatement burdens in a fair and efficient manner. Policymakers may need to be cognisant of the likely trade-offs between such mechanisms and the implications of choices between options. Further, it would be important to put in place safeguards to account for exceptional circumstances, for example through the establishment of a National Reserve of emission permits/rights to enable new entrants into the sector.

Placing a cap on production or livestock numbers, possibly based on a historical reference period (grandfathered basis) to protect farmers who have invested in their holdings in recent years, could support the sector in meeting its Climate

Action Plan targets by regulating emissions output. A Quota System would allocate production permits to producers to limit production or livestock numbers at an aggregate level, where the ceiling could be progressively reduced over time if required. This would be administratively simpler, given the evidence base of the DAFM Animal Identification and Movement (AIM) tracing system. However, it could lead to larger abatement among relatively emissions efficient producers than would be realised under least-cost abatement unless the quota was tradeable, in which case it could lead to a least costs outcome. A quota could also lead to significant unintended consequences on environmental and/or animal welfare outcomes; for example, a limit on livestock numbers could induce producers to attempt to increase the output (yield) per livestock unit, which in turn could increase emissions intensity and place strain on animals. Limiting production output could lead to a significant regulatory burden of controls and would be less efficient than a model which would use market-based incentives, although it would reduce negative externalities.

Alternatively, a Cap-and-Trade system would allocate emissions permits to either a farmer or industrial processor, but would enable producers and/or processors to trade within an overall emissions limit. Such a mechanism would be economically efficient as it would incentivise least-cost abatement, meaning the 'polluter pays' principle would be upheld and those with the lowest economic emissions efficiency would be most likely to reduce production due to lower direct abatement costs. This could have the effect of a transfer of production to relatively efficient producers while maintaining overall emissions within a sectoral carbon budget. This would not, however, account for secondary socio-economic effects, particularly in terms of leading to a greater concentration of agricultural output in the dairy sector due to its relatively higher economic returns; such a concentration could also have localised environmental implications, particularly for water quality, if appropriate safeguards were not implemented. The low direct cost of abatement in the beef sector would, in particular, likely result in significant reductions in specialist cattle farming – which would have multiplier (knock-on) effects for cattle-reliant farming households and wider rural development. It is uncertain whether this would translate to fewer or smaller farms – although the numerous cattle farms and their generally small size at present suggests downsizing is less likely than sector exit or transfer to other production systems[78] if the cattle population were to reduce – however the effects would be likely to be significant in aggregate terms and be spatially concentrated, reflecting the regional distribution of specialist systems. Equally, a Cap & Trade mechanism would require farm- or processor-level data to monitor, report and verify emissions (i.e. transaction costs) which could be substantial at the outset; although such costs could reduce over time as systems are established, technologies improve and those involved learn and become more familiar with the processes.

Equally, a Cap and Trade model could hold the potential for offsetting the farm-level costs of emissions accounting or carbon levies at the holding level, through income diversification from payments for carbon farming activities and other ecosystems services (public goods). This would arise due to the changed incentives landscape, compared to the current production incentives generated by existing agricultural commodity market signals. Co-benefits for water/air quality and biodiversity could also flow from such actions, due to additional climate actions generated from these new incentives. Such an approach could possibly enable recognition of individuals' climate actions and be translatable to the National Inventory. This would, however, require careful management to guard against unintended consequences or deadweight loss from poorly designed incentive structures, for example restrictions which would prevent the purchase of large areas of land for emissions farming purposes.

Fiscal measures and instruments (i.e. taxes and subsidies) could also be used to change relative (dis)incentives to reflect full societal costs and benefits, internalising externalities in the prices (or costs) facing producers and/or consumers. Tax and spend incentives can encourage positive environmental outcomes, as seen in the grant aid provided to primary producers for the purchase of Low Emissions Slurry Spreading (LESS) equipment through the

[78] It is possible some farms could change their production system, such as moving to dairy-beef systems or sheep enterprises, although the emissions savings from ceasing cattle production would be at least partially offset by such a move.

Targeted Agricultural Modernisation Scheme (TAMS)[79]. There could also be alternative ways to reorientate subsidy supports in order to incentivise actions which reduce negative environmental externalities – such as reduced water quality, biodiversity loss and GHG or ammonia emissions. The Dasgupta Review[80] cites agriculture, among other sectors, as receiving public subsidies which create perverse production incentives leading to the avoidable degradation of natural capital, translating to significant cumulative societal costs over time. Carbon taxation (levies) and congestion charges are examples of effective Pigouvian taxation (i.e. fiscal incentives) which have been implemented to date in some countries; if a social cost of environmental damage is internalised by markets, decision-makers can balance environmental and economic impacts from consumption/production to reflect societal priorities if externalities were to be priced appropriately. Such measures can, however, be regressive and could reduce the provision of other public goods such as food security and rural sustainability; equally, it is challenging to price externalities appropriately and such interventions could create distortionary incentives which could lead to perverse outcomes. They may therefore require revenue recycling or other mechanisms to ensure they are effective and equitable.

A3.5 Induced Changes in Land Use

If economic returns in the primary sector are limited, and the wider domestic economy grows at its natural rate, this could incentivise farmers to exit the sector or rely to a lesser degree on agricultural income. This would be in favour of stronger ties to the non-agricultural economy in terms of off-farm employment, with significant implications for the shape of the rural economy in general as well as the orientation of local rural economies – particularly those which disproportionately rely on primary production, the servicing of the agriculture sector or ancillary activities. The stability provided by such economic structures, and their endurance to date, could be challenged by changes to production, which may require particular attention to ensure local economies are not destabilised. This could also give rise to risks of land abandonment and the resulting loss of public goods, which are provided by extensive systems in High-Nature Value (HNV) areas – largely in the North and West – in particular. Such land use trends would be driven by both changes in agricultural economic incentives and wider economic development. Conversion of grassland to cropland could be associated with increased land-use emissions due to cultivation, also, while soil type would affect outcomes considerably; as such, the environmental impacts of land use change would depend in part on local conditions.

It should also be borne in mind that the EU Fit for 55 package proposes to change the emissions accounting mechanism applied to the Land Use Land Use Change and Forestry sector in Europe. This accounting change as proposed will mean that the profile of emissions and sequestration for this sector in Ireland will look significantly different than as set out under the current rules. Given the large proportion of land use accruing to agriculture in Ireland, this could have significant implications for the primary sector in the context of Climate Action.

Related to the implications for land use of changes in GHG emissions from the agriculture sector, are the food security implications. This is in the context of the need for the Global food system to address the triple challenge in the coming decades, namely feeding a growing population in an environmentally sustainable way while supporting the livelihoods of producers[81]. The most recent OECD FAO Outlook report[82] estimates that the Global average growth rate of Total Factor Productivity[83] (TFP) would need to triple from its rate over the past decade – or 28% growth in agricultural

[79] As of April 2021, over €40.4m had been paid through the LESS measure in TAMS II, with 7,736 farmers approved to purchase machinery through the scheme. Parliamentary Question 21345/21 to Minister Charlie McConalogue, 28.04/2021.

[80] Dasgupta, P. (2021) *The Economics of Biodiversity: The Dasgupta Review.* UK*:* HM Treasury

[81] The Triple Challenge, as it is termed by the OECD, refers to the need for the Global food system to ensure food security and sufficient nutrition for a growing population in the coming decades, and supporting the livelihoods of those working in the food supply chain, while doing so in an environmentally sustainable way.

[82] OECD-FAO (2022) *Agricultural Outlook 2022-31.*

[83] TFP is a measure of the relative efficiency of agricultural output, with increases over time implying more food can be produced with fewer resources/inputs, with positive implications for the emissions efficiency of agricultural production from TFP growth.

productivity on average by the end of the coming ten-year period – to meet UN Sustainable Development Goal 2 (zero hunger, food security and improved nutrition) while facilitating a 6% reduction in GHG emissions from the AFLOU sector under the scenario examined. This illustrates the scale of the challenge to maintain or enhance Ireland's contribution to global food security, whilst meeting GHG emissions reduction targets.

A3.6 Just Transition

Just Transition can be broadly defined as taking *"steps to ensure the benefits of climate action are felt widely, while the costs do not unfairly burden those least able to pay"*[84]. Delivering a Just Transition is based on recognising the significant level of change required, ensuring burdens and opportunities are fairly distributed, and that no member of society is left behind. While the transition to a low-carbon future requires collective action, it is important to recognise that certain groups may need more targeted support to adapt due to social, economic, infrastructural or environmental factors. This may be particularly true for rural communities which are not in close proximity to large urban settlements where alternative economic opportunities may be more limited. The fiscal implications of a Just Transition will depend on its scope in terms of investment, funding and other supports put in place to assist those most affected.

Stakeholders need supports to become resilient to shifting industry practices through appropriate up-skilling, re-skilling, and education. The innate ties to nature in the Irish Agri-Food sector, and exposure to climate change risks, means a sustainable transition will be crucial for the future of the sector. Just Transition recognises farmers as part of the solution as custodians of the land, and for the Irish Agri-Food sector, a Just Transition will entail building socio-economic resilience through diversification; creating climate resilience through sectoral adaptation; and ensuring the dissemination of knowledge and uptake of best practices. A Just Transition should acknowledge that effects are likely to be locally concentrated and disproportionately affect certain communities, meaning targeted measures may be required in response to emergent challenges. Further, consensus-building and participatory frameworks which are inclusive of all stakeholders can support the delivery of a Just Transition in the agriculture sector. Climate Action Plan 2021, CAP Strategic Plan 2021 and the EU Green Deal incorporate the principles of Just Transition into their frameworks and proposed actions, with several measures relevant to agriculture:

- Development of the Agricultural Knowledge & Innovation System under the CAP Strategic Plan;
- Investment in renewable energies to transform energy generation and usage, including on-farm energy generation as well as Investment in infrastructure in areas such as transport and flood defences;
- Focusing on sustainable and circular bioeconomy – emphasising principles of sustainability, cascading use, 'food-first' and precaution – for opportunities to add to biobased systems, business models and value chains;
- Establishing public consultations to shape policies and ensure policy efficacy through better scheme design and high scheme participation rates; and
- Competition policy reforms to support sustainable, local and environmentally conscious producers to compete, with producer prices reflecting these efforts.

A3.7 Non-Monetary Factors which can Influence Decision-Making

Further to the economic incentives which shape decision-making at farm and enterprise levels, socio-cultural factors will also shape behavioural responses during the transition to a low-carbon agriculture sector. In particular, it should be acknowledged that value, beyond monetary rewards, is derived from farming – sometimes termed 'non-pecuniary

[84] Scottish Just Transition Commission (2020) *Advice for a Green Recovery.*

benefits'[85] – is a key factor on Irish farms. The non-pecuniary benefits of farming activities may be an impediment to only using fiscal or other economic incentives to shape the transition, as there may be a willingness to continue producing irrespective of the economic viability in some cases, or a lack of willingness to embrace alternative practices such as agro-forestry, even if significant economic signals may incentivise such practices. As such, the level of benefits derived from farming can go beyond the economic performance of the farm, as farmer values, preferences and social norms can also affect their motivations.

As a result, policymaking should take account of such factors and be cognisant of the range of factors influencing the decision-making of stakeholders. Where appropriate, effective communications and Knowledge Transfer could be important to ensure stakeholders receive comprehensive and clear messaging on what practices are sustainable and the social, economic and environmental benefits accompanying them. This could help to overcome reservations among stakeholders as to the practicalities of implementing changes – and assist farmers in taking advantage of what opportunities the transition to a low carbon economy of the future offers. Providing certainty or reducing ambiguity will be important, as will highlighting early adopters or champions of good management practices or mitigation technologies will be helpful to overcome these barriers. Moreover, actions which generate public goods that have objective, visible and local benefits could be emphasised, as farmers likely value the sense of appreciation from their peers in the community if wider benefits – in air/water quality or biodiversity, for example – arise from their climate actions.

Related to this, it will also be important to support technology adoption by ensuring producers have access to new innovations as they come on-stream in the coming years. This could involve support for individual skills and knowledge; addressing wider social norms; the appropriate design of governance rules and regulation; shaping finance signals through (dis) incentives; the provision of supporting physical infrastructure; and stakeholder engagement and awareness.

A3.8 The Role of Demand-Side Factors

While this report has focused on supply-side considerations around the transition, given Ireland is a net exporter of agri-food, it is also important to focus on demand-side factors as part of a food systems approach – particularly in light of the need to transition to a low carbon agriculture sector.

Recent research has highlighted that supply-side measures will not be sufficient alone for the EU to reach its Green Deal targets relevant to food systems transformation; and demand-side changes will be required, otherwise there is a risk that environmental pressures could be aggravated in the absence of shifts in consumption (diets and/or food waste)[86]. This is in order to guide European food systems toward greater holistic sustainability in a socio-economically efficient and fair manner, while maintaining food security and limiting environmental pressures. The need for changes in demand (i.e. preferences) is illustrated by modelling which has examined the implementation of agro-ecological practices, which would see considerable changes in farm practices – such as leguminous crops grown to replace synthetic fertilisers; the integration of crops and livestock; low-input management; reliance on local resources; and diversification.

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[85] Howley, P., Dillon, E. and Hennessy, T. (2014) *It's not all about the money: Understanding farmers' labour allocation choices* in Agriculture and Human Values, Vol. 31, pp.261-271.

[86] For example, Billen et al. (2021) *Reshaping the european agro-food system and closing its nitrogen cycle: the potential of combining dietary change, agroecology, and circularity* in One Earth, Vol. 4, Issue 6, pp. 839–850. This research illustrated that implementing agroecological practices, coupled with changes in diets (consumption) can feed the expected European population at 2050, while reducing current Nitrogen losses to the environment by half.

For example, a recent paper[87] found "*large-scale implementation of agroecological practices, without concurrent changes on the demand side, and without regulations in place to prevent land freed up from increases in yield and livestock productivity being used for additional production, environmental pressures could be aggravated".* An alternative scenario is also examined in the paper, in which agro-ecological practices are rolled out on a widespread basis – as part of efforts toward sustainable intensification – alongside drastic food waste reductions and dietary changes (toward greater plant-based diets, in line with the EAT-Lancet reference diet, meaning EU meat consumption would at least halve). The research found that such a scenario "*would allow major improvements in environmental indicators to be achieved*" around climate, biodiversity, ammonia emissions and other outcomes – enabling the EU to reach many of its Green Deal targets for agriculture.

This demonstrates that, at an aggregate level and in an international context, supply-side measures will be necessary but insufficient alone in the absence of concurrent demand-side (food waste and dietary) changes, and have the potential to aggravate environmental pressures. This is due to the greater land use requirements to meet current demand, owing to lower yields under agro-ecological practices, risking greater absolute environmental pressures – including creating additional pressures in third countries in the event that production cannot be sourced within the EU. As such, given the Globally-orientated nature of Irish agri-food and the recent adoption of a sustainable food systems approach, it will be important to ensure demand- and supply-side measures are coherent, compatible and founded around socio-economic conditions. This emphasises the need for a whole-of-system approach to ensure each pillar of sustainability is balanced – economic, social and environmental.

[87] Röös, E. et al (2022) *Agroecological practices in combination with healthy diets can help meet EU food system policy targets* in Science of the Total Environment, Vol. 847, pp.