Achieving greenhouse gas reductions in the Irish dairy sector through carbon pricing: The feasibility of living labs and the attitudes of stakeholders

ACHIEVING GREENHOUSE GAS REDUCTIONS IN THE IRISH DAIRY SECTOR THROUGH CARBON PRICING

The Feasibility of Living Labs and the Attitudes of Stakeholders

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List of Acronyms & Initialisms

AFOLU	*Agriculture, Forestry and Other Land Use*
AKIS	*Agricultural Knowledge and Innovation Systems*
ALL	*Agroecosystem Living Lab*
CAN	*Calcium Ammonium Nitrate*
CSO	*Central Statistics Office*
DAFM	*Department of Agriculture, Food and the Marine*
EBI	*Economic Breeding Index*
EEA	*European Environment Agency*
ENoLL	*European Network of Living Labs*
EPA	*Environmental Protection Agency*
ETS	*Emissions Trading System*
FFI	*Family Farm Income*
GHG	*Greenhouse Gas*
GWP	*Global Warming Potential*
ICBF	*Irish Cattle Breeding Federation*
ICMSA	*Irish Creamery Milk Supplier Association*
IFA	*Irish Farmers' Association*
IPCC	*Intergovernmental Panel on Climate Change*
LESS	*Lower Emission Slurry Spreading*
LULUCF	*Land Use, Land Use Change and Forestry*
MACC	*Marginal Abatement Cost Curve*
NDC	*Nationally Determined Contribution*
NFS	*National Farmer Survey*
ULL	*Urban Living Lab*
UNFCCC	*United Nations Framework Convention on Climate Change*
VCM	*Voluntary Carbon Market*

Declaration of own work

I certify that this thesis is my own work. This work has not previously been used to obtain a degree in the University of Galway or any other university.

Joseph McDonagh

Abstract

The Irish government has committed to a 51% reduction of national greenhouse gas (GHG) emissions by 2030 as compared to 2018, in line with European Union directives, international treaties, and the Climate Action and Low Carbon Development (Amendment) Act of 2021. Given the proportion of Irish GHG emissions originating in the agricultural sector and the difficulties in reducing these emissions to date, new approaches may be required to achieve emissions reduction goals. One potential approach may be the introduction of voluntary carbon markets (VCM). In a VCM participating farmers implement GHG emissions reducing technologies of their choosing on their farms. The GHG emissions reductions achieved can be sold to generate an additional income stream. There is however uncertainty about the feasibility of VCMs due to limited implementation and the complexity of their establishment and operation. Given this complexity, the establishment of a full-scale test VCM would be unrealistic, however, utilizing the Living Labs Framework, a small-scale pilot VCM is feasible. This will provide insight into the feasibility of VCMs, the willingness of farmers to participate, and the demand for carbon credits generated by farmers. This thesis will examine these issues through the lens of the SmartDairy project[1] including its living labs. In addition, interviews conducted among Irish dairy farmers by the SmartDairy team will be examined to assess farmers willingness to engage in VCMs, their thoughts on the potential structures of those VCMs and who they believe should be tasked with organisation and oversight of VCMs.

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1. Introduction

Over time the earth's climate goes through natural changes, with different areas of the planet experiencing shifts in temperature and weather patterns. These regional and global shifts in climate patterns are called climate change and can be influenced by a number of factors. Some of these factors occur naturally, such as terrestrial shifts in ocean currents, plate tectonics, volcanic activity, and vegetation coverage (British Geological Survey, 2024; NASA, 2024). Other natural factors originate in the atmosphere, such as the amount of solar radiation the earth absorbs or reflects. These types of factors change the climate over thousands of years. However, since the mid-19th century and the onset of industrialization, anthropogenic factors have caused climate change to occur at a much faster rate (NASA, 2022). The results of this faster climate change include increased global temperatures and more extreme and variable weather. 2023 is the warmest year on record globally, 1.18°C above the mean temperature of the 20th century, and 1.35°C greater than the mid-19th century average (Lindsey and Dahlman, 2024). This trend is not new, as the 10 warmest years on record have all occurred within the last decade (Lindsey and Dahlman, 2024). The continued impacts of climate change are expected to be widespread and severe, including more frequent and powerful storms, more severe droughts and wildfires, extreme temperature variations, changes in plant and animal habitat, and increased levels of both coastal and river flooding (EPA, 2024c; Lindsey and Dahlman, 2024; United Nations, 2023).

The Intergovernmental Panel on Climate Change (IPCC) found that increased emissions of greenhouse gases (GHGs) from human activities are the largest contributing factor to global warming and climate change (IPCC, 2023). GHG emissions can occur naturally, but the increased levels of anthropogenic GHG emissions from activities like burning fossil fuels has strengthened this effect. Therefore, it is important to understand the role of GHGs in climate change, and how they trap heat in the earth's atmosphere leading to an increase in global temperatures.

There are seven GHGs recognised by the Kyoto Protocol; carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), sulphur hexafluoride (SF_6), hydrofluorocarbons (HCFs), perfluorocarbons (PFCs) and nitrogen trifluoride (NF_3). CO_2, N_2O and CH_4 make up the largest proportion of GHG emissions with the remaining four gases, collectively known as the 'F-gases', responsible for less than 5% of global GHG emissions. In order to compare the environmental impact of different GHGs, a standardised unit of measure was created called carbon dioxide equivalent (CO_2eq). The Global Warming Potential (GWP) of different GHG is used as a conversion factor and takes into account longevity and potency of the GHG over 100 years as compared to the base GHG, CO_2. GWP is used to convert tonnes of any GHG into the equivalent tonnes of CO_2 (CO_2eq) needed to achieve the same environmental effect. In the most recent calculation of GWP, in its Sixth Assessment Report (AR6), the IPCC calculated GWP of 28 and 265 for CH_4 and N_2O, respectively. This means for every tonne of

CH_4, 28 tonnes of CO_2 would be required to achieve the same environmental effect, while for every tonne of N_2O, 256 tonnes of CO_2 would be required. While the base unit of measurement for GHGs is the tonne, given the volumes of GHGs emitted nationally, when discussing emissions on a national level mega tonnes or $MtCO_2eq$ are often used. This maintains the GWP measure while accounting for the large quantities, with 1 Mt representing 1 million tonnes.

Given the global nature of pollution and climate change, countries must work together to achieve meaningful progress in avoiding so called 'tipping points' from which climate change effects would be irreversible (IPCC, 2019). The avoidance of these tipping points is the focus of many international climate and environmental treaties. In fact, various national governments have come together on several occasions to work together to help limit climate change. For example, the decline of the 'F-gases' over time is the result of international efforts to decrease and prohibit their production, through agreements such as the Montreal Protocol.

The United Nations Framework Convention on Climate Change (UNFCCC) is another example of national governments coming together to tackle climate change and the GHG emissions which drive it. The framework considers both the global nature of climate change as well as the differing circumstances of countries in terms of emissions profiles and economic development. In 2015 the latest UNFCCC agreement, the Paris Agreement, was signed by 174 countries, with an additional 20 countries signing since. The Paris Agreement commits signatories to limit global temperature increases to at least below 2°C above pre-industrial levels but aim to limit this temperature increase to below 1.5°C. These temperature limits correspond to the aforementioned tipping points. The European Union (EU) is a signatory to the Paris Agreement and submitted a reduction pledge on behalf of its member states, pledging to a reduction of 40% in GHG emissions by 2030 as compared to 1990. Under the European Climate Law however the EU and its member states are mandated to achieve a 55% reduction in emissions by 2030.

As mentioned previously, climate change effects the frequency and strength of natural disasters which can impact agricultural lands and food security. Food production, however, is responsible for an estimated 30% of CO_2eq emissions globally (European Commission, 2023). Agricultural CH_4 emissions arise from enteric fermentation and the damaging of carbon sinks such as the clearing of trees for pasture. Agricultural N_2O emissions arise from the use of fertilizer and manure decomposition. Food production emissions also include 'food miles', or emissions resulting from the transportation of food or additional areas such as product packaging. Primary agriculture, however, is responsible for approximately 24% of global emissions (Niles et al., 2018). In Ireland this proportion is even greater (EPA, 2024a), accounting for 38% of national GHG emissions as compared to 11% at the EU level (EEA, 2024). Given commitments to drastically cut GHG emissions, significant reductions in the agricultural sector would make critical progress towards reaching GHG emissions reduction targets.

The necessity of agricultural production is one of the difficulties in tackling GHG emissions from agriculture. The global demand for food is predicted to rise by up to 70% due to an increasing global population due to surpass 9.7 billion by 2050 (van Dijk et al., 2021). To meet rising demand there will be an increase in agricultural production leading to rise in the amount of GHG emissions if current production techniques are continued. However, if the emissions intensity of food production decreases, absolute levels of emissions can remain stable if not decrease while meeting rising demand. As people get wealthier, their demand for 'luxury' food items such as dairy products and meat, which are carbon intensive, will increase, potentially in excess of 50% (van Dijk et al., 2021). This double impact will be particularly great as the demand for food, and especially carbon intensive animal products, grows with the increasing population.

1.1 The Irish Agricultural Sector and Dairy Industry

The agricultural sector is referred to as 'Ireland's largest indigenous industry' (DAFM, 2022a). In 2020 there were 135,037 farms in Ireland, a 3.4% decrease in the previous decade and a decline of approximately 21% on 1991 (CSO, 2022). Of these farms over half (55%) are beef producers, with sheep (13%) and dairy (11%) the next most popular farm types. Exports from the agri-food sector increased by 50% from 2011 levels, with exports in 2021 valued at €15.4 billion, accounting for almost a tenth (9.4%) of all exports (DAFM, 2022c). Ireland is heavily reliant on livestock with animal output valued at three and a half times crop output in 2021 (Eurostat, 2024). Of this livestock derived output, milk accounted for 45% in 2021 of economic value. Table 1 provides some insight into the numbers of farms in Ireland and the number of workers employed both within the agri-food sector and within the dairy industry. Irish farmers are predominantly older with approximately a third over the age of 65 and an additional quarter between the ages of 55 and 64. For over half of farmers (53.3%) farming is their sole occupation and for 20.5% of farmers it is the more important of their multiple occupations. The remaining 26.2% view farming as a subsidiary employment. These figures vary by farm type, with dairy farmers the least likely to have off-farm employment.

Table 1 Number of Farms and Employment in the Agri Sector and Dairy Industry

Employment in agri-food sector	165,000 (DAFM, 2022a)
Agri-food Exports 2021	€15.4 billion (DAFM, 2022a)
Farms in Ireland 2020	135,037 (DAFM, 2022a)
Dairy farms in Ireland 2020	~18,000 (Teagasc, 2020)
Employment in dairy industry	5,561 (EY, 2023)
Indirect employment from dairy industry	40,000 (IFA, 2021)

Table 2 Mean Standard Output by Farm Type in 2020 (NFS, 2021)

	Dairy	Tillage	Mixed Crop and Livestock	Mixed Livestock	Beef
2020 Mean Output	€209,006	€101,262	€78,539	€49,648	€19,269

Table 2 highlights the difference in output across farm systems in Ireland, with dairy farms generating the largest output and revenues by a significant margin, over double that of the next highest type, tillage. These differences in farm output are also reflected in 2022 family farm income (FFI) figures. The mean FFI for all farmers was €45,809, with dairy farms FFI as the highest performing category at €150,884. The 2022 FFI figure for dairy farming was somewhat of an outlier on previous years, however in 2023 it has reduced to more normal levels. In all years, dairy FFI remains the largest of all farm types.

While only 15% of all farmers earned in excess of €100,000 in 2022, 62% of dairy farmers did. This increase in profitability in the dairy sector was due to increased margins as the 49% increase in milk prices outpaced the 34% increase in production costs, leading to an increase in the national margin per litre of milk from 14.2c/L in 2021 to 24.2c/L in 2022 (Dillon et al., 2022). Table 3 provides information on the average farmer in comparison to the average dairy farmer, illustrating how dairy farming is on average more viable than other farm types, with higher farm income and farm size and a lower reliance on CAP direct payments. However, dairy farmers are more likely to have debt and their mean debt is higher.

Table 3 Average Farm Characteristics for Ireland (NFS, 2021)

	Dairy Farms	All Farms
Farmer Age	54	58
Farm Income	€98,745	€34,719
Farm Size	64ha	45ha
Farm Income per Ha	€1,538	€773
Direct Payments per Ha	€331	€406
Direct Payment as % of FFI	21%	52%
Farms with Debt	66%	40%
Average Loan amount	€139,031	€70,788
Farm Income per Unpaid Labour Unit	€73,941	€31,789
Off Farm Employment (Holder or Spouse)	55%	56%

In 2015, 18.6% of the 7.4 million cattle in Ireland were dairy cows. This figure has grown year on year and in 2022 stood at 22% (CSO, 2022). While the total number of cattle has increased over this period, it is driven by an expansion of the dairy herd. Between 2015 and 2021, the national dairy herd grew at a rate of 23.8%, vastly outpacing the increase in total cattle of 5.7%. The Irish dairy industry continues to expand, with the national dairy herd increasing for the 11^{th} year in a row in 2021 (FoodVision 2030, 2022). While the dairy industry has seen rapid growth since 2015, this is in large part to the repeal of the EU milk quota which was introduced in 1984. This policy was designed to limit the subsidies provided by the EU to the dairy industry, and in exchange EU farmers received a price guarantee for milk. Given the increase demand for dairy products on the global market, the EU removed its quota in 2015 in order to allow European farmers and dairy processors to meet this demand. Between 1984 and the abolition of the milk quota in 2015, the Irish dairy sector saw a dramatic restructuring. In 1984, 80,000 dairy farmers milked an average of 18 cows, while in 2015, 17,500 farmers had an average of 64 cows. Farm efficiency also increased by almost 50%, from 3,500L per cow to 5,200L per cow, with an overall average total farm output increase from 70,000L to 330,000L (Donnellan et al., 2015). The lifting of the milk quota saw farmers invest in their capacity to increase production in future years, a move which was encouraged by the Irish government, with farmers assured increasing capacity would not be rolled back in the future. Then DAFM Minister Simon Coveney stated, "I will not allow a situation where the potential for further growth and expansion in agri-food will be compromised by the setting of emissions limits" (Healy, 2014). The minister did however stress the importance of sustainably produced dairy.

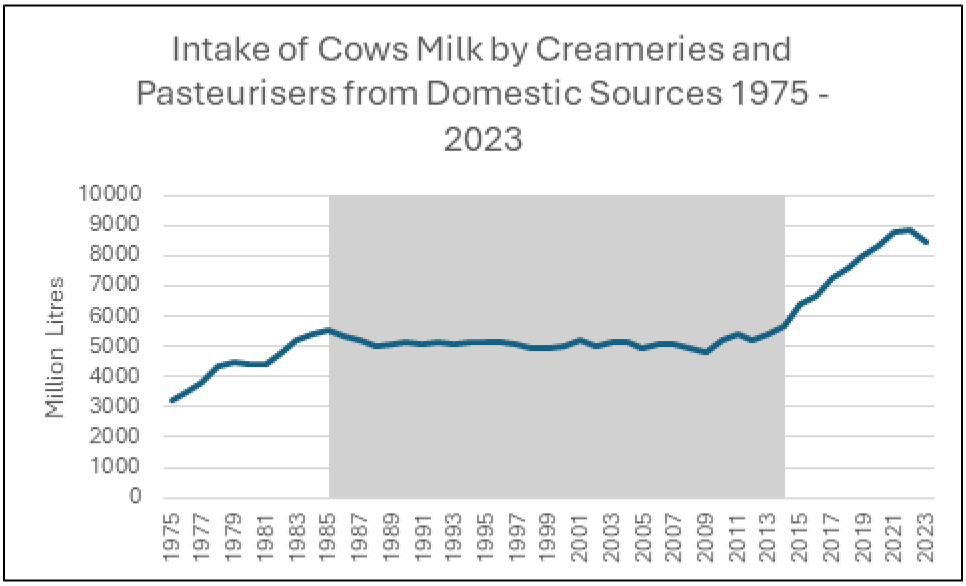

Figure 1 Intake of Cows Milk 1975 - 2023 (CSO, 2024a)

Almost 9 billion litres of milk are produced in Ireland annually, a greater than 50% increase on pre-2015 levels. Figure 1 illustrates the effect of the milk quota with a significant increase in output following its removal. The vast majority of this volume (>90%) is exported to more than 100 countries, with the largest export destinations being the Netherlands, UK and China. Of the almost 8.8 billion litres of milk produced in 2021 some of this was used by the Irish dairy sector to produce in excess of 275,000 tonnes of butter, 285,000 tonnes of cheese and 130,000 tonnes of skimmed milk powder per annum (CSO, 2024b).

The Irish government is keen to see growth in the Irish agri-food sector and to expand its impact on the world stage but does see the need to reduce emissions intensity in the sector, as well as improve sustainability in other areas. Speaking at the AGM of the IFA, Ireland's largest farming representative organisation, then Taoiseach Micheál Martin (2022) stated "Irish agriculture has a very strong future. It can continue to produce world class food while improving its environmental credentials and lowering its emissions, thanks to a science-based approach that also improves biodiversity and improves the quality of the water in our rivers, lakes and estuaries".

1.2 Ireland's GHG Emissions

Ireland emitted 55.01 MtCO_2eq of GHG in 2023 (EPA, 2024b). According to the CSO (2023) Ireland is the second worst emitter of GHGs per capita at 12.3 tonnes of CO_2eq per capita, compared to the EU average of 7.8 tonnes. The Irish emission profile differs from the EU profile in terms of sectors responsible for GHG emissions. While energy is the single largest contributor to EU emissions in 2020, with over a quarter of emissions generated in this sector, in Ireland the energy sector represents just 14% of GHG production with this level falling and predicted to continue to fall as renewable energy gains a larger share of electricity generation. Agriculture is the single largest contributor to GHG emissions in Ireland, equal to the emissions generated by the next two largest emitting sectors, transport and energy, combined (EPA, 2024b). Figure 2 shows the dominance of the agricultural sector in terms of GHG emissions. High levels of agricultural emissions leads to Irish emissions being comprised largely of two GHGs, CH_4 and N_2O, as opposed to CO_2 as is the case in other EU countries. Specifically, agriculture accounts for approximately 90% of Ireland's CH_4 and N_2O emissions (Teagasc, 2024). In Ireland about two thirds of all agricultural GHG emissions are CH_4, which arises from processes such as enteric fermentation (EPA, 2024a). The other third of emissions are mainly N_2O emissions from the use of fertilizer. These emissions are mainly due to beef and dairy farmers accounting for two-thirds of all farms in Ireland (CSO, 2021), whereas at the EU level, dairying, cattle-rearing and fattening make up just 10% of all farms (Eurostat, 2022). Figure 3 highlights this disparity, with the proportion of livestock farms in Ireland almost four times greater than the EU-wide figure. The Food Vision Dairy report estimates that 40% of Irish agricultural emissions originate in the dairy industry due in part to its large (50%) share of nitrogen use (FoodVision 2030, 2022). Given the most recent change in calculation of global warming potential (GWP) to give a larger weighting to CH_4 emissions, agriculture is responsible for a larger proportion of emissions than was previously the case. This better reflects the damage of the emissions generated in the sector, due to the long-lasting effects of CH_4 and N_2O, which are emitted in larger proportion from the agricultural sector than other sectors. Although the quantity of livestock generates a significant level of emissions, the emissions intensity of Irish agricultural products compares well internationally. The carbon footprint of Irish milk is 0.6 – 2.13kg (O'Brien et al., 2014; O'Brien et al., 2019; National Dairy Council, 2023), comparing favourably to the global average emissions per litre of milk of 1.39kg CO_2eq, (Schlesinger, 2019).

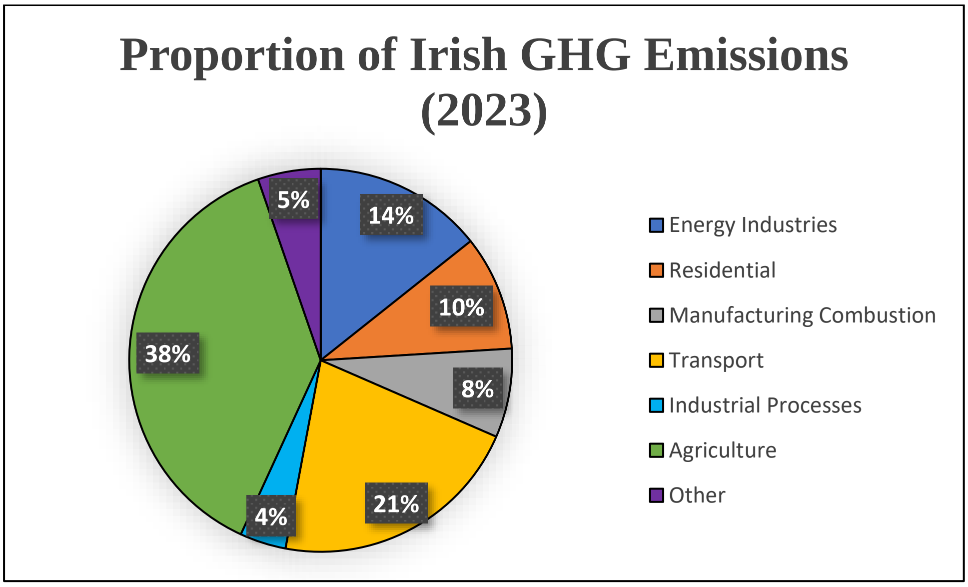

Figure 2 Proportion of Irish GHG Emissions by Sector 2022 (EPA, 2024b)

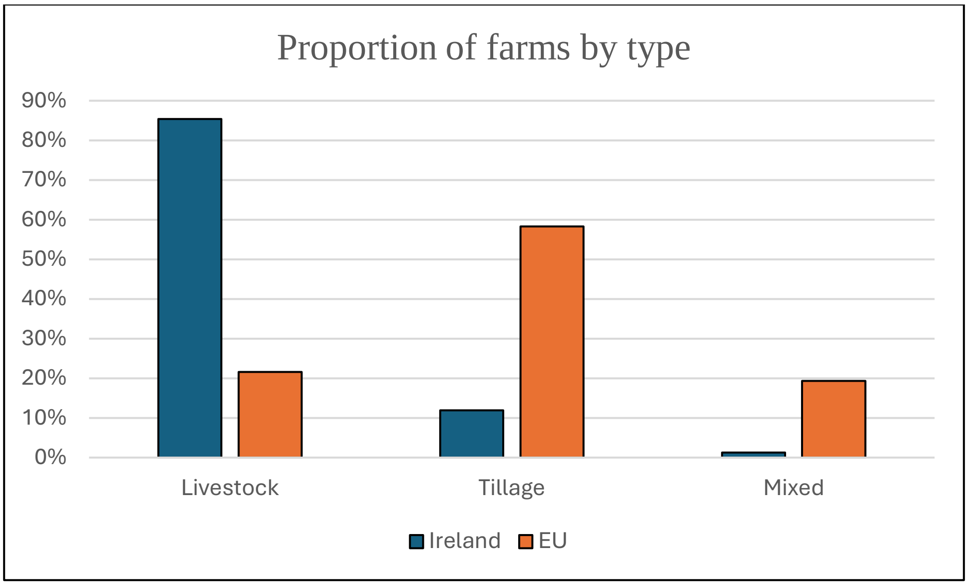

Figure 3 Proportion of Farms by Type in Ireland and the EU (CSO, 2022; Eurostat, 2022)

While Irish agriculture emissions increased from 32% of total emissions in 2021 to 37.8% in 2023, the EU-27 agricultural emissions were 10.8% for 2022. Globally the proportion of emissions allocated to agriculture forestry and other land use (AFOLU) was 24% in 2010. Failure to mitigate agricultural GHG emissions could lead to it becoming the sector responsible for the largest proportion of global emissions by the middle of this century (OECD, 2019). Figure 4 compares the sectors responsible for the largest shares of emissions at the EU level and in Ireland. The industry and energy supply sectors are responsible for almost double the proportion of emissions in the EU as in Ireland, while transport also contributes at a higher rate. The greatest contrast is seen in the agricultural sector and in LULUCF sector which is a carbon sink at the EU level while remaining a net emitter at the Irish level.

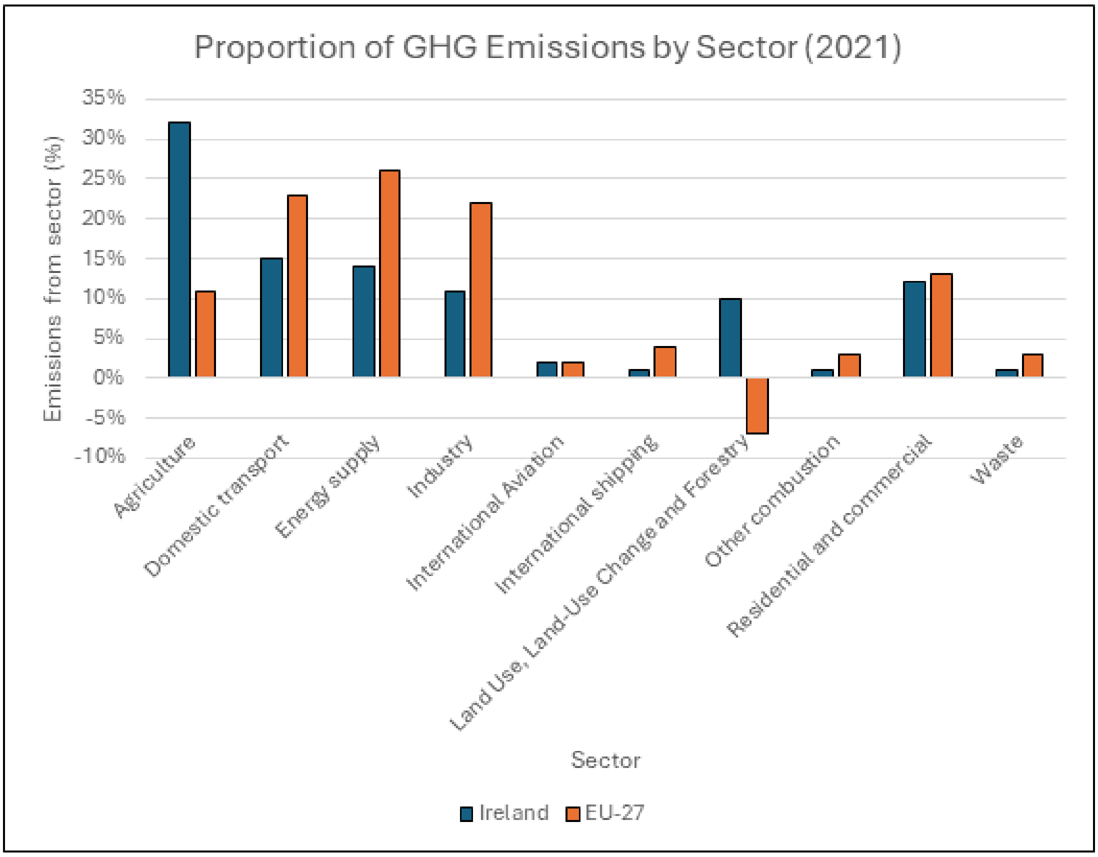

Figure 4 Proportion of GHG Emissions by Sector in 2021 for Ireland and the EU (EEA, 2024)

Given that the sector responsible for the largest proportion of emissions in Ireland is the agricultural sector, the profile of GHGs in Ireland differs from the profile in other countries. Approximately a quarter of all Irish GHG emissions are CH_4, twice the EU average of 12%, and N_2O emissions in Ireland are 9% of total emissions as compared to 5% in the EU. This can be seen in Figure 5, which highlights the increased level of methane as a proportion of emissions in Ireland compared to the EU. In 2019, Ireland accounted for 1.3% of the EU's CO_2 emissions, but 5.1% of agricultural N_2O and 6.8% of agricultural CH_4 (The World Bank, 2023).

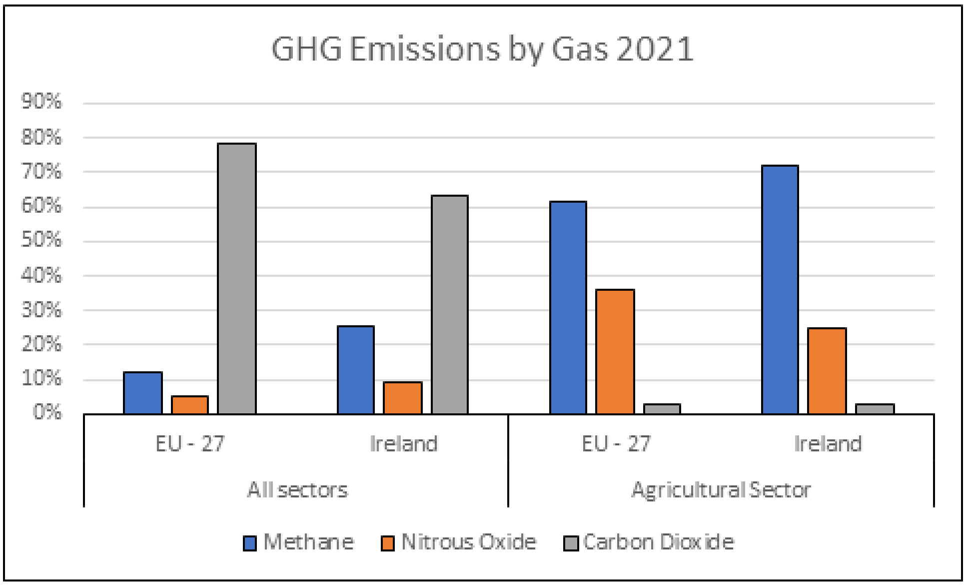

Figure 5 GHG Emissions by Gas for Ireland and the EU in 2021

Ireland's binding national emissions targets commit to a reduction of 50% of GHG emissions relative to 2018 levels by 2030. Although the agricultural sector is responsible for the largest proportion of emissions, it only has a 25% reduction target, the least stringent reduction requirement of all sectors. Most other sectors have a reduction requirement of either 43% or 50%, with the electricity generation sector requiring the highest level of reduction of 70%. The sectoral emissions ceilings were decided upon with consideration to abatement potential, cost, feasibility, socioeconomic impact, and achieving government climate commitments by 2050 (Department of The Environment, 2022). Figure 6 illustrates that if all sectors met their emissions targets, the agricultural sector would still emit almost three times more GHGs than the next largest emitting sector.

National emissions targets are structured as 5-year carbon budgets. For the first carbon budget from 2021 – 2025, a limit of 295 $MtCO_2eq$ is implemented across all sectors. 46.6% of this budget has already been consumed by the emissions produced in 2021 and 2022 (Burke, 2023). This limits emissions from 2022 to 2025 to roughly 157$MtCO_2eq$. The agricultural sector has a limit of 106 $MtCO_2eq$ for the 2021-2025 budget period, and by the end of 2022 approximately 47 $MtCO_2eq$ have been emitted (Burke, 2023). This leaves 59 Mt CO_2eq for the remaining period. In order to meet the 2025 target in the agricultural sector an annual reduction of 4.8% was required each year between 2021 and 2025, while from 2026 onward an annual reduction of 8.3% is required to achieve 2030 requirements, assuming 2025 targets were reached (Lanigan et al., 2023). Ireland is currently not on target to meet emissions reductions as seen by the emissions levels above. Only a 19% reduction in emissions, as opposed to the 25% target, is projected for the agricultural sector by 2030 based on uptake of additional measures (EPA, 2023). 2019 saw a 4.1% decrease in emissions output, while 2020 saw an increase of 1.6% and 2021 an increase of 3.7% on the previous year. This represents a 1% increase in emissions generated within the agricultural sector between 2018 and 2021 (EPA, 2023b).

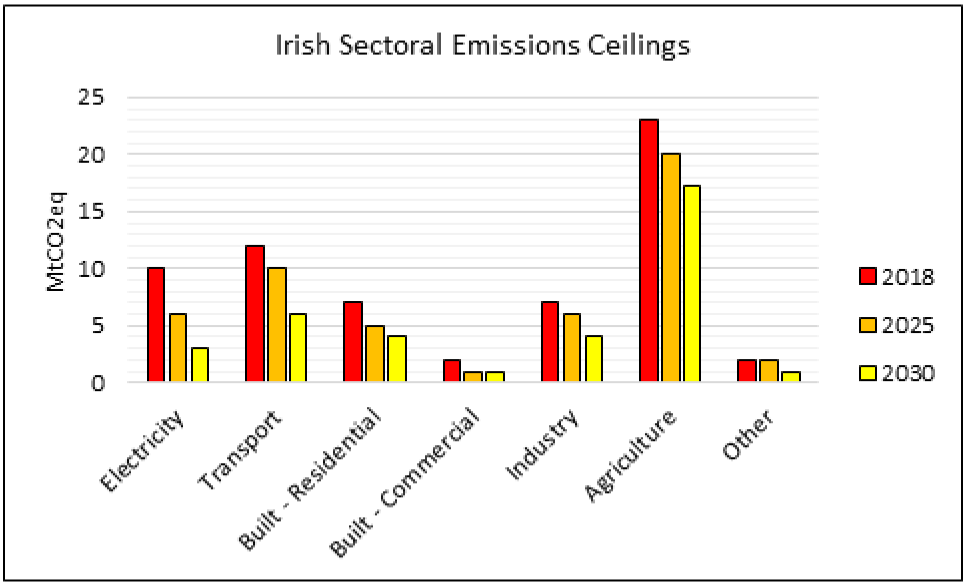

Figure 6 Irish Sectoral Emissions Ceilings for 2025 and 2030 (Government of Ireland, 2023)

Figure 7 shows Ireland's agricultural emissions between 1990 and 2021 as well as projected levels up to 2030. It shows the emissions increased every year between 1990 and 1998 before falling in the 1999 – 2007 period. Between 2008 and 2011 fewer emissions were generated than in 1990 due to the decline in the agricultural sector alongside other sectors of the economy during the Irish financial crisis. Since 2011, emissions from the sector have reached their highest level with a year-on-year increase in all years except for 2019. Given a need for 6-7% annual reductions to be made, even slight increases in emissions year-on-year jeopardize Ireland's ability to meet its targets.

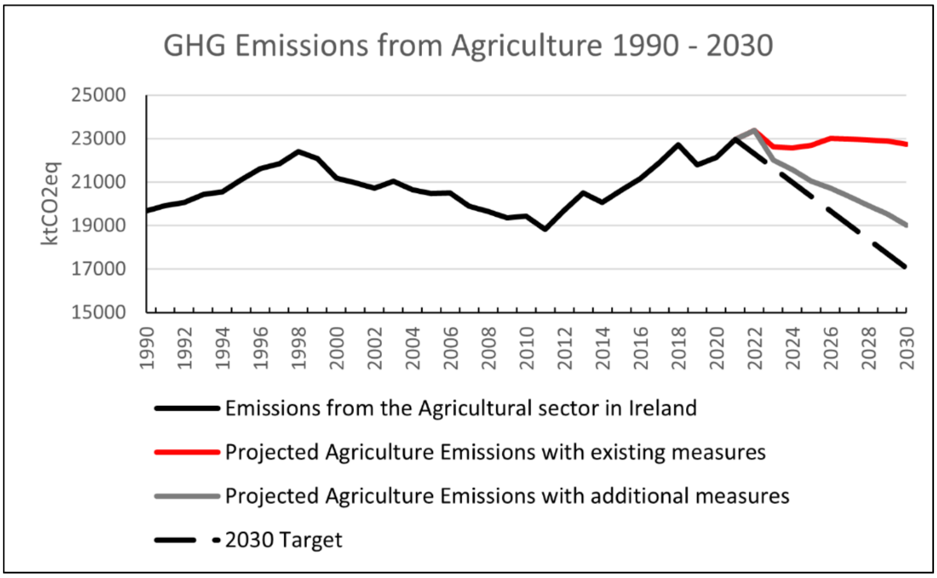

Figure 7 Past and Projected GHG Emissions from Agriculture 1990 - 2030 (EPA, 2023)

1.3 GHG Mitigation Measures

Progress toward the GHG emissions reductions that the Irish government has committed to achieve in the agricultural sector could be made by the implementation of a range of emissions reducing practices on farms. The implementation of emission reductions is difficult in the agricultural sector due to concerns of impacting food supplies, the complex nature of emission measurement, and establishment of emissions baselines. Farmers raise additional concerns such as fairness across regional and generational divides as well as additional time and labour constraints. Farmers are also reluctant to adopt emissions reducing technologies due to perceived impacts on profitability and poor or overly complicated messaging. While a majority of Irish farmers believe reducing GHG emissions from agriculture is an important issue and in excess of 70% of farmers believe they can personally contribute to mitigating climate change, 47% farmers believe that reducing GHG emissions will negatively impact farm profitability (Läpple et al., 2022). Irish farmers are also resistant to any mandatory mitigation practices that may result in decreased milk production. This is due in large part to the large farm investments to increase capacity since the abolition of the milk quota in April 2015. This was done in response to the encouragement of the government who in July 2010, looking forward to the abolition of the milk quota announced a target of a 50% increase in production by April 2020 (Department of Agriculture, 2010). A supplementary element of the 2013 National Farmer Survey found 60% of farmers planning to expand their production between 2015 and 2017 (Donnellan et al., 2015).

A number of practices aim to achieve GHG reductions on farms, such as Low Emission Slurry Spreading (LESS), grassland management, improved Economic Breeding Index (EBI), use of sexed semen and use of protected urea. The extent to which farmers are aware of these practices, requirements for implementation, and cost implications varies. Some farms have already implemented a version of a practice, or it may not suit the local climate or geography. Other practices will be limited in their implementation due to cost or time constraints.

Further practices, including anti-methanogenic feed additives, are also being examined for their effectiveness. In addition to natural changes to diet, such as the introduction of seaweed, to reduce methane emissions, chemical additives such as Bovaer and 3-NOP are undergoing extensive testing. These additives have been shown to achieve emissions reductions with 3-NOP reducing methane by 30% in calves (Kirwan et al., 2024), however, some drawbacks have already been identified. Chief amongst these is that the effects are greatest when animals are housed rather than at pasture (Dineen et al., 2023), while cattle in Ireland graze outdoors for the vast majority of the year. Additionally, the cost of these additives are likely to be too expensive to achieve a large uptake by farmers and regulatory approval is still required.

Other measures such as slurry amendments are also being studied while other measures have been studied and their ability to reduce GHG emissions on farms has been proven however, related policy changes and strategies are still being considered. These measures are often most focused on renewable energy particularly in biomethane and anaerobic digestion.

In 2023, Teagasc published the 3rd edition of the Marginal Abatement Cost Curve (MACC) for Irish agriculture (Lanigan et al., 2023), following on from previous publications in 2012 and 2018. The MACC sets out the measures that could be enacted in the Irish agricultural sector to reduce GHG emissions and the magnitude of emissions reductions resulting from the implementation of these measures. The 2023 MACC analyses the potential GHG emissions and mitigated GHGs against the predicted level of uptake of the measures (pathways) and growth in livestock numbers (scenarios), which are presented in Table 4. Regardless of the growth in the sector, unless adoption rates of reduction measures increase, the MACC predicts no possible way to meet emission targets. When adoption rates are higher, it is possible to meet GHG emission reduction targets, illustrating the need to generate buy-in from farmers. An expansion of farm advisory services, like the Teagasc Signpost Program, could allow for the required level of up-take, to be achieved.

Table 4 GHG Emissions in 2030 under MACC Pathways and Scenarios

	Emission levels in 2030 ($MtCO_2eq$) (Target = 17.25)	
	Pathway 1 Adoption of measures in line with previous rates	Pathway 2 Adoption rates close to maximum feasible level
Scenario 1 Likely growth scenario (8% increase in cow numbers)	19.1	17.0
Scenario 2 Lower than expected growth (4%)	18.4	16.4
Scenario 3 Higher than expected growth (12%)	19.7	17.7

The MACC considers 16 agricultural measures, including measures to both reduce absolute emissions and emissions intensity. 5 of these measures are concerned with reducing CH_4 levels, 7 with the reduction of N_2O and 4 concerned with both. These measures include actions such as changes to feed, extended grazing, and slurry management. Only 4 measures are considered for improvements in agricultural efficiency: beef genetics, dairy EBI, extended grazing and animal health. The Economic Breeding Index (EBI) compiles a number of factors in order to determine the profitability of an animal based on various production factors such as milk production, fertility and carcass weight (ICBF, 2024). EBI allows farmers to identify the best bulls and cows for breeding to improve the herd. In addition to providing insight into the ability of the sector to meet emissions targets, the MACC also indicates the priority in which measures should be adopted. Each measure is assessed in terms of both the emissions savings and the cost implications of its introduction. The MACC allows farmers and researchers to easily identify those measures which would generate a financial saving for farmers, those which would incur costs less than the carbon price and those which would generate costs in excess of the carbon price. The measures outlined in the above section are only some of the options available to reduce the emissions intensity of agricultural systems. While some involve significant costs, either initial or ongoing, others prove more cost effective than current practices. One such case is the use of protected urea over other forms of fertilizer. While protected urea is more expensive per kilogram of fertilizer, it is less expensive per kilogram of nitrogen. Therefore, greater implementation of protected urea would result in cost savings for farmers while at the same time reducing N_2O emissions. This illustrates that as well as researching and investing in technologies and practices capable of reducing GHG emissions, it is equally important to inform the necessary parties and partners of these technologies and practices and their effectiveness, and promote and if necessary, incentivize their uptake. Some of these approaches such as informing and subsidising efficient practices through schemes and funding streams are already in place. In Ireland information about more environmentally efficient practices are disseminated to farmers by DAFM as well as Teagasc, Ireland's farm advisory and research service. Many schemes run by either the Irish government through DAFM or by the European Commission, have environmental components which must be adhered to in order to receive grant funds.

There exists other ways in which the government may constrain firms and in this case farmers from emitting GHGs. These approaches take the form of market-based incentives and use a 'carbon price' to account for the social cost emitting a ton of CO2eq. A carbon price may have two forms, a carbon tax directly applied on firms and payable to the government or carbon markets whereby the total volume of GHGs which may be produced are restricted.

While carbon pricing has been introduced in Ireland and in the European Union, and officially forms part of Irish government strategy to meet long-term climate objectives, it has not yet been implemented in the agricultural sector. Given the pressing need to reduce GHG emissions in the Irish agricultural sector and dairy industry, establishing whether carbon pricing could drive down GHG emissions in the agricultural sector is of vital interest. The methods of establishing carbon pricing and the difficulties involved are areas which require further research.

The theory of carbon pricing tools, the feasibility of implementing voluntary carbon markets in the Irish dairy sector and the ease of establishing living labs in Ireland in order to test this feasibility will be further examined in the following chapters. Dairy farmers' receptiveness towards living labs and carbon markets as well as attitudes towards GHG mitigation will also be examined. Having in this section examined the role of GHGs in climate change, the background of the Irish dairy industry, its importance to the Irish economy and its contribution to Irelands GHG emissions, the following sections will examine the potential to meet GHG reduction targets through the voluntary implementation of carbon mitigation measures on Irish dairy farms. Chapter 2 will conduct a review of the existing literature regarding carbon pricing, focusing on voluntary carbon markets. Chapter 3 will discuss the living labs approach to innovation and research, and the challenges encountered in establishing a living lab as part of the SmartDairy project. Chapter 4 will examine the interviews conducted amongst Irish dairy farmers and industry experts regarding their views on dairy sustainability and carbon pricing, while Chapter 5 provides a conclusion of the thesis and future recommendations.

2. Objectives

This thesis will investigate the potential of carbon pricing instruments, namely voluntary carbon markets, to facilitate the reduction of greenhouse gas emissions in the Irish dairy sector. It will do so by examining the literature surrounding carbon pricing, its forms, and examples of its implementation to date as well as the benefits and challenges associated with the introduction of such a scheme.

Given the lack of existing schemes and the gap in current research surrounding the use of carbon pricing in agriculture, this thesis will examine the potential for voluntary carbon markets in the Irish dairy sector. This will be carried out through the lens of ‘Living Labs’ and a series of semi-structured interviews with farmers, stakeholders and dairy industry experts, which were carried out as part of the ERA-NET, SUSFOOD2 funded SmartDairy project. Given that agriculture is excluded from the majority of active carbon pricing tools, such as the EU ETS, there is little information available on the impacts of carbon pricing on the sector. The establishment of carbon pricing, albeit a voluntary scheme rather than a compliance one, in the Irish agricultural sector where a larger than usual proportion of GHG emissions originate could generate useful insight into the feasibility of such a tool in other countries.

Given that living labs are a relatively new research tool, their uses to date have been limited. This paper will explore the feasibility of living labs as a research tool to test the viability of complex schemes such as carbon markets and to examine the ease of establishing living labs in Ireland and in the Irish agricultural sector more broadly. While the number of projects utilising living labs has increased drastically in recent years and thus the literature on their outcomes has increased, the literature surrounding the difficulties in their establishment is sparce. This paper seeks to add to that literature by noting the challenges faced by the SmartDairy team and highlighting the lessons learned and recommendations from this project.

Interviewing a selection of dairy farmers and industry experts allows us to assess the willingness of stakeholders to engage in a potential voluntary carbon market and the barriers to the creation of such a market. Additionally it provides insight into the current level of understanding regarding carbon trading in its various forms and the level of awareness if any of the price at which carbon may trade. This information will be of benefit to future researchers and policy makers in attempting to establish and publicise any future voluntary carbon markets.

3. Literature Review

The previous chapter introduced the environmental impacts associated with GHG emissions, the sources of Irish GHG emissions, particularly from the agricultural sector, and the need for their mitigation. Given the legislative commitment to achieving a 51% reduction in GHG emissions, and the lack of progress towards meeting this goal by 2030, increasing the uptake of GHG mitigating practices and technologies is vital. There are a variety of methods to increase uptake of emissions reductions in Ireland, through both incentivising emissions reductions and disincentivising emissions productions. These methods all fall under the umbrella term of 'carbon pricing'. This chapter will examine the economics of GHG emissions generation and how governments combat them through the lens of carbon pricing, in particular carbon taxes and carbon markets.

During the production of goods and services, firms generate GHGs as a negative externality and market failure. Externalities are an additional outcome affecting public welfare that is not priced into the provision of goods or services (Marshall, 1890). Market failure occurs when the provision of goods and services by the market is inefficient (Bator, 1958). Specifically in the case of GHG emissions, the market does not account for the negative social impacts GHG emissions causing a misalignment between social cost of the production and the firm's private cost of production. Firms only consider their individual marginal costs and marginal benefits when deciding their optimal level of production. As a result, the firm's marginal costs are lower than the social marginal cost of production, leading to welfare loss equal to the difference between the socially optimal and privately optimal supply levels. The social cost of carbon is a monetary figure reflecting the present social value of emitting a marginal tonne of CO_2. The production of externalities like GHG emissions are not disincentivised as the cost is shared globally and only the supplier feels the benefit. Similarly, given that any action to remedy externalities such as GHG emissions generates a shared social benefit, or social good, rather than a private benefit and does incur a private cost there is little incentive for individuals or firms to reduce production. As a result of this misalignment of private and social incentives, firms will continue to emit more than the socially optimal level until they are made to incorporate all costs, tangible and intangible. However, in the meantime, the negative effects of GHG emissions and climate change impact society as a whole. Where polluting is free of any penalty or punishment, pollution is costless thus making it the default option (Bayon et al., 2012). The overuse of the environment, specifically the atmosphere, as a carbon sink is similar to the Tragedy of the Commons, whereby individuals generate gain for themselves by overconsuming a common resource and limit its future use by depleting that resource beyond its natural ability. The Tragedy of the Commons is more often cited in terms of consumption of resources, but in this example, it is the overconsumption of an environmental service; the atmosphere's ability to act as a carbon sink. Unfortunately, the negative impacts on ecosystem services can in turn have further negative impacts on food production, water quality, and animal and human health.

In order for governments to correct the market failure of GHG emissions, marginal social cost of GHG emissions must be internalized into firms' production decisions by putting regulations in place. One policy a government may use to correct market failure is incorporation of the marginal social cost of production into firms' marginal private cost. This would equalise private and social costs and generate the optimal level of production for both firms and society. The government attempts this using a tool, called carbon pricing which measures the external costs of GHGs and applies them to goods and services which generate GHGs (The World Bank, 2024b). It does not dictate by whom and how emissions should be reduced, but rather provides a signal to the market and allows individuals and firms to either internalize the cost or reduce emissions through a change in behaviour (The World Bank, 2024b).

By setting a carbon price, governments seek to enforce the 'polluter pays principle' and ensure those responsible for environmental damage are also responsible for paying for the damage done. This returns the responsibility for pollution to those who generate emissions rather than taxpayers, while at the same time generating an advantage for those firms who are comparatively more sustainable. While some concerns remain about firms passing the carbon price onto consumers, as more firms become innovative and sustainable and do not have to pay the carbon price, they gain a price advantage in the market. Those firms subject to a carbon price must either increase their prices and potentially lose market share or maintain prices and earn reduced profits. Implementation of a carbon price or increasing the rate of the price by €1 per tonne CO_2 has been shown to reduce emissions by 0.73% (Sen and Vollebergh, 2018). The private cost of carbon may also be decreased, primarily through subsidies. This lowering of the private cost of carbon generates output at a greater than efficient level. The effective carbon rate at a given time is the combination of all carbon price changes; carbon taxes and related fuel taxes as well as the cost of purchasing required carbon permits (OECD, 2021) as well as fossil fuel subsidies. Given the popularity of fossil fuel subsidies, the effective carbon rate may be negative (Edenhofer et al., 2021) and in 2018 was negative at the global level (Boyce, 2018). In 2017, carbon prices ranged from $1 per tonne to $140 per tonne but the vast majority of GHGs were priced at $10 per tonne or lower with an average carbon price of $2 per tonne. This compared to an average subsidy of $10 per tonne, resulting in a global effective carbon rate of -$8 per tonne (Boyce, 2018).

In 2018, carbon pricing affected 15% of all GHG emissions (Boyce, 2018). G20 countries priced 19% of emissions at €60 per tonne or higher with significant variance by economic sector. For example, 80% of emissions from the road transport sector were covered compared to only 5% from the electricity sector (OECD, 2021). Across countries, Brazil had the lowest rate of coverage at just 1% while Switzerland had the highest at 69%. 6% of global emissions were estimated to be regulated by carbon taxes with an additional 10% under emissions trading schemes, (Edenhofer et al., 2021). In

2023 this rose to 23% of GHG emissions being regulated (The World Bank, 2024a), with 73 schemes in place across 39 countries and 33 sub-country regions. Of these 73 schemes, 37 are carbon taxes covering 5.6% of global GHGs, while 36 are categorized as an ETS, covering 17.64% of GHGs.

Carbon pricing is not widespread due to the political, economic and social difficulties involved in its implementation. The free rider problem and the race to the bottom are two ways in which these difficulties manifest. The free rider problem is a form of market failure whereby those who benefit from a given condition or resource do not pay adequately if at all for that condition. When attempts are made to rectify this underpayment, the free rider may seek to avoid these measures. A race to the bottom occurs where multiple countries or regions, in an attempt to compete with one another to attract investment, pause or actively dismantle the introduction of environmental regulations. Each region attempts to make themselves more economically competitive than the others and respond with greater and greater levels of deregulation. These attitudes can result in carbon leakage where firms from regions with high carbon emission regulation move production to a region with lower carbon emission regulation (Huang et al., 2021). In some cases, global emissions may actually increase due to the emissions from transportation or more inefficient production. As a result, without international co-operation, efforts by a single country or government to implement emissions regulations which reduce their national emissions, may not reduce global emissions levels (Guo and David, 2023).

These difficulties arise in negotiating terms of climate action treaties as well. National governments are subject to the free rider problem when considering implementation of measures such as carbon pricing, with countries who do not introduce carbon pricing benefiting from the reduced emissions brought about by those who do (Edenhofer et al., 2021). Additionally, governments are also incentivized to lower its country's own reduction requirements at the expense of another country (Pindyck, 2017). Without international co-operation on carbon reduction commitments or carbon regulation, some countries may attempt a race to the bottom by reducing existing regulations and limiting the introduction of new policy instruments such as taxes, in an effort to grow their own economies by attracting firms from more highly regulated nations. Firms may move production facilities to countries with lower levels of regulation due to reduced profit margins in their home country from increased costs and uncertainty with regards to future costs (Huang et al., 2021). This uncertainty pertains particularly to carbon trading schemes where an emissions price is not set, but subject to the market. These overseas production shifts, weakens both the economy and the impact of the regulation of the firm's home country (Huang et al., 2021). Firms may also move abroad if they are subject to double taxation, (Mengden, 2023), which may occur if countries implement more than one carbon pricing instrument where there is an overlap in sectors covered.

Stepanyan et al. (2023) analyse the potential implementation of carbon pricing in Germany as either a unilateral scheme or by the EU. Their results suggest that although an emissions reduction would be achieved under both scenarios, the effect would likely be five times greater under a coordinated EU scheme. They note that under a unliteral introduction of carbon pricing by the German government, displacement of firms to other countries would likely occur although this would not officially be designated as carbon leakage, as they would remain within the common market. As a result even countries within the EU may be reluctant to unilaterally expand carbon pricing to sectors outside of the EU ETS due to the risk of firms moving to elsewhere within the EU.

3.1 Forms of Carbon Pricing

Carbon pricing generally takes one of two forms: a carbon tax or a carbon market. Carbon markets can be either compliance markets or voluntary markets. In this section we will focus on compliance markets, also known as cap-and-trade or emissions trading systems (ETS), due to their greater frequency and as government tools used to regulate industry. Voluntary markets may also be established as part of a government scheme and can give firms an incentive to do more than required by regulation to tackle GHG emissions. Carbon taxes are levied on goods, primarily fuel sources, based on carbon content, while carbon markets are systems which require the trading of permits representing CO_2eq tonnes of reduced emissions. While a carbon tax allows the market to continue to pollute at whatever level firms wish, so long as the tax is paid, carbon markets restrict the ability of firms to pollute by setting a limit on the total volume of emissions, which can be produced as well as adding a financial cost of pollution. Regardless in differences in function, the end result of both forms of regulation is increased cost to firms based on the level of emissions they produce. This encourages firms to either reduce their emissions intensity, reduce their emissions level by reducing production or pay to maintain production levels. Carbon pricing affects changes in behaviour by increasing the cost of pollution and thus incentivizing innovation and a move away from the status quo.

While generally a carbon tax or carbon market is implemented, a strict choice does not have to be made between the two. Countries can implement carbon taxes, markets or a hybrid scheme, with the potential for both to be in operation simultaneously (Fankhauser and Hepburn, 2010a; Barry et al., 2001). This was the case in Australia with plans for a scheme to be initiated as a carbon tax and later transition into a carbon trading scheme (Zakeri et al., 2015). Germany and Austria have also both implemented carbon taxes in recent years, with plans for these taxes to transition into an ETS by 2026 (Mengden, 2023).

3.1.1 Carbon Taxes

The introduction of taxes discourage the purchase of goods seen as being harmful both to individuals and to wider society. Examples of taxed goods include plastic bags, tobacco and alcohol products, and sugar sweetened beverages. A Pigouvian tax is one kind of tax which aims to reduce an externality by imposing an additional cost on the producer of the externality (Pigou, 1920). Carbon taxes are a Pigouvian tax, which seeks to limit the production of GHGs and their subsequent contribution to climate change by making those responsible for emissions pay the cost. Carbon taxes are generally not a primary source of revenue for governments but have the additional benefit of raising revenues that could be spent on combating the effects of climate change. Other outlets for these funds include the return of the tax to the public either through a 'dividend' system or reforms to the tax system by reducing tax rates in other areas. Dual benefits of carbon taxes also include incentivising cost-effective carbon reductions in the short-run while spurring innovation and investment in green technologies in the long-run (Boyce, 2018). However, the introduction of carbon taxes will only bring about desired abatement targets if the level of the tax is high enough and demand on the good on which the tax is levied is elastic enough (Clinch et al., 2006).

While the majority of countries who have implemented carbon taxes are located in Europe, there are also taxes levied in Japan, South Africa, Chile, Argentina, Uruguay, Colombia, Canada and Mexico. Figure 8 below, shows the rates of carbon tax throughout Europe as of March 2023. While 21 European countries have a carbon tax in place, the rate of tax varies greatly from below €20 per tonne to over €100 per tonne, and the average rate of carbon taxes present in Europe is €44,49. The Irish carbon tax has since been increased in both October 2023 and October 2024 and is now €63.50, with further annual increases to bring it to €100 per tonne by 2030. While the Irish carbon tax applies to petrol and diesel, it will be applied to all other fuels from May 2025 onwards.

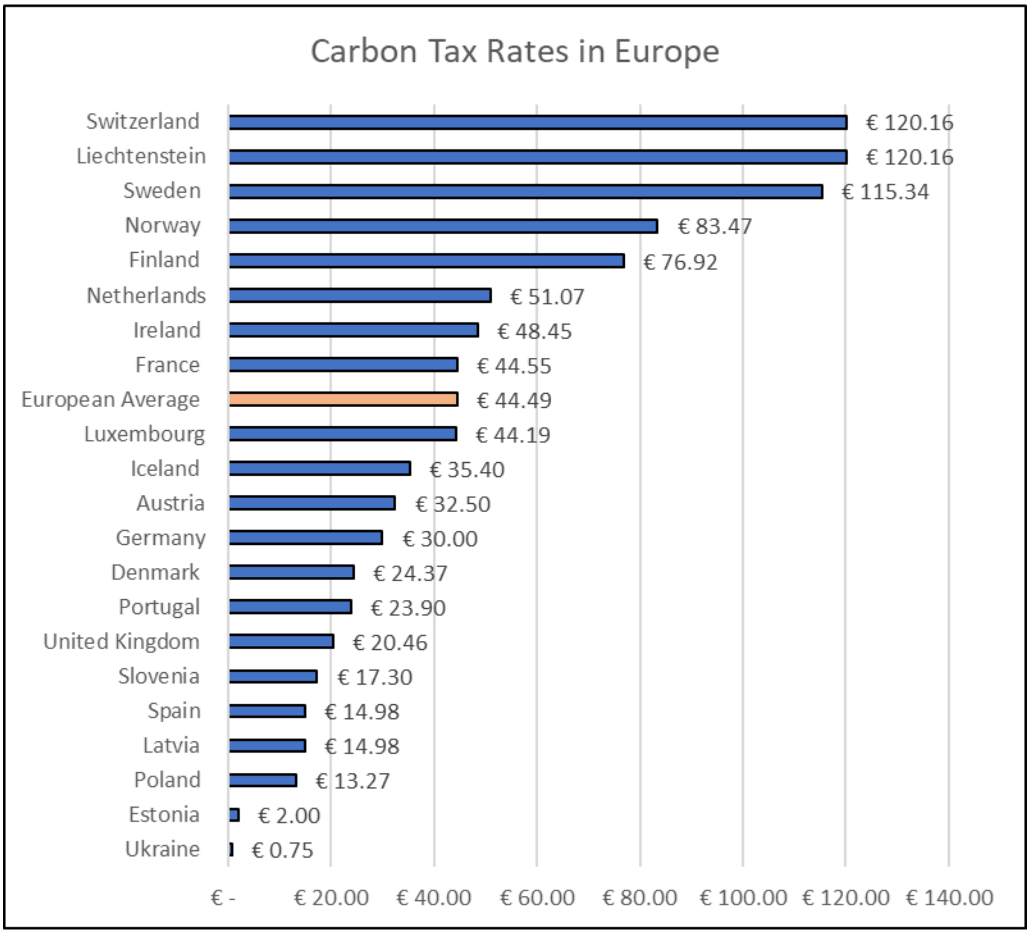

Figure 8 Carbon Tax Rates in Europe 2023 (Mengden, 2023)

3.1.2 Compliance Markets

Compliance markets exist whereby the government puts in place a limit on the emissions generated by industry by requiring a permit to emit GHG. The total number of permits available are fewer than the number of tonnes of GHG emitted the previous year, with one permit representing one CO_2eq tonne of GHG. Firms who fail to purchase enough permits to cover all their emissions from the previous year must pay a fine. This gives firms a choice between paying for current levels of emissions or working to reduce their emissions for future years. Compliance markets often focus on a specific industry or industries, particularly those carbon intensive industries where emissions outputs are more easily measured such as heavy industry, air transport and electricity generation.

The most common form of compliance markets is an Emissions Trading System (ETS) with the most well-known being the European Union ETS (EU ETS) which is discussed in greater detail later in this section. The power of ETS derives from different firms having different abatement costs which allows for companies to benefit from trading permits, price signals indicating the potential for money to be made from emissions reductions and a continued incentive to reduce emissions through innovation (Barry et al., 2001).

3.1.3 Pricing Levels

Carbon taxes and markets differ in the price set by each instrument. While the rates of carbon taxes are set directly by governments, the demand for permits determines the price in carbon markets. While governments may easily alter the rate of taxation, influencing the price of carbon credits is more difficult and likely requires changes to the emissions cap. Setting the price level is difficult due to the requirement to value the removal of a tonne of CO_2eq from the atmosphere that is an intangible good. Three methods for valuing sequestered carbon have been established, the damage avoided approach, the offset approach, or the avoided cost of compliance approach (Clinch, 1999). The damage avoided approach values the sequestration of one tonne of carbon by the cost of the damage done by global warming had the tonne of carbon not been sequestered. The offset approach values a tonne of carbon sequestered by the cost of sequestration using the next cheapest method. Finally, the avoided cost of compliance approach values a tonne of carbon by the cost not incurred from regulatory instruments which would have been had the carbon not been sequestered. Given the political nature of compliance markets, distortions are likely to occur which would price carbon below the social cost of emissions, which would be sub-optimal (Fankhauser and Hepburn, 2010b). The rate of taxation may be at a level deemed politically acceptable rather than socially optimal, with levels of environmental taxes often based on political considerations rather than marginal social costs (Edenhofer et al., 2021). Given the effective rates of carbon discussed earlier in this chapter, large numbers of both carbon markets and carbon taxes are priced sub optimally.

3.1.4 Geographic Scope

Given that localised emissions still have a global impact, emissions reductions are not a local public good but an international one. Larger carbon markets, covering a greater geographic area, allow for greater efficiencies (Bayon et al., 2012) due to the increased number of firms subject to the market and shared administrative costs. While compliance markets may be implemented at local, national, or regional level, larger scale markets are more difficult to implement and sustain due to the difficulties involved in cross-border regulation. It is likely the first global carbon market will arise from a linkage between existing regional markets (Fankhauser and Hepburn, 2010b). A major advantage of carbon trading over carbon taxes is the greater likelihood of international co-operation and co-ordination, due to the ability to assess whether countries are keeping emissions below agreed upon limits as opposed to verifying the imposition of taxes (Krugman, 2009). While the introduction of a transnational carbon tax is unlikely, political support for carbon pricing measures may rise if it was linked to international agreements. A global or regional harmonised carbon tax could allow for national implementation, with politicians defending its introduction to the electorate by stating the decision was out of their hands (Pindyck, 2017).

3.2 Difficulties in Implementing Carbon Pricing Schemes

The greatest contrast between carbon taxes and markets is the difficulties associated with their implementation. Difficulties with introducing carbon taxes centre on resistance towards their implementation, both political and from those upon who the tax would be levied, as well as setting the level of taxation. It is for political rather than economic efficiency considerations, that carbon trading is often preferred to carbon taxes as implementation of carbon trading schemes is less politically challenging (Fankhauser and Hepburn, 2010b). Difficulties with carbon markets include assigning GHG emissions to firms and the resulting difficulties with insetting, offsetting and double-counting.

One of the major problems with the use of carbon taxes noted in the literature is the difficulty of their implementation. Carbon taxes' low levels of acceptability amongst the public is linked to the public's distrust of politicians, and their belief that the revenues generated will not be used effectively or as promised (Maestre-Andrés et al., 2019). One approach by which public resistance towards carbon taxes may be eased is reframing the carbon tax as something other than a tax. A 'climate contribution' was found to receive a better reception and be easier to implement than framing the same scheme as a carbon tax (Klenert et al., 2018). This reframing is found to be particularly effective in 'fee and dividend' systems where revenues generated are redistributed. Dividend systems may redistribute the revenue generated from the tax either equally amongst citizens or targeting those less well off. This can also ease criticism of carbon taxes being regressive. Welfare of the less well-off in society may be maintained or improved through environmental tax reform (ETR) where the burden of the tax system is shifted away from labour and instead towards activities which are more harmful to the environment. Environmental tax reform could allow governments to "reduce income tax, increase innovation and cut pollution by introducing well-targeted environmental taxes and recycling the revenues back into the economy" (European Environment Agency, 2012). ETR approaches differ mainly in how revenue from environmental taxes is utilised, for tax reductions in other areas, investment in environmental projects, or some combination of both (Clinch et. al. 2006). If ETR is implemented well and inflation is controlled, as well as reducing pollution it can benefit the economy through decreased unemployment (Bosquet, 2000). There is however a lack of knowledge about ETR and its potential forms amongst both policymakers and the public, which restricts its feasibility as a tool. An additional approach to reduce resistance towards the tax, particularly from those against whom it will be levied, is to signal in advance the anticipated future rates and structures of the tax. The Swedish experience of carbon taxes indicates raising rates over time in a stepwise approach and giving individuals and businesses notice of this increase and time to adapt their behaviour, improved the feasibility of carbon tax implementation politically.

One of the key difficulties with cap-and-trade systems is identifying a method of allocation for the initial level of permits (Zakeri et al., 2015). There are two main methods of allocating initial permits: through auctions or the use of a legacy system. The legacy-based approach involves using historical data in determining allocations while using auctions as the initial basis allows both the market to set the initial rate of permits and for firms to attempt to purchase as many as they deem necessary. Regardless of whether a legacy or auction system is utilised initially, auctions for permits play a large role in cap-and-trade schemes as they progress. Even when firms are recipients of cost-free permits in legacy systems, there exists an incentive to achieve emissions reductions, as it allows additional revenue generation through the sale of excess permits, which are no longer needed (Krugman, 2009). While permits or allowances within ETS systems are sold at auction and allow fluctuations in price, regulation can also set a minimum price below which credits should not be sold through the implementation of an auction reserve price (Fankhauser and Hepburn, 2010a).

Carbon markets operate on the basis that each firm is responsible for a certain volume of GHG emissions generated. In order for a firm to know how many permits or credits it requires it must understand how large a pool of GHGs emissions it is responsible for. Emissions may be categorised as belonging to firms in a number of ways. They may be categorised as direct or indirect based on whether they are produced by the firm directly or within its supply chain (Hertwich and Wood, 2018). Additionally, upstream emissions encompass both the firm's own emissions and those of their suppliers, while downstream emissions are concerned with the emissions produced once the good has left the factory until consumption and disposal of the good. Emissions may also be allocated geographically on a consumption or production basis. Downstream emissions are difficult to quantify for firms as is it hard assess what share of an end product it is responsible for (Schmidt et al., 2021).

The accepted standard for categorising GHG emissions is the GHG protocol which groups emissions under Scope 1, 2 or 3. Scope 1 is concerned with direct emissions from sources owned by an organisation, Scope 2 is concerned with emissions from electricity, steam or heat purchased by an organisation, and Scope 3 is concerned with emissions which are the result of an organisation's activities but from a source not owned or controlled by that organisation (Louw, 2022). For the majority of organisations, the largest proportion of GHG emissions arise from Scope 3 (Downie and Stubbs, 2012), which account for three quarters of emissions from the average industry (Huang et al., 2009). In an analysis of 12 different industries, eight have Scope 3 as the single largest source of emissions, with a value in excess of 60% in seven of them (Schmidt et al.). In the remaining four industries, energy, agriculture, transport and raw material extraction, Scope 1 was the largest source of emissions. Some of the firms with the largest scope 3 emissions do not manufacture a product. Financial services firms generate large scope 3 emission by investing in and providing capital to other firms. Firms who provide financial services to companies in the energy industry, particularly those involved in fossil fuels, will have substantial Scope 3 emissions. A case study on Allianz Insurance and their emissions profile suggests the nature of insurance firms' activities being primarily online leads to a large electricity consumption and a greater share of Scope 2 emissions than would be the case in many other sectors (Dawson et al., 2022). In addition, Allianz has significant emissions to account for due to their investments in firms in the areas of gas and coal mining. While currently investing in carbon offsets and renewable projects, in order to fulfil their goal of becoming net zero, Allianz must reduce their investment in GHG intensive industries. Allianz has committed to phase out investments in coal-based industries by 2040.

Given the large number of areas which fall under Scope 3 emissions, the sources of Scope 3 emissions may vary greatly across different industries (Huang et al., 2009). For example, the services sector will generate a more significant proportion of their emissions from employee commuting and business travel than the manufacturing sector. There are two approaches for calculating Scope 3 emissions, the process based and economic input-output methods (Huang et al., 2009). The process method is more precise but is significantly more time consuming, and the input-output method is more efficient but introduces greater uncertainty related to prices (Huang et al., 2009). The difficulty in collating primary data means for many firms it is more efficient to use sectoral data in order to find generic 'hotspots' which may be investigated further. Downie and Stubbs (2012) agree on the difficulty in generating accurate emissions data, stressing where external emissions factors are used, they should be standardized factors calculated by a reputable organization, such as government bodies.

3.3 Carbon Pricing Case Studies

A number of carbon pricing instruments are in place across the world although the majority are found in Europe. For this reason, I will examine three case studies located in Europe: the Irish carbon tax, the Swedish carbon tax, and the European Union's Emissions Trading System (EU ETS). The Swedish carbon tax as well as being amongst the carbon taxes with highest rate is also one of Europe's oldest carbon taxes. The Irish carbon tax is more recent and is set at a much lower rate but is planned to increase substantially in the coming years.

3.3.1 Irish Carbon Tax

The carbon tax was introduced in Ireland in 2009, as one of the measures in Budget 2010 (Parliamentary Budget Office, 2024). The carbon tax is composed of two elements: the Solid Fuel Carbon Tax and the Natural Gas Carbon Tax. The carbon tax applies to fuels used in motor vehicles, although it is incorporated as part of the Mineral Oil Tax (MOT), which is a form of excise duty. The forms of fuel covered by the tax have been expanded over time, initially levied only on liquid fuel and gas, in 2013 the tax was expanded to include solid fuels such as peat and coal (Parliamentary Budget Office, 2024).

The tax is levied on emissions in non-ETS sectors (Parliamentary Budget Office, 2019). Some exemptions from the carbon tax are available, including for farmers who may receive a tax credit to offset the increase in carbon tax paid on diesel for vehicles carrying out work on-farm (Parliamentary Budget Office, 2024).

Since its inception the Irish carbon tax has included an element of planned incremental increases in the tax rate. The initial rate of tax was set at €15 per tonne of CO_2eq with an increase to €20 the following year. The rate of increase slowed considerably, rising by only €6 per tonne in the next decade. In 2020, the new coalition government agreed to increase the rate of tax each year between 2021 and 2030, until a rate of €100 per tonne is reached. This consists of an increase in the rate of €7.50 each year until the final when an increase of €6.50 will be applied (Department of Public Expenditure, 2023). The rate of the Irish carbon tax over time is visible in Figure 9.

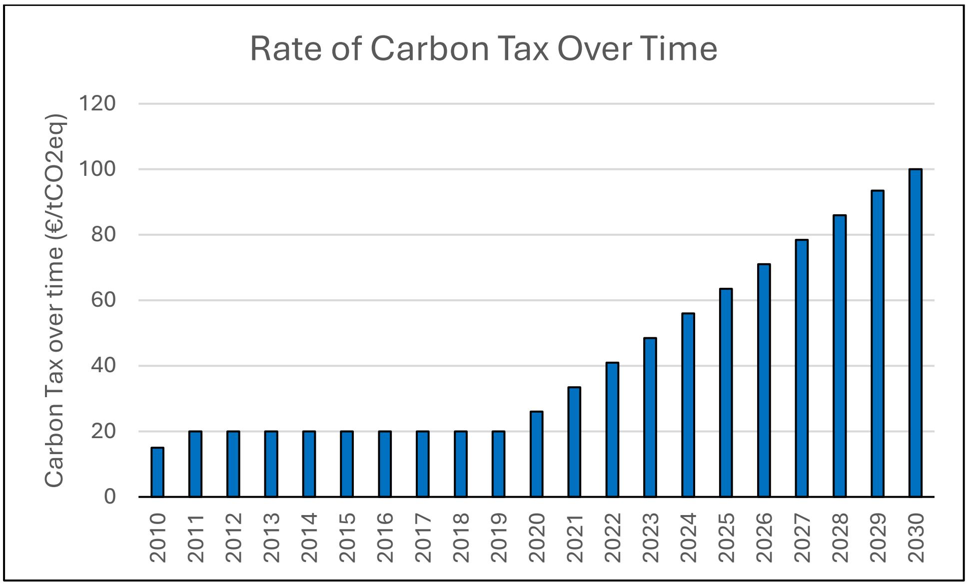

Figure 9 Rate of Irish Carbon Tax over Time (€/tCO2eq)

All revenues in excess of €20 per tonne generated from the carbon tax are ringfenced in order to insure that the tax is levied and distributed in a progressive manner (Parliamentary Budget Office, 2024). Revenues are directed towards policies such as the fuel allowance, improving energy efficiency of homes and the Agri-Climate Rural Environment Scheme (ACRES). Of the €787 million generated by the increase in the carbon tax between 2021 and 2024, €589 million was assigned to these programmes (Department of Public Expenditure, 2023). Outside of these specific programmes, revenues are used to fund the Just Transition and transition to a low carbon economy (Department of Public Expenditure and Reform, 2019). The Department of Environment, Climate and Communications (DECC) was the largest recipient of these funds followed by the Department of Social Protection (DSP). The focus of redirecting revenue to the DSP particularly to the fuel allowance is to account for the fact that lower income households spend a higher proportion of their income on energy and thus any increases in the rate of energy, will have a greater impact on these households (Department of Public Expenditure and Reform, 2019). Tovar Reaños and Lynch (2019) state that while carbon taxes are regressive, targeting revenues towards less well-off households, ensures a progressive outcome.

3.3.2 Swedish Carbon Tax

The Swedish carbon tax is levied on all fossil fuels in proportion to their carbon content. In addition to the carbon tax, the Swedish government also levies an energy tax, sulphur tax and N_2O charge (Johansson, 2000). In 1993, in order to prevent Swedish manufacturing from becoming uncompetitive on the global market, the government reduced the rate of carbon tax payable by industry to 25% of the stated rate (Johansson, 2000). Had this rate reduction not been implemented it is possible that some firms may have moved manufacturing overseas, leading to carbon leakage. This rate was increased to 50% of the standard rate in 1997. In 1995, CO_2 emissions were estimated to be 15% lower than they would have been had the tax not been implemented, and by 2000 this had increased to between 20% and 25%. While the tax reduced the growth in emissions, overall emissions continued to climb, increasing approximately 3% between 1990 and 1998 (Johansson, 2000). Johannson also notes the success of the carbon tax in expanding the market for biofuels and spurring investment in biomass technologies. Additionally, the Swedish carbon tax was adjusted in 2005 upon the introduction of the EU ETS. In order to avoid some sectors facing the dual burden of carbon taxation and carbon markets, these sectors falling under the EU ETS, were exempted from the carbon tax (Tietenberg, 2013).

3.3.3 EU ETS

The EU ETS is the world's largest carbon market and to date the only transnational compliance carbon market. Geographically the EU ETS covers the entirety of the 27 EU countries as well as Iceland, Liechtenstein, and Norway. Firms involved in electricity generation, heavy industry and air transportation are covered by the system. These industries cover 50% of European CO_2 emissions and 45% of total GHG emissions, (Borghesi and Flori, 2018). From 2024 onwards, the shipping industry will also be included. Initiated in 2005, the EU ETS has evolved over time and is now in its fourth phase, which will run until 2030. The initial phase from 2005 – 2007 was intended as a learning and development phase for the scheme.

There are three methods by which a firm may acquire allowances: as part of a free allocation, in an auction run by the ETS, or by trading with another firm who has more allowances than they require. While the system runs across 30 countries, there are some discrepancies in the running of the scheme in individual countries. Member states are responsible for distributing the free allowance they receive amongst participants in their countries. One of the largest criticisms of the EU ETS was the over-allocation of free allowances at the establishment of the scheme (Borghesi and Flori, 2018). Just over half (57%) of allowances are distributed free, with the remainder purchased. Of these free allowances the majority are directed towards firms in the manufacturing industry which may be susceptible to carbon leakage (Twidale et al., 2023). By providing free allowances, overall GHG emissions remain capped while preventing high abatement costs causing firms, and with them emissions and jobs, to move overseas. The use of free allowances may reduce the incentive for firms in these sectors to reduce their emissions.

Although the ETS was initially criticized for allowing too many allowances, with stricter and ever decreasing caps, there have large reductions across the industries covered by the ETS. The emissions cap set by the EU is lowered each year by 2.2% (Martin, 2019). Power plants in the EU have decreased their emissions output by more than a third since 2005. Given that the ETS is a compliance system, there is a penalty in place for firms who do not have an allowance for each tonne of GHG they emit. This penalty takes the form of a fine for each tonne the firm emits above the number of allowances they have. The monetary value of this fine was set to €100 in 2012 and is indexed to the Harmonised Index of Consumer Prices (HICP) for each subsequent year. The fine is in addition to the cost of the allowances that would have been required. The revenue generated from the ETS is primarily distributed by the EU back into national budgets, however some is set aside and invested in low carbon technologies and innovations to improve energy efficiency.

3.4 Agricultural Schemes

While carbon taxes may be levied on specific sectors or as a general measure, carbon markets are usually targeted at specific sectors of the economy most commonly heavy industry, energy production and transport. While the sectors regulated or included varies based on the specifics of individual schemes, one sector which is often excluded is agriculture. The reasons for this include political power of farmers and farming organisations and concerns over increasing the cost of food or reducing food production. Political difficulties are also one of the key impediments to the introduction of agriculture specific carbon taxes, alongside concerns over farmers' rights and the heterogeneity of pollution (Warren et al., 2008). To date no carbon pricing schemes are levied on the agricultural sector, however New Zealand and Denmark are both considering the implementation of carbon taxes on the agricultural sector. In June 2024 the Danish government agreed to move forward with a carbon tax in the agricultural sector from 2030. A tax will be levied on emissions from livestock with revenue from the tax reinvested in the agricultural sector. The European Scientific Advisory Board on Climate Change (ESABCC), has stated that the lack of progress in meeting emissions reductions goals from the agricultural sector is due in part to a lack of financial incentives available to farmers (ESABCC, 2024). In order to meet 2030 targets, it has called on the EU to implement a polluter pays scheme within the EU agricultural sector modelled on the EU ETS. Work has been underway within the EU in order to negotiate potential guidelines for an EU carbon farming scheme.

3.5 Voluntary Markets

While the above sections have compared the carbon pricing tools of carbon taxes and carbon markets, there are other approaches which may incentivize the uptake of carbon mitigating actions. Voluntary carbon markets (VCMs) allow businesses who wish to reduce their emissions but are either unable to do so or believe the cost is too great, may offset their emissions by purchasing carbon credits, each of which represents one tonne of CO_2eq. These carbon credits are generated by other businesses who implement some form of carbon mitigation in order to reduce the number of tonnes of CO_2eq emitted. For each verified tonne mitigated, they receive one carbon credit, which they may sell on the market to other firms or individuals. Voluntary markets may predate compliance markets, or they may be used by firms and industries not subject to an established compliance market. Voluntary markets by their nature of self-regulation and self-imposed costs are smaller in scale than compliance markets. VCMs are an interesting tool as they may provide insight into the feasibility of larger carbon markets as well as the measures which participants are most willing to put into place. Particularly in the agricultural sector where there are few existing carbon pricing instruments, voluntary markets may provide insight into the willingness of farmers to engage in emissions mitigating measures.

While cap-and-trade systems have an emissions cap in place which requires firms to possess permits in order to emit GHGs, VCMs operate through the trading of credits which represents one tonne of CO_2 mitigated elsewhere. By purchasing credits firms may reduce the carbon footprint for which they are responsible without having to invest in actively reducing their emissions levels. Voluntary carbon markets may not themselves be a solution, but an interim measure to contribute to GHG emission reductions while more robust regulation and government schemes are put in place (Guigon, 2010; Streck, 2021). The belief that voluntary carbon markets may serve as a niche market as compared to the larger compliance market is popular (Guigon, 2010). Offsetting may also be viewed as a transitional strategy to accelerate progress towards carbon neutrality and that its use beyond that point will be to offset residual, unavoidable emissions (Streck, 2021). A large driver of participation in voluntary carbon markets may also be ‘pre-compliance’, whereby early investors aim to improve their GHG efficiency in the hopes of gaining a return in future compliance markets (Guigon, 2010). Carbon credits may be generated through either carbon mitigation or carbon sequestration. Some categories of carbon credits have been attempted based on the area in which carbon reductions were made, such as nature-based sequestration, avoided nature loss, avoidance or reduction of emissions, and technology-based removal of CO_2 from the atmosphere (Blaufelder et al., 2021), whole farm audit, peatland rewetting, afforestation or agroforestry and soil organic carbon sequestration (European Commission, 2020).

There are a number of challenges that exist and must be overcome both in order to establish a carbon market and in order to ensure its smooth operation and the production of good quality carbon credits. The challenges involved are not unique to voluntary carbon markets but common to all intangible public goods (Gillenwater et al., 2007), including establishing emissions baselines, credible verification systems, and the establishment of property rights. Additional areas of concern include delays between the establishment of the market and a return of credits and difficulty in establishing consistent price trends for credits, in large part due to the heterogeneous nature of credits and the difficulty in defining co-benefits (Blaufelder et al., 2021).

As with compliance markets, in voluntary trading systems the market decides the rate at which carbon permits or credits are traded. A number of metrics may be used in evaluating the quality of carbon credits generated in voluntary carbon markets. Five such metrics are: realness, additionality, leakage, permanence, and verification (Stubbs et al., 2021). Under these criteria a high-quality carbon credit is one which represents a quantifiable reduction in emissions without generating an increase in emissions elsewhere, which would not have occurred if not for the carbon market and has been independently verified. One of the difficulties in pricing carbon credits is that each credit is heterogeneous, in large part due to the co-benefits involved, if any. Co-benefits are additional services that may be achieved by carbon credits but were not the initial goal. Such co-benefits may improve the attractiveness of particular credits or generate a premium. Examples of co-benefits deriving from carbon sequestration are habitat provision, pollination services, climate regulation, provision of recreational locations (Standish and Hulvey, 2014), biodiversity protection, public health improvements, and job creation (Blaufelder et al., 2021).

Additionality occurs where "emission reductions exceed those that would have happened without the crediting system" (Oldfield et al., 2022). Additionally, as a requirement for carbon credits prevents firms and individuals from generating an advantage by carrying out a carbon mitigation scheme, which they had always intended to do. To allow such measures generate carbon credits would slow the rate of additional carbon mitigation measures. Additional measures are the projects that would not have occurred under a business-as-usual scenario (Liu and Cui 2016). The key for additionality is not whether the income from the sale of carbon credits makes a project more affordable but whether it is the difference between implementation or not (Gillenwater et al., 2007). Not accounting for additionality in designing requirements for a carbon market may build distrust in carbon credits (Oldfield et al., 2022). While most carbon credits are purchased as a form of carbon offsetting, whereby firms wish to reduce their allotted emissions by investing in emissions mitigation projects, in recent years insetting has grown as an alternative. Insetting involves specifically targeting emissions reductions within a firm's own supply chain, and directly lowering their scope 3 emissions. Businesses likely have a higher tolerance for abatement costs from insetting than offsetting, given advantages such as existing relationships, potentially increased efficiency, or improving consumer loyalty sentiment. Additionally, there are fewer operating costs associated with insetting than offsetting given no stringent measuring, reporting and verification (MRV) checks although audits may be carried out. There still exists a possibility for double-counting under insetting if there is not clear communication between parties as to whom the reduction in emissions are being attributed to.

One of the greatest challenges in establishing a carbon market is generating a robust MRV system. The carbon credits produced by a voluntary market will not be trusted by firms to contribute as meaningful offsets without an MRV system in place. MRV involves assessing the stated emissions reducing action was carried out, that it was not later reversed, and it was reported accurately and done so only once. MRV procedures are particularly difficult in carbon sequestration markets where the timelines for emissions reductions are in the medium to long-term. In some cases, soil sampling and the measurement of carbon sequestration may not occur until 5 years after a project is undertaken (Oldfield et al., 2022). Soil organic carbon levels are already difficult to measure precisely leading to difficulty in assigning an exact reduction in CO_2 levels. A balance is required to be struck between costs and environmental protection when designing MRV standards (Gillenwater et al., 2007). Self-reporting may be required in order to limit the administrative costs associated with the system. Spot checks would likely be required in order to ensure accurate data where self-reporting is prominent (Smith et al., 2020).

3.6 Conclusion

The theory of carbon pricing instruments is well established, but its actual effects are more difficult to assess given the relative scarcity of instruments implemented and the gulf in the social cost of carbon and the price levied on carbon by these instruments. The difficulties, both political and practical, in establishing carbon pricing schemes result in few long-term schemes which can be analysed.

The literature notes the difficulties in establishing carbon markets, either in a voluntary or compliance role. These difficulties relate not only to the functioning of the markets, but also to their establishment and the creditability of their results. While some schemes have been implemented and have generated results, few have been in the agricultural sector, resulting in a narrow body of literature from which to draw information.

Implementing carbon pricing in the agricultural sector is something that has been avoided to-date, due to the fears of inflation in food prices, impacting food security, and farmer's power as a voter block. Given the perceived level of opposition acting as a barrier to the introduction of a carbon tax or compliance market, it is possible that a voluntary market could assess the real level of support and opposition amongst farmers towards carbon mitigation measures.

Carbon markets show potential for reducing emissions and voluntary carbon markets can provide insight to develop an improved framework for compliance schemes in the future. Thus, investigating the potential for a voluntary carbon market in Ireland is an interesting proposition. In the next chapter both the feasibility of establishing a carbon market in the Irish dairy sector and farmers' willingness to engage with carbon markets will be examined through the lens of living labs.

4. Living Labs: Lessons Learned

One of the research tools employed by the Irish SmartDairy team to assess the ability and willingness of Irish dairy farmers to adopt more environmentally sustainable practices was living labs. Specifically, the use of living labs in the SmartDairy project aimed to serve as the basis for a trial voluntary carbon market, with the goal of generating carbon credits through the implementation of GHG emission mitigation practices on Irish dairy farms. This would test the feasibility of a voluntary carbon market, farmers' willingness to engage in carbon trading, and the ease of implementing various carbon mitigation practices on working Irish dairy farms. This chapter will examine the concept of living labs, their structure and research benefits. It will then discuss the approach taken by the SmartDairy project in attempting to establish living labs on dairy farms in Ireland, the difficulties that arose, and lessons learned for future implementation of living labs.

4.1 Background

Living labs are defined by the European Network of Living Labs as "An open innovation ecosystem in real-life environments using iterative feedback processes throughout a lifecycle approach of an innovation to create sustainable impact" (ENoLL, 2018). Living labs are one of six forms of test and experimentation platform, alongside prototyping, field trials, testbeds, societal pilots and market pilots (Ballon et al., 2007). Differentiating between these six types of platform can sometimes be difficult due to overlap and common elements (Schuurman et al., 2013). The origin and first usage of the term 'living lab' is disputed (BCIT, 2020; Gualandi and L. Romme, 2019; Scuderi et al., 2023; McLoughlin et al., 2018), as the term was used infrequently before the mid-2000s. The first widespread usage occurred following the establishment of ENoLL in 2006. A search for the term 'living lab' in the literature resulted in 20,000 articles with 80% having been published since 2015 (Schuurman and Leminen, 2021). Particularly important in living labs is the involvement of a variety of stakeholders both public and private sector, and the process of co-creation among all participants (Potters et al., 2022; Westerlund and Leminen, 2011; Steen and van Bueren, 2017). This process is different to other processes as it utilizes the variation in backgrounds and skills of different stakeholder members to build ideas collaboratively rather focusing solely on prototypes like industry lead groups or policy changes like lobby groups.

While living labs originated from Information and Communication Technology fields (Alavi et al., 2020; Bergvall-Kåreborn and Ståhlbröst, 2009), they have since evolved to cover more areas, particularly healthcare and environmental sustainability (Cascone et al., 2024; ENoLL, 2018; Liedtke et al., 2012). Their use has been concentrated in the areas of wearable technology, independent living, 'Smart Cities' and monitoring pollution levels among other areas (Schuurman and Leminen, 2021; McLoughlin et al., 2018). Using the EU Commission database of research projects, CORDIS, a total of 419 projects involving the use of living labs (search terms: 'living lab' OR 'living labs' OR 'living laboratory' OR 'living laboratories') were identified. These projects explored subject areas such as transportation, consumer energy usage, combating air pollution, health, tourism, logistics and education. The above search to isolate living labs operating within agriculture was repeated by adding the required term 'agriculture' or 'agricultural' yielding a result of 128 projects. These projects explored subject areas such as improving farm advisory services, improving soil health, increasing farmer uptake of digital tools, organic farming and reducing food waste. Projects in the area of soil health are particularly common due to promotion by the EU Commission as part of their 'A Soil Deal for Europe' mission.

Living labs have five key characteristics (ENoLL, 2018): real-life setting, co-creation, multi-tool and multi-stakeholder participation, end user involvement, and design and systems thinking applications. A similar set of characteristics is proposed by Steen and van Bueren (2017), who suggest a living lab involves multiple actors of varying expertise in a real world setting, playing an active role in the innovation process while facilitated by researchers. While all 5 characteristics need to be present to have an ENoLL model living lab, the chief distinguishing characteristic for living labs is the real-life or real-world setting. This informs the conditions of the 'experiment' and the changing nature of the innovation process. It emphasizes the importance of flexibility and variability of factors, which occur naturally rather than the strict controls of a lab environment. These real-life contexts are a precondition of all living labs (Bergvall-Kåreborn and Ståhlbröst, 2009). Co-creation focuses on the number and type of actors involved in the process. There should be many and from a variety of backgrounds so innovation is not driven purely by any one group and all stakeholders have the opportunity to contribute.

Multi-stakeholder participation works in tandem with the element of co-creation. Not only should stakeholders from a variety of backgrounds be involved, but multiple stakeholders of each background should be involved to maximise idea generation and increase the levels of experience shared by the living lab members. Living lab stakeholders should be formed from *p*ublic-*p*rivate-*p*eople *p*artnerships, referred to as the 4Ps, (Westerlund and Leminen, 2011). These stakeholders should be drawn from each of the four elements of the 'Quadruple Helix', representing academia, industry, the government and civil society (Finquelievich, 2016). Stakeholders involved in living labs become one of four types of actor: enabler, provider, user or utilizer (Westerlund and Leminen, 2011). Enablers allow living labs to function, particularly through financial means whereas providers allow the lab to make progress by being a source of knowledge and expertise. Users refer to end-users while utilizers will benefit from the resulting innovations but are not themselves end users. Individuals involved in living labs should have a variety of expertise and should play an active role throughout the process as innovators (Steen and van Bueren, 2017). Multi-tool participation requires the use of various methodologies to maximise the experience and expertise of contributors. End-user involvement emphasizes the importance of a product or service designed for those who will ultimately put the good or service into practice not just by researchers or industry. The final element is design and systems thinking applications, which suggests that throughout the innovation process, participants should keep in mind the bigger picture and how each potential innovation could impact on this.

Living labs are used to conduct multi-disciplinary research with active participation and engagement to drive innovation and assist policymakers by undertaking "new methods of user-oriented research" (Liedtke et al., 2012). In the case of agricultural living labs, they augment agricultural knowledge and innovation systems (AKIS) (Potters et al., 2022). AKIS involves the interaction between various actors within the agricultural sector in order to share information and drive innovation (Klenert et al., 2018). Living labs can be a tool to maximise both educational and research objectives, by informing users while also generating data for academics (Fan et al., 2022). One criticism of living labs is their overuse, as other research methods may be better suited or some projects in fact mislabelled as living labs when they are in reality 'pilot projects, showcases, test sites or demos of existing innovations' (Steen and van Bueren, 2017). Four conditions that must be present for the successful establishment of the living lab research method are a challenge and complex enough to warrant bringing together the knowledge and expertise of a variety of actors with a capacity and willingness to fully engage, a setting and supports to allow for innovation, and living lab facilitators that are well versed in the subject matter (Potters et al., 2022). Given that living labs examine both new ideas and technologies as well as individuals and consumer use of and reactions to them, some living labs have been described as where science and social science intersect (Fan et al., 2022). Challenges with living labs include their temporary nature, governance structures, user recruitment, sustainability, scalability and changing circumstances (Hossain et al., 2019).

There are two styles of living labs, North American style and the European style (Hossain et al., 2019). The North American approach focuses on demo-homes or home labs, where users are observed responding to innovations, while the European approach focuses on living labs as a platform to study users' standard habits. Another approach to categorise living labs separates them into five strands: visited places, instrumented places, instrumented people, lived-in places and innovation spaces (Alavi et al., 2020). These strands are differentiated from one another based upon whether it is the individual actor or their surrounding that is being studied and whether the setting is one which is in permanent use or which is used only temporarily. These strands also reflect the distinction between European and American styles, as American living labs often take the form of lived-in-places and instrumented places.

Given the variation in living labs, there are a number of labels used to distinguish categories and sub-categories beyond the styles and strands mentioned above. One distinct form of living labs that has become increasingly popular are urban living labs (ULLs). ULLs are generally of longer duration, have a greater number of participants, and have a defined geographic scope, typically of a city or cities and the surroundings. ULLs are often utilized in sustainability and smart cities research projects. There are a number of sub-category of ULLs, coastal city living labs are one such example. There are also a number of living lab categories based in rural areas or focused on the areas of agriculture and sustainability, such as rural living labs, agroecology living labs, sustainable living labs and agroecosystem living labs (Kiseleva, 2021). Living labs in these categories have distinct focuses, although differentiating between sub-types of living labs can be difficult. In general rural living labs are differentiated by a need to take into account that end-users and participants are likely to have significant demographic differences to those in other areas particularly in cities, population mobility, and a greater impact from climate change (Kiseleva, 2021). Agroecosystem living labs have three components: a transdisciplinary approach, co-design, co-development and monitoring, and they take place on working landscape (ALL Working Group, 2019). It is this last component which differentiates agroecosystem living labs from living labs more generally particularly given that living labs may take place in-person or virtually (Hossain et al., 2019). The requirement for the research to be carried out on a working landscape can be viewed as a more specific application of the real-life setting characteristic. The distinctions between agroecosystem living labs and other forms of living labs also include longer innovation cycles, greater uncertainty from external factors, and the number and diversity of stakeholders involved (McPhee et al., 2021).

Given the diversity of challenges, which living labs are formed to generate solutions for, and the differing actors involved, the exact nature of each living lab will differ. As a result, the activities of one living lab and another may not be comparable making it difficult for the literature to outline a set approach to conducting living labs. One aspect that the literature could provide guidance on however is the roles of organisers or 'staff' within the living lab. Two roles that ensured progress is made within the living lab are the facilitator, which focuses on process progression and the monitor who ensures quality of the progress (Potters et al., 2022). The two roles work in tandem to ensure good quality progress is achieved within a timely manner.

4.2 Objectives

The literature surrounding living labs shows that while sometimes difficult to define and without a distinct structure or methodology driving them, living labs are a useful tool for creating and exploring innovative solutions to complex and dynamic problems.

The scope of living labs has expanded significantly from their initial beginnings in the technology sector with now almost all sectors having hosted a living lab in some form or another. Classification has begun on a number of types of living labs with some, in particular Urban Living Labs, progressing more quickly than others do. In other areas, distinctions between types of living labs are harder to define such as the various types attributed to living labs in the area of agriculture and sustainability.

Given their beginnings in the United States and promotion by the European Union and with the largest support organisation for living labs, ENoLL, based in Europe it is unsurprising that the majority of living labs may be found in Europe and North America however the distribution of living labs within Europe is not entirely equal with Ireland having seen fewer living labs implemented than countries such as Italy or France or those in Scandinavia.

Living labs have a variety of uses and have been implemented in a wide range of roles, as information exchanges, learning experiences, data collection, crafts, quality of life improvements and technology. While some living labs have explored means of improving sustainability within a community through various measures such as rain water harvesting and revitalising disused spaces, as of yet they have not been used as a method of implementing carbon pricing.

Given these current gaps in the literature surrounding living labs, this chapter seeks to examine the living labs in a number of ways including their suitability as a method of introducing carbon pricing to a sector or community, their application to the dairy industry and whether they are a tool, which can be used with success in Ireland. This will be done through the lens of the SmartDairy projects work on living labs which was carried out in Ireland. The goal of the SmartDairy living lab was to bring together various stakeholders in the Irish dairy industry, including dairy farmers, to explore how a voluntary carbon market might operate, and to implement a small scale carbon market in order to test the feasibility of a larger-scale fully functional market into the future.

4.3 Methodology

4.3.1 Stakeholder Workshop

In October 2022, the SmartDairy team hosted a stakeholder workshop in County Meath, Ireland to hear the views of Irish dairy system stakeholders about the potential of voluntary carbon markets in the Irish dairy sector. This workshop acted as an introduction to the SmartDairy project and served as a means of gaining feedback from participants with a variety of backgrounds, including farming, finance, the civil service, dairy processing, journalism, and technology. The organisations of which these stakeholders are members are presented in Table 5.

Table 5 Organisations represented at SmartDairy Stakeholder Workshop

Organisation	**Area of Operation**
Agriland	Farming News
AIB	Banking
Dairy Industry Ireland (DII)	Industry Representative Body
Department of Agriculture, Food and the Marine (DAFM)	Government Department
Devenish	Agri-technology and Nutrition
Farmeye	Soil Measurement
Irish Cattle Breeding Federation (ICBF)	Cattle Breeding and Genetics
Irish Creamery and Milk Suppliers Association (ICMSA)	Farmer Representative Body

The workshop was held on the grounds of a research farm currently implementing best practices and aiming to illustrate the potential for financially profitable low emission farming. After the workshop concluded, a farm-walk allowed attendants to visualise and learn more about the actions implemented on the farm. Throughout the workshop we utilised visual aids, such as slides, flipcharts and post-it notes in the various sessions. These allowed participants to visualise and understand concepts and allowed for work done individually and in-groups to be brought together and integrated or contrasted. The use of these kinds of tools and diagrams is useful in-group project settings, such as living labs. The AgriLink project note the usefulness of diagrams in communicating during collaborative sessions, as a means of framing discussions.

The workshop began by introducing the research team and the overall research project, including the goal of the SmartDairy project to establish a voluntary carbon market in the Irish dairy industry. Participants were then invited to introduce themselves to the group highlighting the organisation they represented and their background. The research team also presented information about carbon markets so all participants could understand the research goal. Workshop discussion utilising the backcasting technique took place both in an open format and in smaller groups. This technique aims to allow for brainstorming of what the solution to a problem would look like first and then looking backwards from that solution to the present to see how the solution can be achieved (Hines et al., 2019). It is helpful in limiting negative talk about how solutions are impossible to achieve and instead focused on barriers to their achievement.

Imagining a functioning carbon market

In the first group discussion participants were asked to imagine a fully operational carbon market already in existence in Ireland and then to define their role or their organisation's role in it's functioning. The second activity built on this, as participants discussed what other roles they felt needed to be carried out within the market and who would be doing so. The stakeholders felt they or their organizations could contribute to a potential market in a number of ways, through measurement of GHG emissions, communication of the benefits to farmers, recording farmer practices, monetizing the credits and encouraging firms to participate in the market. One particularly useful element of this discussion was how carbon sequestration credits and carbon mitigation credits should be dealt with, with a conclusion that potential investors would view both significantly differently. Coupled with the more intensive measurement requirements and increased time horizons, this would likely result in two related but separate carbon markets.

Barriers to implementation and potential solutions

In our third group activity participants were finally asked to identify the challenges they saw in implementing this imagined carbon market into the Irish dairy sector, while in the fourth activity they proposed potential solutions to overcome these barriers. Issues raised included how a baseline for emissions would be established, fears that farmers who had already begun to implement sustainability practices could miss out, the additional administrative burden applied to farmers, the risk of greenwashing by companies, and impacts on food production. The issue of ownership of carbon credits on farms where the land was leased, which had not been previously considered, was also raised. Potential solutions included a legal framework that established clear ownership and rights to carbon credits, the involvement of larger companies and organizations to offer credibility, a data verification framework and flexibility for farmers. The feedback generated from the workshop provided interesting insights into the areas of consensus and the areas which required further investigation and was further used in tailoring additional elements of the living lab.

Over the following weeks, follow-up meetings took place with a number of participants from the workshop in addition to meetings with individuals from other relevant organizations who had been unable to attend the workshop. These meetings yielded additional insights, allowed participants to expand on answers, and raise any further areas they may have considered since the workshop. Additionally, these meetings allowed us to confirm potential partners who could aid in the establishment or running of the living labs. Some of these meetings were also beneficial in terms of connecting with new partners, for example Carbery, a dairy processor currently involved in improving sustainability, facilitated an introduction with their data partner, the Carbon Harvesters team. Carbon Harvesters work in modelling and measuring emissions from Irish dairy farms was vital to alleviating some MRV concerns in the SmartDairy project.

4.3.2 Living Lab preparatory work

The establishment of the living lab to implement such a carbon market incorporated the input from the stakeholder workshop. The number of practices which could be implemented by farmers to yield carbon credits was limited to those which could be implemented and reliably and cost effectively measured within a year. Having established a relationship with the Carbon Harvesters project to measure individual farm GHG emissions, we established a list of 13 practices that could potentially be included in the living lab. These practices included: a reduction in fertiliser usage, the use of multispecies swards, a reduction feed concentrate, feeding cattle a native diet, a reduction in electricity consumption and fuel use, use of chemically amendments in slurry, Low Emission Slurry Spreading (LESS), spreading of all slurry in spring, use of protected urea in place of other chemical N fertiliser, extending the grazing season, increased milk quality and quantity, a reduced replacement rate and the use of anti-methanogenic feed additives. After further consideration about the feasibility of measuring emission reductions, a number of practices were eliminated. Extended grazing and the feeding of a native diet were rejected due to the difficulties involved in the monitoring these actions and the lack of peer reviewed method of measurement. LESS was excluded as the time it was scheduled to become a mandatory practice and thus any resulting credits would not meet the additionality test. Spring slurry, electricity consumption, and increased milk quality were all excluded as well due to various concerns around timelines and availability of information. This left six feasible practices deemed as being feasible to implement within the timeframe of the living labs and for which there is a reliable method of measurement and implementation: reduction of feed concentrate, switching to protected urea, reduced replacement rate, anti-methanogenic feed additives, use of chemically amended slurry and reduced use of N fertilizer.

Table 6 Mitigation Measures Initially Considered by SmartDairy Team and those Included in Living Lab

Mitigation Measure	Included in Final List of Measures
Anti-methanogenic feed additives	Yes
Extended grazing	No
Increased milk quality	No
Low Emission Slurry Spreading (LESS)	No
Multispecies swards	No
Native diet	No
Protected Urea	Yes
Reduced electricity and fuel consumption	No
Reduced feed concentrate	Yes
Reduced replacement rate	Yes
Reduction in fertiliser usage	Yes
Slurry chemical amendments	Yes
Spring slurry	No

In addition, carbon credits generated through sequestration practices such as the planting forestry or increasing hedgerows were considered. These kinds of credits were differentiated from the previous credits, as the above practices mitigate GHG emissions from entering the atmosphere and sequestration practices take emissions out of the atmosphere. Differences of input required and value between these two types of credits were discussed in depth at the stakeholder workshop. Payments structure for these sequestration credits was discussed. Particularly, if payments could be frontloaded or backloaded and the process of how payment could be recovered if the sequestration was found to have been non-permanent or reversed were points of discussion. Due to these concerns these sequestration practices were excluded from the living lab design.

To give our partners an idea of the financial burden required to purchase credits from our 10 living lab farmers, I estimated costs associated with implementing these mitigation practices. Using the Carbon Harvesters model of an average Irish dairy farm, as defined in Table 7, the CO_2eq tonnes of GHG which would be mitigated following the implementation of a mitigation practice could be calculated.

Table 7 Average Irish Dairy Farm - Model Specification

Average Irish Dairy Farm	
Mature cows:	93
Replacement rate:	22.00%
Size (ha):	66
Milk output (L/LU/y):	5700
Fat content:	4.22%
Protein content:	3.54%
Chemical N fertiliser use (Kg N/ha):	173
Feed tons (LU/y):	1
GHG emissions (tCO_2eq):	585

The 10% reduction in feed concentrate yielded the lowest reduction in emissions at 5 tonnes, while the highest performing practice was the switch to protected urea which saw a reduction of 22 tonnes of CO_2eq. While discussing the magnitude of N reduction, we decided the reduction of N content should have two levels: one at which use in pastures was reduced by 10% while the other would require a 25% reduction in use in pastures. Both levels would require a 25% reduction in use on silage fields.

Having finalised the practices available for the farmers to choose from, I calculated the implementation costs for these practices. This would provide farmers with a basis for making financial decisions about which practices would be best for them to adopt and to assist in the setting of the price of carbon credits. The cost analysis encompassed the additional costs required to implement mitigation practices as well as cost reductions brought on by these practices, especially those that called for a reduction in inputs. These financial calculations did not account for any potential changes in milk production or changes in fat or protein content as these effects were too variable to predict with any accuracy. The purpose of these calculations was not to give farmers detailed information on the impact on their own farm but rather to provide a general overview of the approximate changes in income they could expect from participating in the living lab. These calculations were principally designed to assess potential financial implications for farmers who were unaware of the specific practices.

I first established the changes in costs associated with all practices without any additional revenues from credits. This allowed me to establish which practices were cost neutral, cost incurring, or cost saving without having to account for the variability in carbon credit price. Calculations for each of these practices varied in difficulty and complexity with some requiring simple percentage changes in current spending while others required calculations that are more detailed. An example of simple calculations is the case of reducing the use of feed concentrates which required the calculation of the cost associated with the total concentrate use and reducing this by 10%. An example of a practice requiring detailed calculations is the 100% switch to protected urea which involved calculating the current application of N per hectare given the proportional use of Calcium Ammonium Nitrate (CAN), protected urea and conventional urea. Having determined the N usage, the quantity of protected urea required to maintain this amount was derived and the cost of the protected urea calculated. The cost of the new level of protected urea was subtracted from the previous total cost of fertilizer. Appendix 1 provides a detailed explanation of all calculations. Table 8 provides a breakdown of six mitigation practices, their requirements, the estimated number of tonnes of mitigated CO_2eq per practice and the changes in farm costs associated with the implementation of the practice.

Table 8 SmartDairy Mitigation Practices and Cost Implications

Practice	Requirements	Mitigation (tCO_2eq)	Cost Impact (Cost reduction in black, cost increases in red)
Low N reduction	10% reduction in pastures 25% reduction in silage ground	13	€4,105
High N reduction	25% reduction in pastures 25% reduction in silage ground	19	€7,077
Slurry Chemical Amendment	90% reduction in methane and ammonia	21	€2,120
Anti-methanogenic Feed Additive		9	€1,163
Lower replacement rate	Lower rate to 20%	9	€1,538
Protected Urea	Switch from Urea and CAN to Protected Urea	22	€3,242
Reduce feed concentrate	Reduce usage by 10%	5	€4,364

Given the calculated costs, I also calculated costs per litre of milk in order to provide another means of measurement that would be easily understood by farmers. Using the model of 93 cows per farm each producing 5,700L per annum this generated an average farm output of 530,100L per annum. Dividing the measures' costs by this amount generated costs of 0.4 - 0.6 cents per litre for the slurry amendment, 0.22 - 0.44 cents per litre for the feed additive, 0.15 cents per litre for the lower replacement rate in the first year and 1.2 cents per litre for use of protected urea.

During the process to establish the living labs, discussions were held on the price to be offered for the carbon credits generated by the participating farmers. The price level did change depending on the exact nature of the payment process. Initial considerations were for an open market system where farmers would offer their credits for sale at a given price, which could then be negotiated between buyer companies and the farmer. This was not viable due to lack of knowledge from both farmers and potential buyers of the value of carbon credits. As a result, there was no appetite to sign up to a process whereby the return on work carried out was not clear and potentially loss-making if the negotiations were not favourable. This required a change to a new structure of market to mitigate stakeholders' concerns regarding financial risks. Additionally, a financial partner for the project was required to process payments, as there was no platform available to handle this sort of fund transfer. At this point discussions had begun with a financial partner who would process payments. This system involved the purchase of the credits from the farmer by the financial institution, who would then sell the credits to their clients. This system helped alleviate the financial risk that was detrimental to earlier development designs. Credits were initially valued at €100, for the purpose of our calculations, following discussions with our partners; this was adjusted to €75. Establishing a value for credits was difficult, particularly due to the lack of existing data to draw upon. The EU ETS was able to provide us with an upper estimate of the price for credits however given the various factors involved with agricultural credits in terms of transparency and value and a smaller potential market, particularly if sales were limited to Irish companies within the agri-food sector. Additionally, there was discussion of the price offered to farmers and the price of purchase by firms and the difference between those levels. Following the withdrawal of the financial partner from the project due to internal restructuring, we began negotiations with another bank to take over this role. At this point no value was assigned to the credits, with the market rate and the costs involved to generate the credits deemed to be the deciding factors in calculating this value.

Table 9 Required Price Per Carbon Credit to Meet Costs of Practices Which Are Currently Loss Making

Input cost	Slurry Amendment	Feed Additive
Low	€101	€129
Medium	€126	€194
High	€151	€258

Fortunately, one of the participants of the initial stakeholder workshop, AIB, a financial institution, were interested in joining the project as a partner after the withdrawal of our previous financial partner. This new partner saw the project as an opportunity for them to make progress in the area of sustainability and GHG emissions. While there was a willingness to engage in the living labs, the requirement to receive sign off from various levels of management, slowed progress in establishing the living labs. This delay was particularly detrimental due to the tight timelines involved in the SmartDairy project with the living labs aspect scheduled to take approximately 12 months. Approval was required from the management team of the financial institution as well as from additional partners involved. The proposal by the new financial partner would have seen a dairy processor come on board with the project, and their involvement required additional meetings to establish project parameters and approve their involvement. Given this prolonged process, the time period in which we had aimed to launch the living labs, when farmers were least busy on the farm, had unfortunately elapsed. Given the timelines of the project, deferring until the next year was not possible and thus the living labs were unable to be established.

4.4 Lessons Learned and Discussion

While the work carried out to establish the SmartDairy living labs did not yield a voluntary carbon market as planned, it did provide valuable insight into the difficulties and challenges involved in establishing living labs. It illustrated:

- the need for concrete and committed partnerships
- the importance of maintaining relationships with stakeholders
- the need to assess the level of knowledge in a topic
- the difficulties in financing living labs
- the significance of the geographic spread of living labs.

These insights can benefit researchers attempting to establish living labs in the future. While some of the lessons learned during this project are specific to the areas of sustainability or agriculture, others are applicable to living labs across a wide range of fields.

4.4.1 Project Partnerships

The primary reason for the delay in enacting the SmartDairy living labs was unforeseen logistical difficulties that arose with one of the key project partners, who was the financial partner, and the subsequent need to develop a new relationship with another financial partner. Given the nature of working with a large bank as a financial partner, a significant amount of deliberation and bureaucracy was needed before approval to join the project was granted. Ultimately, approval was not received in time to launch the living labs. Following the withdrawal of the first partner, establishing a new relationship with another was difficult during the project's remaining timeframe. This financial partner is an example of an 'enabler partner' (Westerlund and Leminen, 2011), without which the living lab cannot function. For this reason, future living labs should establish partnerships, especially partnerships vital to the completion of the living lab, from the outset by including these partners as active members within project proposals and funding requests. Secondly, potential alternative partners should be identified, and appropriate relationships maintained with them should a situation arise in which they are required. Following the withdrawal of our initial partner, the SmartDairy team was fortunately able to pivot and develop a relationship with another interested partner as communication had been maintained with this partner since the initial phases of living lab development.

An additional reason for the slowing of progress was mission creep within the living lab. Although the purpose of the living lab was the establishment of a voluntary carbon market, whereby farmers could financially benefit from implementing carbon mitigation practices, expanding the limits of the market was discussed. Other project partners sought to discuss the expansion of the market to allow for carbon sequestration credits and the inclusion of biodiversity credits alongside carbon credits. While the inclusion of biodiversity credits was of interest to the SmartDairy team and would make for an interesting living lab, the introduction of carbon sequestration was out of the feasible scope of the SmartDairy project.

4.4.2 Factors Limiting Involvement

Given the importance of the sustainability debate in agriculture, there was no shortage of individuals willing to engage on the issue. The role of agriculture in GHG emissions and need for their reduction is common knowledge however some participants felt they had little in-depth knowledge of the issue. Many actors had strong views but felt they did not have insight into all aspects of the situation. By bringing together stakeholders in a workshop, we were able to assess current knowledge levels, facilitate stakeholder engagement, and share insight and expertise. The ideas and insights generated by workshop participants facilitated the design of the next stages of the living labs and provided some key issues to be addressed. The workshop was also successful in developing and strengthening relationships with stakeholders. Strong relations with stakeholders are key for living labs, especially stakeholders key to their operation and responsible for the generation of solutions. In future living labs, holding an additional number of workshops may be beneficial, particularly in the area of agriculture, as farmers may be unable to travel longer distances to participate. In addition, given the location specific issues in agriculture, stakeholders in different parts of the country may identify different issues or challenges. Although this is less likely to be the case in Ireland given its relatively small size, it may be worth consideration for living labs in larger countries with greater variation in climate or landscape. It may also be worthwhile conducting a secondary workshop with the original participants as subsequent meetings with participants were shown to provide them with time to think in greater detail about the topic, develop responses to issues raised by others, and to discuss the workshop with colleagues who could generate ideas that were not present at the initial workshop. Thus, holding a secondary workshop could allow for additional ideas, and progression of the innovation process. Further workshops could allow for greater exploration of ideas which may be discarded or temporarily set aside and allow for the creation of additional co-benefits.

An additional issue to bear in mind when planning living labs in the agricultural sector, is farmer availability will be dependent on the time of year and weather conditions, as it will affect their workload and thus ability to participate in workshops, talks and demonstrations. In Ireland, given spring calving, farmers have very little free time to dedicate to areas such as living labs during the spring months and dependent on the level of rain and grass growth effecting the availability of feed, farmers may not have the time or resources to devote to the living labs at other times of the year. Targeting workshops and other activities towards times of the year when farmers schedules are slightly more relaxed and farmers are not busy with duties such as calving or cutting silage which are time sensitive is also important and may allow for additional participation.

While we found a high level of willingness to engage in discussions about the issues of GHG emissions and agriculture, and many stakeholders asked to be informed of the project's progression, few stakeholders were able to de directly involved as project partners. This may have been due to a lack of expertise or in the case of those involved in the measurement of GHG emissions, unable to provide their services at a cost-effective level. While stakeholders were willing to engage in idea generation and planning schemes, providing the tools to carry out measurement could in many cases not be provided at a feasible cost for the SmartDairy project, for whom like many living labs, issues arose with financing.

4.4.3 Financing Living Labs

The initial design for the carbon market involved the creation of an online portal through which farmers could sell their emissions reductions in the form of credits. This proposal was later amended to a system whereby a financial partner would purchase the credits and sell them to its clients, limiting the risk exposure of both farmers and buyers. This also allowed for the credits and thus emissions reductions to remain within the Irish agriculture sector as the financial partners would only sell credits within the dairy supply chain, which was a redline identified by farmers in the stakeholder workshop. An alternative design considered the purchase of the credits by a dairy co-operative or milk processor who would hold the credits as a form of insetting. Not all living labs will involve financing or require payments however this was a large element of the SmartDairy living labs, the potential difficulties should be considered if a living lab requires financial transactions.

While other living labs have not attempted to test the feasibility of carbon markets and thus have not needed to facilitate payments to participants, financing of living labs is a recognised issue. Gualandi & Romme (2019) discuss the issues associated with living labs finances and potential solutions. They identify the majority of funding as deriving from research grants and government funding and thus living labs end when funding expires. While living labs can generate economic and business value, much of their output is 'public value' which enhances individual, community or environmental wellbeing and it is difficult for living labs to convert this value into a viable business model (Gualandi and L. Romme, 2019). They develop a 'framework for financial stability' with four potential funding streams: pay per service, subsidies, out of network funds and cross financing. Unfortunately, the majority of these methods focus on living labs which generate products for end users and thus have equipment which may be used to generate this income, and so are not applicable to the SmartDairy project. The finance streams available under this framework would primarily be out of network funds which involves applying to additional funding calls and grant schemes.

Another element of the voluntary carbon market which was not settled was the price of credits. This was due to a lack of data. We found in interviews with both farmers and industry that although there was a willingness to engage in the carbon market, there was little knowledge of credit pricing. The work done in calculating the costs involved in implementing mitigation practices provided some insights as did the two surveys carried out by the SmartDairy team, which analysed the price level at which farmers would be willing to buy and sell credits in a cap-and-trade system, and the willingness to pay of consumers for climate smart dairy.

4.4.4 Living Lab Locations

In the case of other living lab projects, many labs were conducted across a range of sites, often across multiple countries such as the FUSILLI project that is taking place in 12 cities across 11 countries and the UNaLab project that took place in 3 cities in different countries. This allows these projects to progress even if difficulties were experienced in one particular location. While the SmartDairy project was a multinational one, the element of living labs took place only in Ireland. Allowing for a range of related living labs to explore different dimensions of the same topic may be more resilient than a number of interconnected living lab sites relying on the same structure. As well as the structures and partnerships within different cities, regions and countries facilitating the possibility of exploring various living lab permutations, in the case of agricultural living labs, spreading living lab sites geographically also allows to encompass a greater number of areas with different climates and conditions, such as in the Soil Mission Support living labs which took place in 8 different countries and allowed for the testing and improving of soil health in a range of conditions. The UNaLab project which established ULLs focusing on nature-based solutions (NBS) noted that each of the cities chosen for their projects were unique with varying ecosystems of differing levels of complexity and linked to each other in a number of ways (Campillia & Titla, 2019).

4.4.5 Building on Existing Resources

Another element of our living labs which could be improved upon if we were to start again is to better leverage existing resources. We carried out significant work with our partners in devising a set of practices which we could reliably measure and estimating emissions reductions and the cost implications of these measures. However, it would have been more efficient to utilise existing tools such as the Teagasc MACC (Lanigan et al., 2023) and invest our time in other areas such as participant recruitment. This may have allowed us to make more progress. As well as smoothing progress this may also generate additional confidence in farmer participants who may see figures from agricultural agencies, such as Teagasc, with whom they have existing strong relationships as more reliable. This is an area noted by the AgriLink project for the importance of tying-in existing work by trusted organisations when working with farmers.

As well as using existing tools and resources, it is important to leverage existing relationships and notable individuals within agriculture living labs in particular. As noted earlier, one of the key elements of living labs is the engagement of stakeholders in all aspects of the innovation process. Within an agricultural living lab given results of the living lab may affect farmers' livelihood, it is important that trusted stakeholders are brought in to ensure peace of mind that all potential impacts are given due consideration. To this end it can be important to ensure researchers and academics are drawn from an interdisciplinary pool and local public sector official and farmer representative bodies should be well represented (Cascone et al., 2024).

4.5 Recommendations for Future Living Labs

As previously stated, living labs can vary greatly from one project to the next, with their structures, participants and timelines adaptable to the challenge they are tasked to solve. As a result, methods of conducting living labs cannot be prescribed as they may not fit the conditions of any given challenge, location or population, however some advisory recommendations can be provided which can be borne in mind should the conditions and implemented should the conditions present in your living lab allow for it. Some of these recommendations refer to the planning period before a living lab is implemented while others refer to the active duration of the living lab.

Leverage existing resources

At the beginning of any potential new research project, it is important to understand the research which has been done to-date and the resources available concerning a given topic. It is important not only to be aware of these but also to leverage them to their fullest potential. Existing ideas and technologies may be built upon in a previously unknown way, but this cannot be done unless living lab participants are aware the current situation. Ensuring that work is not replicated unnecessarily is of benefit.

Define a geographic area

Where possible a living labs geographic scope should be defined early in the process in order to allow for time and resources to be spent as efficiently as possible. As well as different types of stakeholders being present in different locations, each stakeholder type may have different concerns and attitudes dependent on the area in which they are based. Establishing whether a living lab should operate across a country, in a single region or in multiple sites across a number of regions can help narrow the focus of work and minimize the work done which may later be discarded. This will allow stakeholders to be more easily identified and engaged. While this recommendation is aimed particularly at those living labs whose target is a large industry or sector of society present across a nation, it may also be of use in other areas such as Urban Living Labs in terms of narrowing down specific areas or communities that are to be focused on.

Distinguish between partners and stakeholders

While a living lab cannot function without the involvement of stakeholders, and as great a number of stakeholders as possible from as wide a range of backgrounds as possible is recommended, there is a distinction between living lab stakeholders and project partners. While project partners are themselves stakeholders in the subject matter of the living lab, they offer an additional expertise and are responsible in some way for the delivery of the living lab. They provide a service of some form, which allows the living lab to succeed. While some partnerships may be planned in advance of the living labs commencement, others will form naturally as the living lab progresses. Identifying theses partners in advance and being able to spot and nourish potential partnerships is of great importance.

Be adaptable

Living labs are formed to combat a complex issue, so it is not surprising that difficulties and challenges may emerge over the course of the living labs life. Ensuring that the project team are adaptable and rise to meet challenges they face, is important to ensure the success of the living lab.

Identify potential sources of funding

While some living labs may serve only as a short-term tool to find a solution to a problem, others wish to continue in operation implementing that solution once it has been found. In order to do so it is important to identify potential sources of finance to fund the activities of the living lab and its outputs once initial research funding has expired.

4.6 Broader Public Policy Considerations

In addition to the recommendations for future Living Labs, this experience also provides some insight into broader public policy in the environmental and agricultural sectors.

While the implementation of the SmartDairy Living Labs were stalled as the result of issues with various industry partners, as discussed in detail above, the willingness of farmers to engage in the process was not in doubt during the project. From the outset farmers had made themselves available to participate in the Living Labs and this willingness to participate did not wane during the process. As a result, when considering the establishment of schemes in this sector in the future, the willingness of farmers to engage positively and constructively should not be underestimated.

This experience also highlighted that demand is present for climate mitigation schemes rather than just climate adaptation. Farmers wish to reduce their negative impact on the environment rather than put measures in place after the climate has worsened. This desire to engage in climate mitigation should be encouraged and tapped into, be it through schemes and programmes involving mitigation measures or sequestration.

A variety of tools, techniques and technologies have been and are being researched in under to identify methods of reducing GHG emissions in the dairy industry as well as the wider agricultural sector. As well as examining these tools for emission reductions, it is important to understand farmers' reasons for taking up these tools and particularly their reasons for not utilizing these tools. Understanding why particular methods are used increases the effectiveness of these methods and may be used to better focus the promotion of various methods.

Understanding farmers' motivations for implementing measures may also assist in unlocking synergies between techniques and technologies. When considering the range of mitigation measures, having measures which interacted with one another was viewed as important in order to provide insight into why a farmer may choose to implement one measure, such as increased use of protected urea, but not another such as decreased use of chemical N fertiliser.

4.7 Conclusion

One of the objectives of the SmartDairy project team in Ireland was to utilise living labs in the agricultural sector in order to test the viability of voluntary carbon markets as a mechanism to reduce GHG emissions. This chapter has examined the work done to that end, alongside a review of the literature surrounding living labs, and some of the difficulties and challenges encountered both within the SmartDairy project and from other living labs, with the goal of identifying areas to be addressed in any potential follow-up project in this area.

The varied nature of living labs means a set structure is difficult to define as projects may vary greatly in geographic scope, participant numbers and time horizon among other factors. The AgriLink Living Lab advises that no two living labs are the same and each must be designed and understood in their own right. The uniqueness of living labs is derived from their being tailor-made for a given problem, with their operation and insights a result of its circumstances and the combination of stakeholders and participants. As a result, it is difficult to plan living labs with a great level of detail or certainty. Indeed one of the unique selling points of living labs is that it is project participants rather than organisers who determine the direction of the living labs and to some degree, the speed at which progress is made.

While the SmartDairy goal of a living lab in the Irish agricultural sector examining the potential of a voluntary carbon market did not come to fruition, the work done to prepare for this may yield some insights for the future for research examining both carbon pricing in Ireland and those wishing to carry out living labs.

Living labs remain an interesting platform to deliver innovative solutions to complex problems. Their successful implementation is difficult requiring buy-in from a range of stakeholders who may feel disengaged from research and policy creation. Emphasizing the common discussion, idea generation, and planning elements of the process may increase the willingness of stakeholders to participate. Living labs are most useful when as many constructive thoughts and opinions are gathered and utilised as possible.

5. Stakeholder Interviews

5.1 Introduction

In order to best draft new policies to either encourage voluntary uptake of emissions mitigating measures or enforce the uptake of emissions mitigating measures within the agricultural sector and dairy industry, it is vital to understand the needs, and desires of potential participants. Buy-in from all levels of the sector will be required in particular from farmers themselves. As a result, getting feedback from farmers and other stakeholders is vital to ensure any scheme is designed and implemented with effective methods of emissions reduction. Any strategy, scheme, grant or measure put in place, whether by government or industry, will require significant uptake to be effective. This uptake is best brought about by accounting for stakeholders' current realities and concerns. In order to ascertain what some of the difficulties specific to the Irish agricultural sector might be, I carried out a number of interviews with Irish dairy farmers and relevant stakeholders. This chapter examines those interviews and seeks to ask whether carbon markets will be accepted by farmers and stakeholders within the industry and if so, how they believe that tool should function.

5.2 Background

Eliciting farmers' attitudes towards climate change and means of addressing it are important in order to understand the nature of their beliefs and the nuances that could cause sustainability approaches to succeed or fail. Farmers' attitudes towards sustainability can affect the level of participation in and the success of emissions reduction schemes such as a voluntary carbon market. While a number of schemes have been implemented in Ireland over the years such as the Green, Low-Carbon, Agri-Environment scheme (GLAS) (DAFM, 2022b), the Agri-Climate Rural Environment scheme (ACRES) (DAFM, 2024b), Basic Income Support for Sustainability (BISS) (DAFM, 2024a) and the Targeted Agriculture Modernisation schemes (TAMS) (DAFM, 2024c), levels of enrolment in these schemes have varied. In 2024, in excess of 30,000 farmers applied for BISS (O'Brien, 2024b), while 9,000 applied for the expansion of ACRES (Mag Raollaigh, 2024c). These schemes vary in nature, BISS focused on general agriculture and ensuring farm viability while ACRES requires farmers to implement sustainability measures. While only 9,000 farmers applied to ACRES in 2024, this was more than double the 4,000 new places available on the scheme (Mag Raollaigh, 2024c), illustrating that farmers' demand to improve their farms' environmental impact may be greater than anticipated by government.

Voluntary schemes such as the Signpost Programme (Teagasc, 2023b) or GLAS, ACRES, and TAMS sit alongside compulsory government regulation such as the Nitrates Action Programme (Department of Agriculture, 2022), Environmental Impact Assessments (Department of Agriculture, 2023), and the Sustainable Use of Pesticides (Department of Agriculture, 2013). Bager and Proost (2002) discuss the differences between compulsory regulation, involving legislation and government finances, and voluntary regulation, whereby farmers are set targets to achieve by means they determine. They examine the case of Danish and Dutch farmers attempting to reduce pesticide use and conclude neither compulsory nor voluntary regulation will work in isolation but must be worked in tandem to generate the most efficient result. Thus, a well-designed voluntary carbon market working alongside existing government regulations could be a driver for emissions reductions in the dairy industry.

In establishing an oversight committee or a new body to implement a scheme, participant trust in that new oversight body is extremely important. Farmers' have increasingly shown dissatisfaction with government, both politicians and civil service (Mag Raollaigh, 2024b; Burns, 2021). The dissatisfaction with government has a number of causes; including a feeling from farmers of not being kept informed and in some cases being misled over issues such as the dairy exit scheme (Mag Raollaigh and O'Sullivan, 2024) and what is seen is an insufficient effort to ensure that Irish agriculture retain the EU nitrates derogation (O'Brien and Gleeson, 2023; Ní Aodha, 2023). The loss of the nitrates derogation is however just the latest policy position which has irritated farmers, with a large degree of unhappiness due to Irish dairy farmers being encouraged to expand production by the government in the 2010's and current discussions now focusing on limiting the sector due to its emissions. Having met with farmers and their representative organisations throughout the course of the SmartDairy project, the feeling amongst farmers is that they feel let down, having invested in their herd and facilities and potentially losing out now if a reduction is required. Additionally, there has been unhappiness with the administration of certain schemes particularly those involving forestry due to what farmers feel are rigid rules, which don't allow for the reality of farming.

Farmers feel under additional pressure given a number of circumstances over the last few years that have impacted the sector, including both national and European policy decisions and global economic factors. Issues such as Brexit and the Russian invasion of Ukraine, have presented difficulties in Irish agriculture such as the rapid increase in the cost of fertilizer, feed and energy (O'Brien, 2024a; Maguire, 2023). Fodder crises have occurred and may potentially occur this year, due to alternating unseasonably dry and unseasonably wet weather. In a survey carried out by the ICMSA, over half of farmers (54%) anticipate that they will not have sufficient feed for all their animals (Hurson, 2024). Brennan et al. (2022) found that the main issues reported to invoke stress in farmers are poor weather, workload and financial worries. They found dairy farmers to be the group most likely to feel stressed with nearly 75% reporting so compared with57% of all farmers. Additionally, the sector had come in for increased criticism following the publication of an investigative broadcast examining the treatment of dairy bull calves (Shouldice, 2023). The pollution of Lough Neagh in Northern Ireland, the largest lake on the island of Ireland, has also drawn attention to issues of water quality and fertiliser run-off on farms (McClements, 2023). Farmers in Ireland are not alone in feeling frustration with climate targets and sustainability policies with protests seen across Europe, notably in France (Berlinger, 2024), Belgium (Casert and Carlson, 2024) and the Netherlands (Tullis, 2023).

While the exact motivations behind the protests were different in each country (Mag Raollaigh, 2024a), they all stemmed from farmers' belief that governments were making farming more difficult and less profitable. Given the concerns regarding farm profitability currently being voiced by farmers and that a low or non-existent return on investment has been identified as a barrier to the adoption of sustainable farming practices (Follett et al., 2024), a carbon market which generates a return for farmers may be viewed favourably by farmers. While dairy farming is the most profitable farm type in Ireland, recording the highest Family Farm Income (FFI) each year in the Teagasc National Farm Survey (NFS), it has become increasingly volatile with drastic shifts in FFI from year to year. Figure 10 shows the average FFI reported by dairy farmers in the NFS each year between 2014 and 2023. While 2021 and in particular, 2022 saw substantial increases in FFI, in 2023 it fell dramatically to its lowest level since 2016. Thus, having an additional revenue stream independent of milk prices could provide farmers with reassurance.

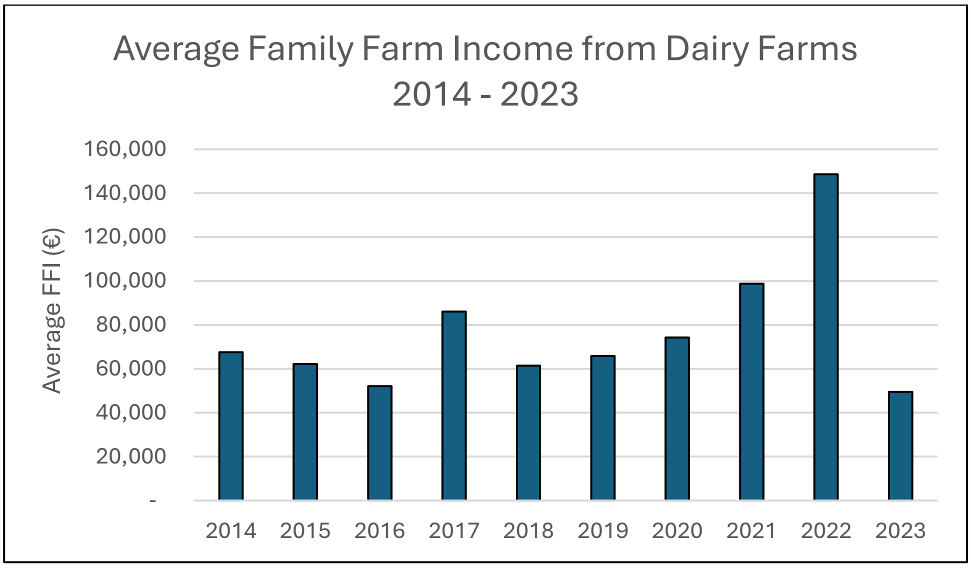

Figure 10 Average Family Farm Income from Dairy Farms 2014 - 2023

5.3 Methodology

5.3.1 Creating the Interview Guide

A semi-structured interview format was developed for this study due to the advantage of this format in maintaining a general approach to the collective interviews while allowing divergence on issues (Monday, 2020; O'Keeffe et al., 2016). Ahead of conducting the interviews, I developed an interview guide in order to ensure certain key topics were discussed in each interview. This allowed participants to spend more or less time focusing on a specific area or issue as they wished while ensuring participant responses could be compared. Interview participants were asked about their thoughts on the level of sustainability of the Irish dairy sector in order to gain a baseline on their belief in the level of change required in the dairy industry. While it was anticipated that many participants would believe that Irish dairy is sustainable, the level of belief and whether participants included caveats or praised any particular aspect of the industry was of interest. I also asked participants their thoughts on the possibility of the Irish government achieving the 2030 emissions reduction targets to assess participant's knowledge of the sectoral emissions ceiling as well as their thoughts on the progress to meeting it. This question did not specify either overall targets or specifically pertaining to agriculture allowing interviewees to address either or both areas as desired. Of interest was also whether farmers belief in whether or not climate targets would be met, further motivated them to engage in sustainability or made them less inclined to engage in sustainability, due to a belief that to do so would be futile.

The next several questions were based on living labs, allowing me to assess participants' familiarity and willingness to engage with living labs. Participants were asked if they would be happy to see them involved in a living lab to assess farmers' levels of trust in various bodies and organisations. This question was first asked as an open-ended question, however if farmers were hesitant or unable to answer a number of examples which they may accept or reject was provided. Examples included both specific organisations such as Teagasc or the Department of Agriculture or more general organisational groups such as co-ops, universities or feed producers. Rust et al. (2021) assesses the level of farmers' trust in various information sources, with level of empathy for farmers and source of funding seen as key criteria to judge trustworthiness. Rather than any external stakeholder, other farmers are deemed as the most trustworthy group. Given that one of the goals of the living labs was for participant farmers to share their experiences with other farmers, assessing if Rust et al.'s findings apply to Irish farmers was of interest. Knowing the trust farmers place in various stakeholders is of interest both in terms of applying living labs to the agricultural sector in the future as well as in other forms of schemes. Knowing the groups and individuals farmers view as most honest and reliable can improve how schemes might be communicated in the future.

From this point onwards I begin to specifically focus on the matter of carbon markets, initially on voluntary carbon markets (VCMs), including their level of knowledge of VCMs, their willingness to participate in a VCM, and their assessment of whether other farmers would be willing to participate. I also asked them to nominate an individual or group(s) who might be tasked with the operation of a VCM in the Irish dairy sector in order to ensure MRV procedures were applied. Given that in designing the SmartDairy living labs and carbon market one of the issues that required deliberation and discussion was the pricing of carbon credits, I asked interview participants whether they had any knowledge of the price at which credits were likely to sell on the market. By asking interview participants their level of knowledge of carbon markets and various aspects of carbon markets such as price levels, this allowed us to establish a relative baseline of knowledge within the sector on the topic.

This can be useful in determining the specific areas, which are most and least understood and should be focused on when tailoring future communications plans should a scheme or pilot in this area be developed.

I then began to ask about another form of carbon market: a cap-and-trade scheme, and how farmers would likely react to its hypothetical introduction. Of interest in this question was not only the attitudes of farmers but also the magnitude. These could then be compared to previous responses regarding the voluntary carbon market. Given that while the government wishes to reduce GHG emissions in the dairy sector without compromising food security, of key importance was, whether the introduction of such a scheme would lead to farmers considering exiting the industry and potential impact on new entrants to the industry. Farmers were also asked whether if such a scheme were implemented soon, they would be in a position to buy or sell credits. This question aimed to have farmers assess their farm's GHG emissions as well as whether it would be above or below any potential emissions threshold. No emissions threshold was stated in the question so this allowed farmers to assess themselves against the emissions threshold they deemed most likely from government. The final question put to interview participants was whether they had any thoughts about additional approaches that could be enacted or should be emphasised by the government in order to help achieve 2030 emissions targets. This question served as a conclusion and allowed participants to either re-emphasise a point they believed to be important or to introduce new topics that had not been discussed up to that point.

Communication with farmers, industry experts and other stakeholders had raised a variety of insights, concerns and anecdotal experiences, however interviewing a sample of farmers and stakeholders allowed participants to explore areas in more depth and as the entire focus of a conversation rather than merely as one topic explored during a wider meeting, discussion or workshop. The interview guides prepared for both the farmer and stakeholder interview participants are in Appendix 2.

5.3.2 Recruitment of Interview Participants

Potential interview participants were identified in a number of ways including through existing contacts of myself and other members of the SmartDairy team, knowledge of the Irish dairy industry and the actors involved, the list of participants in previous workshops, government committees, and steering groups such as the Food Vision Dairy panel and the Bureau VanDijk FAME database. These methods were used to generate a list of companies in Ireland operating within the agri-food sector. Having identified dairy industry stakeholders who could possibly provide insight into the areas I hoped to examine, I contacted these organizations to see if they were willing to participate in an interview, through email or phone call.

In order to seek a range of opinions from across the dairy supply chain, I categorized each contacted organisation by their position within the supply chain. These included processors, industry and farmer advocacy groups, input suppliers, retailers, regulation and research, and adjacent services. This allowed for a sense of feeling from across the supply chain rather than simply focusing on one end or the other. When contacting stakeholders, I introduced myself and the SmartDairy project and explained the content and general direction of the interview and why I felt they or their organisation could make a valuable contribution. In order to generate additional leads for interviews I employed a snowball technique whereby I asked those I contacted to consider any contacts they might have that could be of assistance, and to share these details if possible. This allowed those individuals who were unavailable or who felt they did not have the requisite expertise, to suggest contacts they had who they felt might be a good fit for the interview. This also allowed for organisations or individuals who I may not have previously come across to be made known to me. Of the 53 non-farmer individuals and organisations, I contacted, 5 were interviewed, 6 responded expressing interest in the interview or requesting more information but were ultimately unavailable for interview, 5 responded that they would be unable to assist, and from the remaining 37, I did not receive a reply. The number of organisations contacted from each category are listed in Table 10.

Table 10 Categorisation of organisations and individuals contacted for interview

Row Labels	Count of Contacted	Count of Interviewed
End Use	12	
Farmer Representative Organisation	5	1
Finance	3	1
Processors & Co-op	10	2
Research & Government Oversight	9	
Small Food Producer	11	1
Supplier	2	
Journalism	1	
Grand Total	**53**	**5**

Identifying farmers to interview was a more difficult task. While most companies and organizations had contact details available on their websites, this method does not work for individual farmers. As a result, organisations either representing or working closely with farmers were contacted. While this request was sent to a number of organisations, the Irish Creamery and Milk Suppliers Association (ICMSA) was the most helpful. The farmers in this interview panel were drawn from farmers present at an ICMSA executive meeting in May 2024 in Limerick. Given the make-up of this panel, the interviews may not be representative of Irish dairy farmers as a whole, as interview participants would be more engaged with policy than most other farmers. At this meeting, I also utilised the snowball technique in asking farmers to share details of their peers who may have been interested in conducting an interview. Unfortunately, this did not yield any additional interviews.

A total of 12 interviews were conducted, 7 with farmers and 5 with non-farmer dairy industry stakeholders. The number of interviews conducted was determined by a number of factors including availability of participants, time constraints and added value from interview contributions. Miles (2019) suggests that complexity of the interviews, time availability and the size of the analysis team are the key factors in determining the number of cases on which to carry out analysis. He further suggests that 5 – 6 cases is generally sufficient if the analysis is sufficiently rich, while greater than 10 cases may be unwieldly. Eisenhardt (1989) concurs, expressing a belief that between 4 and 10 cases is generally sufficient to examine and that as well as time and monetary constraints, researchers must also bear in mind "theoretical saturation" whereby a point is reached where each additional interview provides minimal additional insight. The 12 interviews analysed in this paper fits well within the accepted sample sizes discussed in the literature as being at a minimum 4 and a maximum of 10 - 15 (Perry, 1998).

5.3.3 Conducting Interviews

When initiating interviews, participants were reminded of the scope of the interview and informed of the ways in which their answers would be utilized. It was made clear that their participation was voluntary and could be ended at any time. A privacy statement regarding user anonymity and data protection was accepted and permission was sought to record the interview. I informed them that while their insights would be used in analysis, they would not be attributed directly to them. In addition, for the stakeholder interviewees I clarified that while their experiences with their organisations, were providing them with the expertise to speak on the topic, they were not representing those organisations and their thoughts and opinions would be considered their own and not those of the organisation unless they stated otherwise.

Having been assisted in recruiting farmers for interview by the ICMSA, I attended a quarterly meeting of the ICMSA national executive committee where I interviewed a number of farmers. As a result, I had participants from all parts of the country. This included smaller farmers from less dairy intensive parts of the country as well as those from larger and more traditional milk producing counties. These interviews took place individually with the farmers outside the conference room, between sessions and presentations. For the stakeholder's interviews, all five interviewees opted for online interviews rather than in-person. These interviews took place at times suggested by the stakeholders between 24th April and 30th May, 2024.

5.4 Interview Analysis

Recorded interviews were transcribed both manually and with the use of the transcription service Parrot AI. All interviews transcribed with Parrot AI were reviewed manually to ensure accuracy of transcription.

Interviews were analysed alongside another member of the SmartDairy team, whereby the interviews were examined using content analysis in order to determine the trends and identify insights across the 12 interviews. This primarily involved a two-step process of initial individual assessment and then a secondary assessment once initial themes were identified. The initial individual assessment identified broad themes and topics within individual interviews, within the farmer interviews, stakeholder interviews and across the sample of 12 interviews. This was achieved through a process of 'coding' whereby themes and responses were identified and accounted for. Coding is important to allow for the creation of valid categories which may be compared (White and Marsh, 2006; Columbia, 2023). Following this, areas of common interest amongst participants were identified and reanalysed with a focus for these areas. This allowed focus to be put on any particular nuances that may have been missed during individual analysis, while also emphasising the areas which were most important. Having identified themes and areas of concern, this allowed direct comparison of thoughts expressed by the interviewees with one another. This allowed an assessment to be made of how important a topic was to an interview participant based both on the number of times the topic was discussed and also the length of time spent on a given topic. Comparisons and contrasts were both examined amongst individual interview participants as well as the groups of farmer and stakeholder.

Crucially, the content of the responses alone, was not the only matter of importance but also the general attitude and tone of the respondent towards a given question or concept. Of interest was not only an interviewee's specific language but also their strength of feeling with regard to a particular topic. Coding can account for this by identifying not just whether an issue is raised but the levels of engagement with the issue. Responses could be flagged as being particularly positive or negative with regards to an identified theme.

Interviews were re-read as many times as felt necessary in order to ensure topics had been identified and highlighted. This was also key in identifying subthemes as part of broader themes and patterns (Aronson, 1994). Notes made during this process served to easily demonstrate the areas most common to the interview sample as well as highlight where one interview may have diverged from the others in discussing a topic or theme. Reading and re-reading the texts which are being analysed is key to both become familiar with the material and to gain an understanding of the sample as a whole (Erlingsson and Brysiewicz, 2017; Mazaheri et al., 2013).

Having a clear understanding of the subject area and its background was key to undertaking this analysis. Rather than taking individuals respondents' views in isolation, a wider trend could be observed. Grouping these views together and identifying and observing these trends required an understanding not only of the main subject of carbon pricing but tangential issues which were likely to be raised such as renewable energy, farming incomes or the nitrates derogation.

While these interviews particularly examined farmer's attitudes towards carbon prices, in essence they can be likened to an examination of any producers attitude towards price incentives or additional regulatory burdens and fines. Accounting for the perspectives of the various participants was important, particularly in the case of the stakeholders. Ensuring that themes were readily identified across the sample but also that in cases where elements of the supply chain were in contrast to each other that this was noted.

5.5 Data

As previously mentioned, in identifying potential participants, I ensured voices from across the supply chain were heard. I received feedback from a range of sources, including co-operatives, industry, finance, small producers and farmer representatives. The area of expertise of each of the interviewed stakeholders can be seen in Table 12. The farmers who participated in the interview also represented a range of farmers in terms of farm size and herd size. Both young and older farmers participated as well as part-time, full-time and retired farmers. The farm and herd size of participating farmers can be seen in Table 11. The length of interviews varied considerably with the longest interview almost an hour in duration (59:14) while the shortest lasted just under 10 minutes (9:34). Stakeholder interviews were longer in duration with farmer interviews being between 9:34 and 19:22, while stakeholder interviews lasted considerably longer between 32:48 and 59:14 with a mean duration of 41 minutes and 42 seconds.

Table 11 Demographic and farm information for farmer interviewees

Farmer	Farm Size	No. of Cows Milked	No. of Years Farming	Full-time or Part-time	Expansion since 2015	Plans for future expansion
#1		40		Full-time	No	No
#2	110 ac	80	>30	Part-time Son farming full-time	Yes	
#3	100 ac	96	50	Retired	No	No
#4	150 ac	150	40	Full-time	Yes	No
#5	120 ac w/ 40 ac bad	85	55	Full-time	No	No – Currently reducing
#6	100 ac good 100 ac bad	80-90	15	Full-time	No	
#7	34 ha	50	10	Part-time	No	No

Table 12 Area of Expertise of Interviewed Stakeholders

Stakeholder	Area of Expertise
#1	Farmer Representation
#2	Sustainable Finance
#3	Dairy Industry and Processing
#4	Dairy Co-operatives
#5	Farming and Food Production

During the interviews with farmers, I asked what measures if any, they had enacted on farm in order to reduce their GHG emissions. The most commonly enacted mitigation measure was the use of protected urea which had been adopted by four farmers, with a reduction in the quantity of fertilizer used mentioned by three. A reduction in feed concentrates, use of a slurry amendment, solar power and a reduced herd size were each mentioned twice while sowing of clover, use of multi-species swards, improving EBI, planting of trees and installing a heat recovery system were each identified by a single farmer. The range of measures adopted by each farmer can be seen in Table 13.

Table 13 Categories of emission mitigating measures implemented by farmers

Practices / Farmer	1	2	3	4	5	6	7
Slurry Management	✓✓	✓		✓			
Feed Management				✓	✓		✓
Fertilizer Use		✓✓	✓✓	✓✓	✓		✓
Sward Management			✓				✓
Herd Reduction	✓	✓					
Genetics				✓			
Energy Management			✓		✓	✓	
Forestry					✓		

*Each tick mark represents one measure enacted within the wider group of practices

5.6 Potential Constraints in Sample

Prior to discussing the results of these interviews, it is important to understand the potential limitations of the sample and the impacts this may have on the results and how representative they are. There are two elements in particular which may have impacted the representativeness of this sample of interviews, the suitability of the data sample and the potential introduction of bias by the interviewer .

5.6.1 Suitability of the Sample

As discussed in section 5.3.2, the sample size of 12 farmers and stakeholders fits within the sample size recommended by the literature, however there are a few additional considerations which must be borne in mind. While the sample size is likely sufficient for the interviews which were carried out, the suitability and representativeness of the sample require additional discussion.

While there is a good geographic spread of the farmers in this interview, with the seven farmers from 5 different counties in 3 of the 4 provinces, this may in fact have slightly diminished the representativeness of the sample. The Irish dairy industry is heavily concentrated in the south of Ireland, particularly in the counties of Limerick, Cork and Tipperary. None of the sample were from these counties although other large dairy producing counties in the south of the country were represented. Given that many of the largest and most profitable dairy farms are located in counties not represented in the sample this may have resulted in the interview sample overrepresenting smaller and part-time farmers.

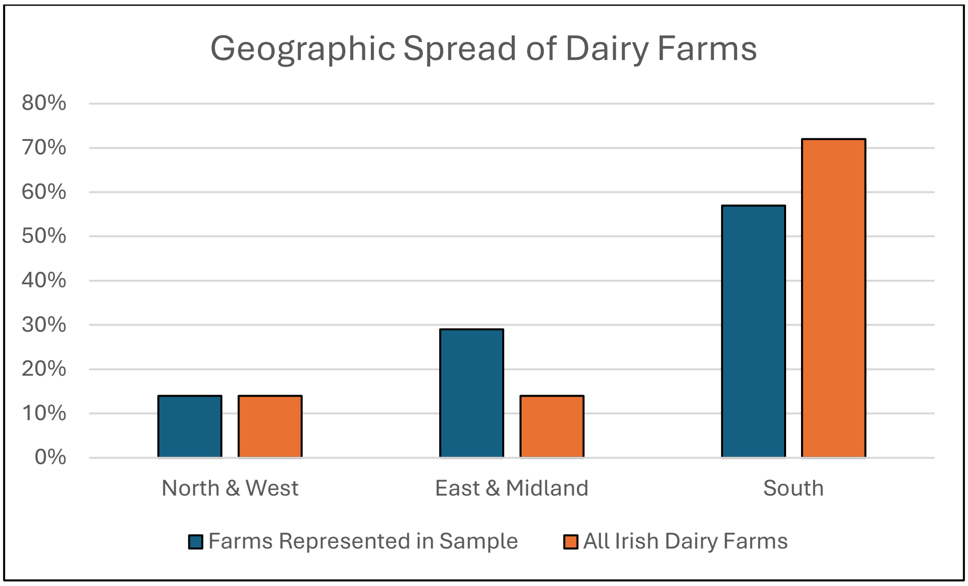

Figure 11 Geographic Spread of Dairy Farms in Ireland and within the Interview Sample (National Farmer Survey 2023)

One constraint in assembling the sample, is one which is common to many surveys and interview processes, the strength of feeling of the participants. Throughout this process, I reached out to individuals and organisations to determine whether they would be willing to participate in interviews. This may have led to a self-selection bias whereby participants who felt most strongly about the topic of carbon pricing, either in favour or against, may have been more likely to respond with an interest in being interviewed. Given that those with strong views may often influence the practices of others, understanding their perspective could be beneficial in developing future policies.

This may have also contributed to, in the case of the stakeholder interviews, some elements of the industry being heavily represented in the sample than others. In particular, members of industry bodies and representative organisations were more willing to engage in the interview process than individuals or businesses. Given that these organisations have a different outlook and approach, results and analysis must be carefully considered.

5.6.2 Potential Introduction of Bias

When conducting analysis of these interviews and drawing broader public policy considerations, it should be considered that some of the interviews may have been tainted by the introduction of bias. This potential introduction of bias was considered during interview analysis alongside the potential bias from self-selection of interview participants. Salazar (1990) suggests that unstructured interviews generally require a greater level of skill on the part of the interviewer due in part to the need to avoid the introduction of bias.

As detailed in the interview guide, which is available in Appendix 2, where respondents were not aware of or had limited knowledge a topic which was of importance to the interviews, such as voluntary carbon markets, a short definition of the topic was provided to them. This was to enable the interview to continue and allow respondents with a more limited understanding of the issue to give their thoughts.

While these definitions were carefully considered in order to impart the necessary knowledge of the topics while maintaining a neutral perspective, it is possible that bias may have been introduced to the interview process and some interviewees responses may have changed as a result. Responses may have been adjusted from interviewees true thoughts due to either the definition provided by the interviewer or the tone in which the definition was delivered.

Ensuring that interviewers are trained in interview techniques will improve the interview process and quality of response (Salazar, 1990). In preparing to conduct the interviews outlined in this paper, I was conscious of a number of issues such as the potential to impart bias either through providing additional information, phrasing of questions and non-verbal cues, each of which has been identified as a potential source of bias (Monday, 2020).

5.7 Results & Discussion

5.7.1 Environmental Attitudes

Both the tone and content of each of the twelve interviews established that there was a positive or neutral attitude towards environmentally sustainability amongst each of the interviewees. Of the seven farmers, two were neutral towards the concept while the remaining five had a positive attitude, while amongst the stakeholders two were deemed to express a positive attitude while three had a neutral outlook. That none of the twelve interview participants had a negative outlook on sustainability but rather offered criticisms or scepticism regarding policy areas was of interest and is reflected throughout the interviews.

Farmers regarded sustainability as an area of importance and acknowledged that farmers have a responsibility to the environment. This attitude is reflected each of the farmers listing at least one mitigation measure which they had adopted on farm, as documented in Table 13. Each of the farmers were also able to suggest additional measures that they would like to implement but were currently constrained from doing. The stakeholders each also acknowledged the necessity for the dairy industry to act sustainably and that there is currently capacity to improve the sustainability of the industry although, three of the five stakeholders stressed that environmental sustainability is only one aspect of sustainability. These stakeholders stressed that social sustainability and financial sustainability are also important and cannot be jeopardized in order to enhance environmental sustainability.

The interview participants were overwhelmingly positive in their assessment of the Irish dairy sector. Five farmers as well as all five stakeholders responded that Irish dairy was either sustainable or very sustainable and the remaining two farmers indicated that while the majority of dairy farms operate sustainably that a small number of farms were not. Farmer #2 indicated this was the case for farmers who “grew too big”, and idea with which Farmer #5 concurred, suggesting that those farms with a herd size of greater than two hundred cows are unlikely to be sustainable. Each of the five stakeholders as well as one of the farmers pointed out that Irish dairy is ranked favourably against dairy produced in other countries for sustainability.

5.7.2 Emissions Reduction Projections

While the interview participants had a positive attitude to Irish dairy sustainability, their projections for the overall sustainability of the Irish economy were less optimistic. While only a single interview participant expressed a belief that the Irish government would achieve its 2030 emission reduction targets, overall participants were bullish on how the agricultural sector would perform in comparison to other sectors. Participants expressed their belief that the agricultural sector would be the sector closest to achieving its target. A number of participants cited the energy and transportation sectors as amongst those who would most struggle to achieve the required reductions. Farmer #5 in particular focused on the aviation sector as driver of emissions which has to be curtailed, "The first thing they should be doing is tackling the airlines and they should be limiting the number of flights someone can take in a year because you know they're out there every day pumping out thousands of tonnes of emissions".

Three interviewees did offer a percentage emissions reduction they felt was likely in the agricultural sector. Farmer #4 suggested an 18% would be easily attained and this could potentially reach 20% although it would be difficult, Stakeholder #1 was in agreement with this, suggesting that the agricultural sector would reduce by approximately 19%. Farmer #7 was the only one of the opinion that emissions reduction targets would be met, predicting that 2030 emissions will fall by 27% compared to 2018. This prediction was however contingent on emissions from the agricultural sector being recalculated to what Farmer #7 believes is their true value, with current measurement being inflated. One observation which was made by two stakeholders is that emissions reduction is not likely to be linear and this could result in reductions being ‘back ended’ with the majority of emissions reduction occurring in the final years of the reduction period: "It could be very back-ended, even by 2027 it could look like we're going to miss the targets but we'll speed up out of necessity" (Stakeholder #2). Another stakeholder raised the same issue although as an area of concern, worried that ramping up emissions reductions in the last few years of the period could lead to new regulations being introduced that would undermine the viability of farms.

5.7.3 Attitudes to Carbon Markets

Having showcased a positive attitude towards sustainability and detailed the efforts made individually to address emissions on their own farms, each of the farmers expressed, as well as the stakeholders expressed an interest in learning more about voluntary carbon markets.

While carbon markets were a subject that the majority of participants (9) had heard of previously, there was very little existing knowledge of the issue. Where participants were aware of the issue, it was generally only on basic level, although the level of knowledge was greater amongst stakeholders compared to farmers. One farmer remarked he had not heard of the term but he could figure it out, “Not as such like but sure I know what carbon is” (Farmer #3). Farmers, however, understood quickly when offered a brief explanation and were able to spot areas of concern or expand upon the explanation I offered. Overall farmers were amenable to the concept of voluntary carbon markets but caveated an acceptance of them with a requirement to see any scheme specifics. “It’s something I’d have to find out more about but yes. Obviously, anything that reduces the amount [of GHG emissions] is good” - (Farmer #2). Farmers did not want to be locked into a scheme that they might later find did not work for them as anticipated. None of the seven farmers dismissed the idea of participating in a carbon market, although two of the seven did express scepticism of voluntary carbon markets.

Farmer #3 expressed scepticism that companies would become involved in a voluntary carbon market “Who’s going to buy it? There’s no one going to buy it”. This farmer did however suggest it was something he would like to see in operation and if there was appetite from firms, he would be willing to engage “I can’t see that one’ll do it but I’d like to see it happen”. Farmer #7 shared that he heard of carbon markets and seemed to be more familiar with the concept than the other farmers interviewed, however he had a negative perception of carbon markets viewing them as a “scam”. “[I’m] really familiar [with the concept of carbon markets]. My familiarity is that they’re more or less a scam”. This view was based on this farmer’s perception that companies would pay farmers not to engage in activities they had no intention of doing and thus gain carbon credits although no change was brought about. The example provided by this farmer was an airline that might pay him not to chop down trees which he had not planned to chop down. This farmer’s concerns highlight the issues of ‘greenwashing’ as well as additionality concerns and stressed the importance of transparent and rigid MRV procedures in any carbon market as well as the importance of communicating the importance of additionality to all participants. Farmer #7 was also however willing to join a potential carbon market although again with a caveat: “If it can deliver a return and is tangible with my farm practices without any additional cost to myself then yes [I would join]”.

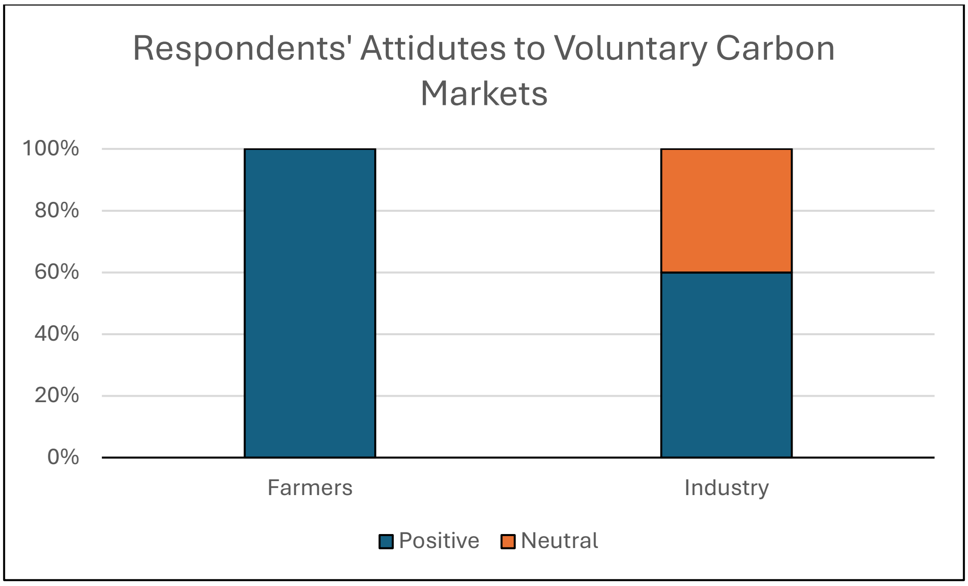

Figure 12 Respondents' Attitudes to Voluntary Carbon Markets

The two conditions most identified by farmers as being necessary for them to participate in a carbon market, were a reasonable workload without requiring a large amount of additional paperwork or navigating bureaucracy and having up to date scientific measurements. Four farmers identified workload as being a key deterrent to them implementing any new farm practices. Concerns regarding paperwork to be carried out to register for and take part in any new scheme were also raised. Farmer #6, who said he would consider participating in a voluntary carbon market, stated that "If it's adding an extra workload to me and I'm not getting a decent return from it … its worthless. […] We spend the whole time forming rather than farming". This view was echoed by Farmer #5 "The workload and the paperwork and the fact that you might have another fella coming inspecting you, and we have enough of those fellas". The issue of workload and managing time on farm is one which is becoming increasingly of concern to farmers (Beecher, 2023), with one of the sessions at the Teagasc National Dairy Conference in 2023 dedicated to this topic (Teagasc, 2023a).

Ensuring the science was up-to-date was also a view expressed by three farmers as well as four stakeholders. This view took three forms; additional measures were required to be researched as currently known measures are not sufficient, current areas of research such as feed additives require additional research and regulatory approval, and finally emissions generated from dairy farming need to be calculated as accurately as possible. This final point was made by one of the farmers who works off-farm in cattle genetics and by Stakeholder #3 our industry representative both of whom believe methane emissions are currently over-estimated and that they will be revised downwards in the near future, thus reducing the emissions attributed to the dairy sector and reducing the work required to fall below the sectoral emissions ceiling. An additional concern, which overlapped with the desire of farmers for the science of emissions mitigation to be up-to-date was the lack of acknowledgement or what was viewed as misreporting of current emissions mitigating measures which are being carried out by farmers. This particularly involved carbon sequestration in trees and hedgerows, and the generation of renewable electricity on farm. There was a view from both farmers and stakeholders that some actions carried out are not currently credited correctly with the state personally accounting for carbon sequestered in trees rather than it counting for individual farmers. Carbon farming is benefitting government rather than farmers. Farmer #4, when discussing mitigation measures he would be interested in enacting, stated he would rule out the planting of trees, as he wouldn't "get the benefit of them" as they would not be "allowed under the land use". Anecdotally, this was also a major concern of other farmers with whom I spoke but did not interview at the ICMSA meeting. The interviewees universally agreed any carbon market should allow for sequestration as well as mitigation measures, indicating there would likely be a greater uptake of forestry if regulations more easily allowed for it.

A common sentiment within the interview participants was that the way in which renewable energy is currently being regulated could be improved. Two of the farmers interviewed currently generate solar power on farm while another aims to install it in the future. However, they raised some concerns with how microgeneration is dealt with. Farmer #5 highlighted how the inability to sell excess electricity back to the national grid was damaging uptake, given the high initial cost to install solar panels. "The big problem for farmers you can put in all those panels. You have to have the money to do it. But then you can't sell it back" (Farmer #6). Stakeholder #3 also highlighted that current accounting does not incentivise renewable energy within the agricultural sector, as all electricity even when used entirely on farm is attributed to the energy sector. This does not incentivise farmers to produce low carbon electricity, as it will not reduce their farms carbon footprint. "Agriculture gets all the emissions, and every piece of electricity produced is given to the electricity bucket in current legislation. That's not just transition, that's not climate justice" (Stakeholder #3). Additionally, Stakeholder #4 highlighted the lack of development on the government's behalf in biomethane energy specifically anaerobic digestion. He laid out the timelines involved in publishing a biomethane strategy and constructing large-scale plants means biomethane processing plants and large-scale anaerobic digesters are unlikely to be operating before 2030. This was another source of frustration: the government does not seem willing to seriously acknowledge work done by farmers or firms in the agricultural sector to generate renewable energy rather than draw from the national grid which is still predominantly fossil fuel powered.

One interesting distinction between the farmer and stakeholder groups was their views of the factors most significant in carbon market participation from farmers. Amongst stakeholders when asked what level of participation they believed was likely amongst farmers, they stressed price as being the most important factor in determining participation rates. "Ultimately if there's money to be got, farmers will switch on pretty quickly" (Stakeholder #2). Farmers viewed this differently however and while they acknowledged revenue from carbon credits as an important consideration in determining participation, it was not the primary motivation with the previously mentioned workload, bureaucracy, and farmer independence seen as being of greater importance.

While farmers had expressed concern regarding the level of administrative work and bureaucracy involved in a potential voluntary carbon market, they were not outright opposed to regulation of the project, recognising that transparency and oversight are key aspects of carbon markets, "You can't just say I'm going to do this and not do anything. I wouldn't mind having people overseeing it" (Farmer #1). There were however some differences amongst farmers in who should be carrying out this oversight. While a consensus seems to be the main body responsible for this oversight should be the Irish government whether through the Department of Agriculture, Food and the Marine (DAFM) or the Department of Environment, Climate and Communications (DECC), feedback was generally that they should not be solely responsible but work in conjunction with other bodies such as co-operatives and farmer representative organisations. One farmer, Farmer #7, suggested that a new, non-governmental independent oversight body should be created similar in structure to bodies such as Bord Bia. Other farmers offered less specifics but suggested that governmentally and private bodies should be represented.

When farmers were asked about their potential participation in living labs, they were also asked what organisation they would like to be included or if there were any organisations they would like to see excluded from some a project. This question served as a means of assessing which bodies farmers had trust in and who they viewed as likely to be able to contribute to solutions to emissions management in the sector. The general approach from farmers was that they were happy to see all organisations have a seat at the table and share their views even if they felt there were some organisations with a greater level of insight and understanding than others were. Farmers were most receptive to the idea of Teagasc and farmer representative bodies such as the ICMSA and IFA participating, as they viewed these bodies of having a good knowledge of farming and the difficulties involved. While less enthusiastic towards them, farmers also suggested that DAFM would have a seat at the table in any such discussions or projects and although the attitudes toward DECC were even less positive, it was viewed that they too had the right to participate in any such discussions. The organisations that received the greatest pushback from farmers were universities. While farmers were happy to see agricultural colleges be involved, there was a more mixed reception towards non-agricultural third level institutions. While three farmers were happy to see them involved, two were not, with one suggesting that a college with specialism in agriculture should be involved but not the sector more broadly while the other was not in favour regardless.

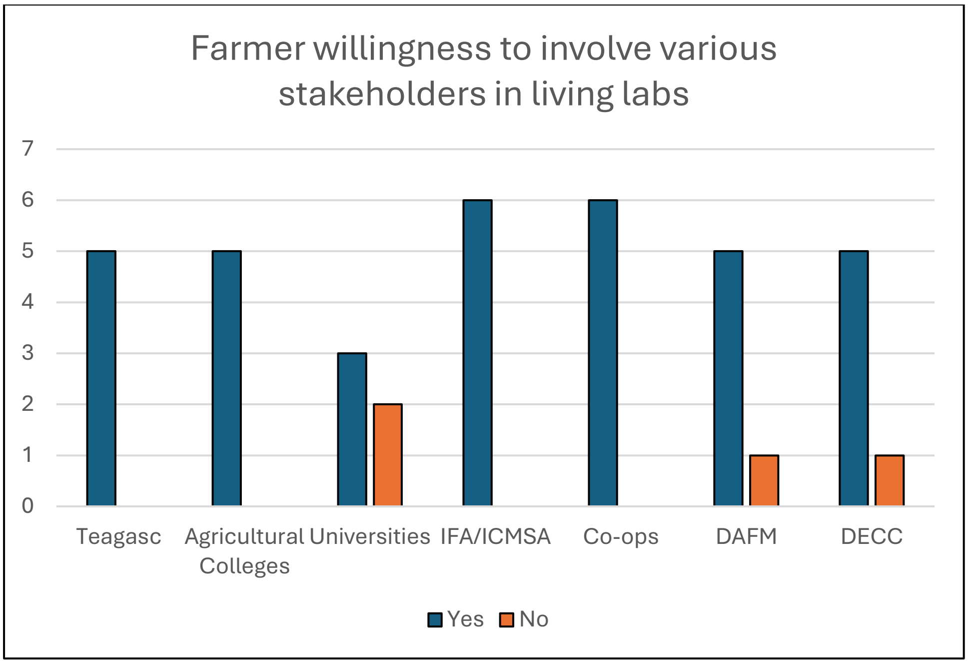

Figure 13 Farmer Willingness to Involve Stakeholders in Living Labs

These interviews were illuminating in terms of identifying farmers motivations for embracing voluntary environmental schemes. Farmers' willingness to engage in agri-environmental schemes has long been attributed to a variety of factors such as profit-maximising behaviour, farm characteristics and farmer attitudes (Cullen et al., 2020). Each of these factors was displayed by the farmers in the sample when asked to consider their participation, with regards to both living labs and to voluntary carbon markets. Additionally, these responses highlighted the risk averse nature of farmers and their desire to gather information before committing to an alternative approach to farming (Läpple, 2013).

While farmers had some concerns to be alleviated and required some additional details before they would commit to partaking in a voluntary carbon market, there was an underlying willingness to participate as a means of both reducing carbon emissions and increasing sustainability on farm, but also to potentially open an additional revenue stream. How large this potential revenue stream would be is however difficult to forecast. When put to farmers, few of them had an idea of the prices involved with trading carbon credits. While the majority of farmers simply responded that they did not know what the price level was, two farmers attempted to put a figure on this. Farmer #7 offered a figure in the region of €100 per tonne, suggesting that this was a price which had been floated in other countries while Farmer #4 suggested that carbon trading within industry has generated a price of roughly €200 and that agriculture would likely be similar.

This interview attempted to in small part gauge the receptiveness of various companies and industry stakeholders to purchase carbon credits from Irish dairy farmers, however this uptake was difficult to judge. Given that within the small sample size of stakeholders there were three representative bodies and two for-profit enterprises, this uptake is hard to estimate. This is due in part to the structure and rules governing representative bodies that strictly control how funds generated from members may be used. Stakeholder #4 clearly laid this out "We're a representative group so we don't A) have the structure and B) have the funds to do that [purchase carbon credits]."

While farmers' attitudes to voluntary carbon markets was positive although hesitant, their attitudes to compulsory markets were negative and decisively so. Only one of the seven farmers, Farmer #1, was supportive of the idea of a compulsory carbon market, with each of the six opposed suggesting its implementation would cause them to reconsider whether to continue farming. Of those opposed to the compulsory market, one was definite in stating he would cease farming while another stated that it would depend on his son's willingness to continue. The remaining four stated they would reconsider their position but did not indicate whether they were more likely to cease or continue farming. The most common criticism of this system was an over reliance on punishment rather than reward, with a view that it would significantly damage the dairy sector. The introduction of a cap-and-trade scheme was viewed by both farmers and stakeholders as something that would drive farmers to exit the sector and stop farming. This was viewed as particularly likely to occur amongst older farmers and those who did not have an established successor, "I meet people every day of the week with no family or family not interested in taking over [the farm] and anything like that will just push them out" (Farmer #2). One farmer took issue with the emissions cap being revised downward annually suggesting it was "moving the goalposts".

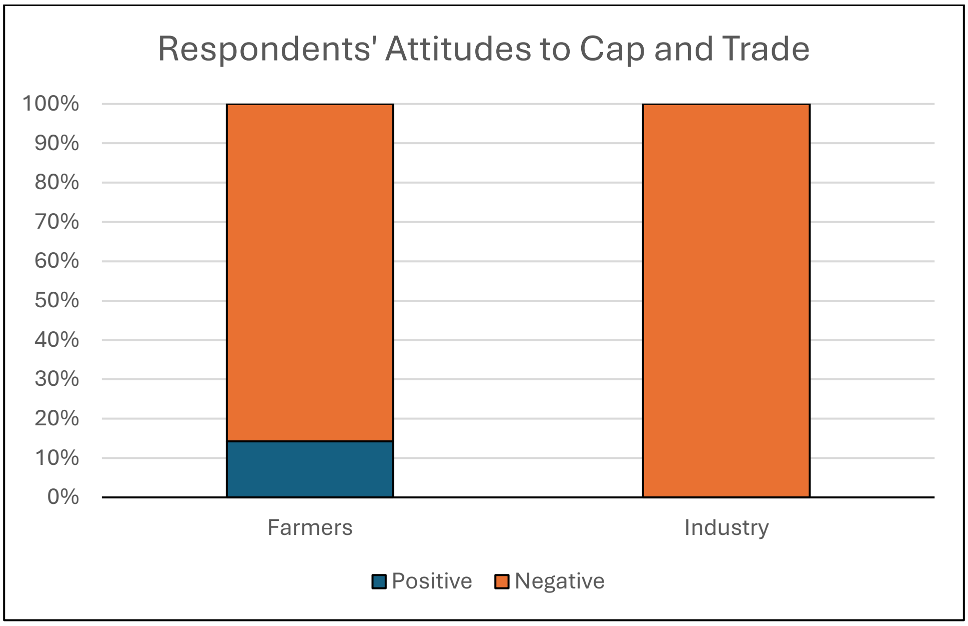

Figure 14 Respondents' Attitudes to Cap and Trade

5.7.4 Alternatives to Carbon Markets

One of the final questions that I put to interviewees was if they had any thoughts on alternative approaches which could lead to the agricultural sector meeting its 2030 emissions targets. This yielded a range of suggestions that again illustrate that environmental attitudes of farmers are positive and that they wish to improve sustainability but desire that supports be put in place for them to do so.

Farmer #2 suggested an investment in anaerobic digestion (AD), in order to generate renewable electricity while reducing waste product on farm. He suggested that an investment in AD, would generate additional returns both in financial and sustainability terms by reducing the quantity of gas imported into the country. Farmer #4 also made a suggestion that involved increasing our self-dependency and reducing the need to import, this time in the area of proteins for animals. He suggested that increasing production of legumes and other crops in Ireland while reducing the importation of crops such as soya could bring about benefits and that a "synergy between tillage and dairy" could yield positive results. Additionally, Farmer #4 suggested planting of trees on land should be encouraged in order to increase carbon sequestration. This follows on from comments made from other farmers and stakeholders that they would be happy to increase the planting of trees but at the moment are unwilling to do so due to the lack benefits when compared to alternatives. Farmer #5 suggested that if the ESB commit to a price for selling excess electricity generated to the national grid that it would incentivize further investment in renewable energies by farmers. This was part of an overall suggestion that it should be easier for farmers to invest in sustainable improvements, with more money upfront in grant schemes. He suggested that currently farmers do not have the excess funds to implement measures and wait for money to be refunded and that it is not feasible to get a loan to invest as the interest will offset the grant income. Finally, Farmer #7 suggested that improving knowledge transfer amongst farmers is the key to achieving emissions reduction targets.

Stakeholder #2 suggested that the key to achieving emissions reduction targets was to provide additional quality income streams to farmers and that these income streams should be analysed to ensure that they are easily understood and streamlined. Stakeholder #1 also touched on the issue of income, suggesting that while subject to Irish and EU regulation, farmers are also subject to a global milk price and that while consumers state they desire sustainability, they currently do not pay a premium for it and that this will have to change into the future. Stakeholder #5 also took a financial view of this question, suggesting the best way to promote sustainability actions was to financially reward 'first movers', those farmers who are the first to invest in new technologies and implement new techniques and that further, farmers and firms with a bio-economy led approach should be incentivised. Stakeholder #3 focused on the area of research and science, stating that the time for pilot programmes had ended and that it was now time for the science and technology to be implemented. He suggested that where a technology was proven to be generate returns in reducing emissions but that it was not cost effective for farmers or firms, that the government should recognise those technologies as a public good and invest in them and provide them to farmers and other who might make use of them.

The alternative approaches to achieving the required GHG emissions reductions suggested by farmers and stakeholders are not novel approaches but rather technologies and techniques which have not yet been implemented in Ireland at scale. The reasons for the lack of implementation vary but include, insufficient demand, perceived regulatory burdens and an approach to the sector which fails to integrate its component industries.

Research has indicated a willingness for farmers to engage with new approaches, including some of those identified by the interview participants, such as anaerobic digestion (O'Connor et al., 2021), renewable energy and forestry (Irwin et al., 2022). In order to further progress these methods of GHG mitigation and meet Ireland's emission reduction targets, clear policies are required to be implemented (Auer et al., 2017), which encourage farmers to adopt a broad range of mitigation measures. This requires sufficient promotion of both individual measures as well as broader suites of measures. In order to ensure uptake and engagement, collaboration should be sought with those organisations who most enjoy farmers' trust, such as Teagasc, dairy co-operatives, the IFA and ICMSA, amongst others

5.8 Conclusion

The contents of these 12 interviews were insightful in terms of answering the question of whether carbon pricing would be an acceptable method of driving emissions reductions in the Irish dairy sector. While the answer returned seems to be possibly, dependent on conditions, it does give us greater understanding of what the conditions are which might generate uptake. Feedback from farmers and stakeholders have firmly shown us a compulsory carbon market is not a method that would be well received, with a strong belief amongst interviewees that it could lead to farmers leaving the sector and damaging agriculture more than any emissions reduction would improve things. Interest in a voluntary carbon market is less definite, with most farmers showing an inclination to at a minimum learn more about the idea. Given a well-tailored scheme that provides sufficient incentive for farmers, take-up could likely be high. While stakeholders viewed monetary reward for emissions reduction as a sufficient driver for farmers, farmers themselves stressed the need to balance this with feasible regulatory requirements, low levels of paperwork and measures that could be implemented without drastically increasing farmer workload.

Overall, these interviews illustrated that Irish dairy farmers are keen to play their part in tackling environmental issues, although they have concerns that their work-to-date is not being acknowledged. While they are happy to implement emissions mitigating measures on farm, given the strains on farm finances they require a sufficient level of reimbursement. The level of reimbursement is not entirely known, with farmers and stakeholders alike failing to put a figure on the price at which carbon credits would trade. Should the price of credits be sufficiently high, the measures that are required of farmers have a scientific basis, and the regulations imposed be fair and reasonable, farmers indicate that they would be willing and in many cases enthusiastic to implement sustainability practices on farm. Any future examination of carbon pricing measures in the Irish dairy industry or wider agricultural sector should bear this in mind.

6. Discussion & Conclusion

This paper has examined the need to reduce GHG emissions in the Irish agricultural sector particularly within the dairy industry and the feasibility and acceptability of carbon pricing as a tool to achieve this reduction. It has done this in the Introduction chapter by examining the policies within the agricultural sector, the emissions generated by Irish agriculture and Irish dairy and the emissions reduction targets established by the Irish government and required under Irish and European law. The Literature review has examined carbon pricing in various forms and the potential role of carbon pricing in accelerating emissions reductions. The Living Labs chapter documents the work carried out by the SmartDairy team in attempting to establish a small scale voluntary carbon market in the Irish dairy sector in order to test the real-world viability of carbon pricing in achieving emissions reductions in the dairy sector in Ireland. While this attempt did not achieve its desired aims, for reasons discussed in that chapter, it may still provide insights to any future efforts to establish carbon markets, be that through a living lab approach or another means. Finally, the Farmer and Stakeholders Interview chapter outlines the responses received in interviews carried out amongst a number of individuals with expertise in the dairy sector. These interviews assessed the level of knowledge of and interest in carbon markets, both in their voluntary and compliance forms and sought to generate insight into how these markets should be structured in order to achieve maximum effectiveness in the Irish dairy sector. Together these four chapters aimed to assess the feasibility of enacting carbon markets within the Irish dairy sector, the acceptability of carbon markets amongst farmers and other industry stakeholders and whether living labs are an appropriate tool for enacting carbon markets on a small-scale. This chapter serves as a final discussion of the previous four chapters and aims to answer the question as to whether voluntary carbon markets are a feasible route to meeting emissions reductions in the Irish dairy sector.

Ireland's GHG emissions reached their lowest level since 1990 in 2023, having fallen by 6.8% from 2022 (EPA, 2024b). Despite the progress made in reducing emissions in 2023, there is still substantial work required in order to achieve necessary emissions reductions required by 2030. This failure to meet emissions reduction requirement will have financial impacts as well as environmental, with the Irish government likely to be faced with fines in the region of €5 billion by 2030 (O'Sullivan, 2024). Although emissions from the agricultural sector decreased by 4.6% in 2023, it remains the sector responsible for the largest proportion of GHG emissions at 37.8%. Therefore, in order to meet national emissions targets, emissions within the agricultural sector must be tackled with urgency. Emissions from agriculture stem mainly from the volume of livestock kept in Ireland, particularly cattle, which is reflected in the larger proportion of CH_4 in Irish emissions than in other countries. The Irish dairy industry in particular is responsible for a large volume of emissions with an estimated 40% of agricultural emissions or approximately 15% of overall national GHG emissions, generated in this sector. Generating large scale reductions in emissions in the dairy industry or wider agricultural sector will be facilitate the meeting of national emissions targets.

Agricultural emissions may be reduced in a number of ways, through carbon sequestration, changes in land management, animal breeding and implementation of new technologies on-farm. There has been substantial research to date on the means by which farmers can reduce emissions on farm, with the Teagasc MACC being foremost amongst them in the Irish context, and other practices are currently undergoing testing, however take-up of these practices remains lower than desirable. While scientific and technological advancements continue in the agricultural sector, additional difficulties arise in initiating emissions reductions. While agriculture is no longer as large a contributor to the economy as it once was, it remains an important cultural aspect of Irish life and given the small size of average farm continues to support families and rural communities. Any changes to the agricultural sector that could be perceived as damaging family farms or Ireland's food production would not be well received. Farmers and the public may also oppose any efforts to reduce Irish production while also allowing for increased importation of products seen as less sustainable.

Given this opposition to any scheme which would restrict the viability of the Irish agricultural sector, any additional requirements levied on the sector would likely need to be accompanied by funding which would at a minimum offset any additional costs if not provide funding beyond this. One such tool, which would reward farmers for additional work carried out to reduce emissions on farm and improve sustainability is a voluntary carbon market. Voluntary carbon markets incentivize the implementation of measures to reduce carbon emissions whether through carbon mitigation to reduce the release of GHG emissions or carbon sequestration that looks to capture carbon in soils and forestry and reduce net carbon in the atmosphere. By quantifying reductions in carbon emissions and assigning property rights to those responsible for the emissions reduction, carbon markets aim to create an additional good that can be traded. Trading of carbon credits allow those individuals such as farmers who implement practices that reduce their carbon footprint, to generate additional income by putting this emissions reduction on the market. In doing so, it allows for other individuals or business to purchase this carbon credit and claim the emissions reduction for themselves. By allowing the person deemed as being responsible for the emissions reduction to change, carbon credits generate a demand and with a value for emissions reductions.

Carbon markets allow for an additional revenue stream, without which it may not have been possible for the carbon mitigation or sequestration to occur. While farmers may theoretically be willing to engage in practices to increase sustainability, in practice they may be less willing to do so if it would increase costs or present an opportunity cost to them. By allowing farmers to trade this emissions reduction as a carbon credit on the carbon market, farmers have an opportunity to generate income that may allow for them to implement mitigation practices that would not otherwise have been feasible to introduce. By providing a financial incentive to farmers to adopt emissions mitigating practices on farm, the adoption of sustainable practices within the sector should be accelerated. With a sufficient adoption of sustainable practices emissions intensity of production will fall leading to a reduction in emissions from the dairy sector without negatively effecting output. This will allow farmers to continue the production of high-quality low emissions milk to feed a growing population at home and abroad.

There is currently no carbon market in operation in the Irish dairy industry or in the wider agricultural sector; however this does not mean that there is no appetite for the introduction of one or a belief that it will not bring about required emissions reductions. While there is opposition amongst industry and farmers to any implementation of a compliance market in the sector (IFA, 2022), this does not apply to the voluntary model. While the interim report of the FoodVision Dairy group called for exploring the possibility of a cap-and-trade scheme, following concerns raised by stakeholders the final report instead included amongst its recommendations an examination of a carbon farming framework. In combination with recent work by the European Union to establish a carbon farming regulatory framework, it shows an anticipation that farmers will be willing to engage in carbon mitigation and sequestration in a voluntary capacity.

Estimating this level of engagement is key in determining how large a role voluntary measures will play in meeting emissions reductions. The greater the uptake of measures by farmers in a voluntary capacity, the less the compliance and regulations that will be enacted in the future. While this thesis has not sought to estimate the quantity or proportion of farmers who would engage with a voluntary carbon market, it has sought to generate insight from farmers and dairy industry stakeholders into what they believe uptake could be, what factors could drive uptake and what they view as potential obstacles to implementation. Engagement with farmers throughout the SmartDairy project, demonstrated an interest amongst farmers in at a minimum learning more about carbon markets and potentially a desire to engage in carbon mitigation and sequestration on farm in order to participate in carbon markets. Farmers showed a desire to be sustainable and were happy to do so provided they were fairly credited for the work they carried out. While farmers required additional information on the mechanics and requirements of any potential scheme, they demonstrated a genuine desire to learn more and engage if any scheme would be judged sufficiently fair and transparent. Alongside fairness and transparency, farmers valued minimal paperwork, mitigation measures with scientific backing and a sufficient credit value to cover any incurred costs.

There was a belief amongst farmers and stakeholders alike that there would likely be an overall positive attitude towards any voluntary carbon market and a general willingness to participate, although this was again dependent on the specifics of any such scheme. This was in stark contrast to feedback surrounding compliance markets that was overwhelmingly negative and raised concerns of a damaged dairy industry.

While interview participants demonstrated a willingness to engage with stakeholders of all backgrounds, there was a general view that any viable carbon market would have the involvement of the Government through either the Department of Agriculture, Food and the Marine (DAFM) or the Department of Environment, Climate and Communications (DECC). It is therefore likely that any future roll out of a voluntary carbon market in the agricultural sector would likely require the involvement of either or both departments as partners if not as the principal agency. This may generate existing trust in any scheme, given the resources available and existing relationships with farmers. This does not preclude the involvement of universities and research institutions in future carbon markets or organising them whether as living labs or through some other means.

The work done on the SmartDairy living lab, while unfortunately not resulting in a functioning carbon did illustrate some of the benefits of the co-creation focused approach with useful generated during the process. Some of these insights, identified barriers and proposed solutions will be of use in any later endeavour focused on living labs. The number and variety of stakeholders interested in engaging with the living labs illustrated the desire amongst the industry to engage with sustainability and innovation processes. Given the large scale of global warming and environmental sustainability issues, it is difficult for any one measure or approach to bring about the necessary change; however as one tool within a suite of measures, voluntary carbon markets show potential. In conjunction with other measures and regulations, voluntary carbon markets will likely encourage the usage of sustainable practices and technologies and spur additional innovation in developing GHG mitigation strategies. Carbon markets will allow for individuals and businesses to express their demand for climate action from agricultural producers and allow those producers to demonstrate their capacity and desire to deliver sustainable production.

Given the ever-increasing threat of climate change and associated difficulties, environmental and sustainability issues are likely to be to the forefront of government and society for the foreseeable future. This will allow additional resources to be focused on the best paths forward to meet national and global emissions targets and ensure resources are spent in a sustainable as well as efficient manner. The agricultural will be key to meeting these targets, due to both its role in emissions production and as the sector responsible for food production. Food production will need to adapt to changing climates and scale upwards to meet increasing populations. Achieving improved emissions intensities in agricultural goods will assist in feeding a growing population while ensuring emissions are kept suitably low to avoid reaching climate-tipping points. A range of measures will likely be required to achieve emissions reductions in agriculture and across the economy and it is likely that voluntary carbon markets will be one such measure that will allow for emissions reduction targets to be met.

This thesis has examined the feasibility of a voluntary carbon market in the Irish agricultural sector; however, there remain areas that require further study. Work is ongoing into researching the effectiveness and viability of various mitigation measures on farm, both generally and in an Irish specific context, however more work is required in this area in order to provide farmers with sufficient pathways to reach their emission reductions goals. Alongside the study of potential mitigation measures, research should examine the best methods of promoting sequestration and mitigation measures to farmers. Strengthening AKIS and ensuring that farmers are well informed about new developments in science and research will allow farmers to implement techniques and technologies to the greatest extent possible. The living labs have highlighted the difficulties involved in implementing complex structures such as carbon markets, while the interviews have aided us in identifying areas of concerns as well as strength in both future living labs and voluntary carbon markets that may be attempted in the Irish dairy industry. In conjunction with the existing literature, these insights generated from the work done in living labs and stakeholder's interviews may contribute to the future planning of the establishment of carbon markets.

Overall this research has highlighted, that carbon markets are still a concept with which a relatively small proportion of farmers and to a lesser extent other stakeholders are familiar with, however there is a desire for environmental sustainability initiatives that ensure the financial sustainability and viability of dairy farms. There is also an acceptance that the level of emissions within the sector must be reduced and that current targets are not on track to be met. While the sustainability of Irish dairy compared to other countries was stressed by interviewees, there was an acceptance that more could be done. As a result, there is a desire to learn about and engage with researchers as to the future operation of any carbon market targeting the Irish dairy sector.

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Appendices

Appendix 1: Mitigation Measures Cost Calculations

Reduction of N content

Assumptions:

- A split of 70:30 between land under pasture and silage ground.
- The only approach taken to reduce N content is reducing the use of chemical N fertilizer.

This measure has two levels of uptake, a high reduction of N content or a lower reduction. Under a heavy reduction, a farmer needs to reduce N by 2855kg over 66 hectares and under a low reduction by 1656kg.

Given a current split between conventional urea, CAN and protected urea of 20:73:7, the reduction in N would focus on CAN and conventional urea while protected urea would not be reduced. This reduction would be split between conventional urea and CAN as 22:78.

For heavy reduction:

Fertilizer type	Kg N	Kg fertilizer	Price per tonne	Reduced cost
Conventional Urea	614	1335	€950	€1,267.78
CAN	2241	8300	€700	€5,809.04
			Total cost reduction	€7,076.82

For lower reduction:

Fertilizer type	Kg N	Kg fertilizer	Price	Reduced cost
Conventional Urea	356	774	€950	€735.31
CAN	1300	4815	€700	€3,369.24
			Total cost reduction	€4,104.55

Slurry Amendment

Assumptions:

- Farm produces 1,060 tonnes of slurry per year
- Price of slurry amendment fluctuates between €2 and €3 per tonne of slurry

Total cost of slurry amendment per farmer is between €2,120 and €3,180.

The treated slurry has a higher N content than usual which would slightly reduce the volume of chemical N fertilizer required.

Feed Additive
No widespread availability currently, with significant fluctuations in price.

Assumptions:

- Minimum price of €50 per cow per annum
- Maximum price of €100 per cow per annum
- Feed additive is only used while animals are housed
- Irish dairy cows are house for only 3 months of the year

Use for only 3 months of the year generates a reduced cost of between €12.50 and €25 per cow per annum.

For a farm of 93 cows this gives a cost per farm of €1,163 - €2,325 per annum.

The use of the anti-methanogenic additive is estimated to reduce methane emissions by 30%.

Lower Replacement Rate
The model farm has a replacement rate of 22%, this measure requires a reduction to 20%. For a farm of 93 cows this would be a net calf loss of 2. Given an upkeep cost of €600 per calf per year this would be a cost reduction of €1,200. Sale calves are valued at €169.

The reduced payment for cull cows would also need to be taken into consideration. Given a price per cow of €1,200 and 2 fewer cows this is a reduced income of €2,400.

In year 1, this would have positive income change of €1,538, in year 2 this would increase to €2,738 and in year 3 this would fall to €388, for a net of €4,614 over a three-year cycle. In all subsequent years there would be an increase of €338.

Protected Urea
Assumptions:

- 173 kg N required per hectare
- Current split of Conventional Urea, Calcium Ammonium Nitrate (CAN) and Protected Urea is 20:73:7.

This measure requires 100% of chemical N fertilizer used to come from protected urea.

This would see current use of fertilizer per hectare change from conventional urea (75kg), CAN (468kg) and protected urea (26kg) to 376kg of protected urea only.

Given prices per tonne of €950 for conventional urea, €700 for CAN and €1000 for protected urea, this would result in a cost reduction of €3,242 for a 66 hectare farm, from €28,063 to €24,822.

This calculation does not currently take into consideration changes in the use of compounds as a result in the change of fertilizer use.

Feed Concentrate

Assumed consumption of feed concentrate per cow of 1,173kg and a price per tonne of feed concentrate of €400.

The total amount of feed concentrate required for a farm of 93 cows is 109,089kg. A 10% reduction equals 10,909kg.

At €0.40 per kilogram, costs would be reduced by €4,364 if concentrate was reduced by 10%.

Changes in feed concentrate would however effect milk yield which needs to be taken into consideration.

Appendix 2a: Farmer Interview Guide

Introduction:

My name is Joseph McDonagh and I am a Master's student in the University of Galway. This interview is being conducted as part of the research for my MSc. thesis and as part the SmartDairy project. The SmartDairy project is examining the sustainability of Irish dairy and the potential for mitigation of greenhouse gas (GHG) emissions on Irish dairy farms. In order to examine the possible paths to reduce GHG emissions in Ireland, understanding farmers' and dairy industry experts' opinions on sustainability and potential schemes and tools available to achieve reductions in GHG emissions is important. Your participation in this interview is very much appreciated.

This interview is entirely voluntary, and you may stop it at any time. Some of the feedback from this interview may be used, in combination with data from a large number of Irish farmers, either in a Master's Thesis or research by the SmartDairy project, but this information will not be attributed to you. Your data will be stored securely and anonymously by the University of Galway in line with GDPR.

Background questions:

In order to provide some background on the interview participants, a small number of demographic and farm information questions will be asked. This will also allow the interviewee a chance to get settled before launching into the more detailed questions.

- Size of farm
- No. of cows milked
- No. of years farming
- Full-time or part-time
- County
- Co-op membership
- Expansion since 2015
- Plans for future expansion

Q1. How sustainable do you believe the Irish dairy sector is and how much room is there for improvement?

Q2. Do you think the Irish government will meet its 2030 emissions reduction targets?

Living Labs:

Q3. As I mentioned, this interview is part of the SmartDairy project, one element of which was planned to be a Living Lab in the Irish dairy sector. Have you heard of Living Labs before?

If yes -> What is your understanding of a Living Lab?

If no -> Provide explanation of Living Labs. "Living Labs bring together people from a variety of roles and backgrounds, to work collaboratively to generate solutions. The potential solutions are implemented and worked on in real-time".

Q4. Knowing what a living lab is, have you ever participated in one? Would you be willing to participate in a living lab with the goal of finding a path to reduce GHG emissions in the dairy sector and meet agricultural emissions targets?

If no -> Why would you not be willing to participate? What could be changed to secure your involvement?

If yes -> Are there any preconditions you would have? Are there any limitations that would put you off?

Q5. Living Labs require a range of stakeholders to be involved to achieve an effective outcome. Are there any individuals or groups you would definitely like to see included or excluded from a potential living lab?

Allow to answer with as many names/groups as they wish. If no answer suggest some groups that they may accept or reject: Teagasc, Agricultural Colleges, Industry (Feed companies), Universities, IFA, DAFM, ICMSA, Co-ops, Coillte, County Councils, Department of Environment etc.

Voluntary Carbon Markets:

Q6. The SmartDairy Living Lab would have seen the implementation of a small-scale carbon market on Irish dairy farms. How familiar are you with carbon markets?

If unfamiliar, provide explanation: A carbon market is where the farmer would implement some technology of practice which would reduce the amount of GHGs their farm was producing, They could then sell this reduction to interested people and businesses for cash.

Q7. The SmartDairy carbon market, would have been a voluntary market meaning that there is no widespread requirement to reduce emissions amongst all farmers, only those who would opt in. If a farmer chose to participate they could generate an additional revenue stream. Would you be willing to participate in a voluntary carbon market?

If no: Why would you not be willing to join?

If lack of knowledge: Would the provision of a list of measures and associated costs and information on productivity impacts affect your decision?

If measures too expensive: Would assistance in identifying low-cost measures or measures which generate a net cost-saving change your decision?

If unsure of price: Would a guarantee of price be required for your participation? Do you know what region the price would have to be for you to join?

If yes: What would your motivation for joining be? Would you have concerns about joining?

Q8. Do you believe there would be widespread participation by dairy farmers in a voluntary carbon market?

If no: Why do think that?

If yes: Who do you think would be willing to join, younger or older farmers, larger or smaller farms?

Q9. In order to ensure that the carbon credits generated are genuine, there would have to be some kind of system to track emissions and verify that farmers implemented the measures they stated they would. This would require somebody to operate the carbon market, what organisation do you think should have that responsibility?

If no answer suggest some groups that they may accept or reject: A new dedicated semi-state body appointed by the government, Teagasc, Agricultural Colleges, Universities, DAFM, ICMSA, Co-ops, Coillte, County Councils, Department of Environment etc.

No need to suggest all groups, prioritize new semi-state, govt departments, co-ops, ICMSA.

For each acceptance or rejection seek a reason why.

Compliance Markets:

Q10. An alternative to a voluntary market is a compliance market which is set up by the government and requires all farmers to participate. Under this system there would be a maximum permissible level of emissions. Farmers would be required to either generate emissions below this limit or would have to purchase credits to make up the amount by which they are over the limit. If you were below the limit, you would be able to sell the difference to other farmers. Would you support the government in introducing this system?

If yes: Why do you support this?

If no: Why do you oppose this system?

Q11a. If this system were to be implemented would it affect your decision to continue farming?

Q11b. Do you think it would affect other farmers decisions to retire/downsize/exit farming?

Q11c. How do you think it would affect new farmers attempting to start out?

Q12. Do you think you would be in a position to sell credits or do you believe you would have to buy?

> *If buy*: How long do you think it would be before you were in a position where you no longer had to buy credits?
>
> *If sell*: What measures have you implemented/ would you implement that would enable you to sell credits?
>
> Would these funds be used to 'pay-back' the measures you have already implemented or to implement additional measures and reduce your emissions greater?

Q13. Do you think such a scheme should be limited to carbon mitigation? Would you support carbon sequestration being included?

Q14. What alternative or additional approaches do you think could be put in place to facilitate the agricultural sector meeting its 2030 targets?

Appendix 2b: Industry Expert Interview Guide

Introduction:

My name is Joseph McDonagh and I am a Master's student in the University of Galway. This interview is being conducted as part of the research for my MSc. thesis and as part the SmartDairy project. The SmartDairy project is examining the sustainability of Irish dairy and the potential for mitigation of greenhouse gas (GHG) emissions on Irish dairy farms. In order to examine the possible paths to reduce GHG emissions in Ireland, understanding farmers' and dairy industry experts' opinions on sustainability and potential schemes and tools available to achieve reductions in GHG emissions is important. Your participation in this interview is very much appreciated.

This interview is entirely voluntary, and you may stop it at any time. Some of the feedback from this interview may be used, in combination with data from a large number of Irish farmers, either in a Master's Thesis or research by the SmartDairy project, but this information will not be attributed to you. Your data will be stored securely and anonymously by the University of Galway in line with GDPR.

Background questions

Q1. What is the role of your organisation in the dairy industry?

Q2. What is your role within the organisation?

Q3. Are you yourself a farmer?

Q4. How sustainable do you believe the Irish dairy sector is and how much room is there for improvement?

Q5. Do you think the Irish government will meet its 2030 emissions reduction targets?

Living Labs:

Q6. As I mentioned, this interview is part of the SmartDairy project, one element of which was planned to be a Living Lab in the Irish dairy sector. Have you heard of Living Labs before?

Q7. The SmartDairy Living Labs goals was to find a path to reduce GHG emissions in the dairy sector. Do you think your organisation would be willing to partake in such a living lab, to share your experience?

Q8. Is there anything you'd need to know or any preconditions before you'd agree to join a living lab?

Q9. Are there any stakeholders whom you would definitely want or not want involved?

<u>Voluntary carbon market</u>

Q10. The goal of the SmartDairy living lab was to trial a voluntary carbon market. How familiar are you with voluntary carbon markets?

Q11. What do you think the response from farmers would be to a voluntary carbon market?

Q12. What factors do you think would influence farmers likelihood to participate?

Q13. Would your organisation be willing to purchase credits in a voluntary carbon market?

Q14. What level of demand do you believe there is from firms for credits?

Q15. In order to ensure credits are genuine there would have to be some system of verification in place, requiring somebody to operate the market. How do you think should have that role?

<u>Cap-and-Trade</u>

Q16. An alternative approach to the voluntary market is a cap-and-trade model. How familiar are you with this approach?

Q17. Do you think the introduction of a cap-and-trade system would influence farmers decisions to remain in farming?

Q18. Do you see any potential impacts for new entrants to farming?

Q19. Within any emissions reductions schemes should the focus be on mitigation or allow for sequestration as well?

Q20. Do you have any insights into the price at which credits would trade?

Q21. What alternative approaches do you believe could be put in place by government to meet its emissions targets?