Bridging The Gap in Ireland's Effort Sharing Decision

An Examination of Potential Agricultural Greenhouse Gas Abatement Measures

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Abstract

Under the effort sharing decision, Ireland is required to deliver a 20% reduction in non-ETS greenhouse gas emissions by 2020 (relative to 2005 levels). Ireland's current 2020 forecast for non-ETS emissions, shows that non-ETS sectors are expected to breach the effort sharing decision target of 37.8 Mt/CO_2eq by 4.3Mt/CO_2eq. The five agriculture greenhouse gas abatement measures chosen are aimed at reducing the two most prominent greenhouse gases in Ireland's agriculture sector, methane (Through animal nutritional abatement measures) and nitrous oxide (Through fertilizer application abatement measures). The adoption potential of the five selected measures shows that the combined realistic abatement potential, in 2020, to be 3.2 Mt/CO_2eq. The applied adoption rates (per annum) for behavioral change measures and measures that require investment was set at 6.5% and 5% respectively. With the implementation of the chosen abatement measures, Ireland's 2020 gap is reduced to just 0.7Mt/CO_2eq. The selected agricultural greenhouse gas abatement measures will only be successfully adopted through incentivisation and through the introduction of advisory programmes.

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Abbreviations

GHG	Greenhouse Gas
ETS	Emission Trading Scheme
Non-ETS	Non-Emission Trading Scheme
GWP	Global Warming Potential
CO_2	Carbon Dioxide
Non-CO_2	Non-Carbon Dioxide Emissions
CO_2eq	Carbon Dioxide Equivalents
N_2O	Nitrous Oxide
CH_4	Methane
HFCs	Hydroflourocarbons
PFCs	Perfluorocarbons
SF_6	Sulphur Hexafluoride
Mt	Mega Tonne
TJ	Tera Joule
Ktoe	Kilo Tonne of Oil Equivalent
Kg	Kilogram
EPA	Environmental Protection Agency
SEAI	Sustainable Energy Authority of Ireland
CSO	Central Statistics Office
GDP	Gross Domestic Product
GNP	Gross National Product
CAP	Common Agricultural Policy
SPS	Single Payment Scheme
NCCS	National Climate Change Strategy
REPS	Rural Environmental Programs
EU	European Union
UNFCCC	United Nations Framework Convention on Climate Change
CDM	Central Development Mechanisms
JI	Joint Implementation

1. Introduction

The European Union has become a global leader in climate protection and has set ambitious greenhouse gas emission reduction targets since the end of the Kyoto agreement. Collectively EU states are required to reduce greenhouse gases (GHG) by 20% relative to 1990 by 2020 (European Commission, 2011). Ireland's Climate policy is developed in the relation to the EUs commitment to the 1992 United Nations Framework Convention on Climate Change (UNFCCC). Greenhouse gas mitigation is fundamental to climate change policy and Ireland has currently two commitment periods. The first commitment period ran from 2008-2012 and was established by the Kyoto protocol. Ireland committed to a 13% limitation of greenhouse gas emissions, above 1990 levels, and as of this year Ireland has succeeded in reaching this target, but only as a result of the economic downturn.

Ireland's second commitment period between 2013-2020 follows Europe's 2008 Climate and Energy Package (European Commission, 2011). This policy package sets out climate and energy targets to be adhered to by 2020, commonly known as the "20-20-20 targets". Europe's 2020 reduction target involves two sub-targets, one for the Emission trading scheme (ETS) and one for non-ETS sectors. This research focuses on the non-ETS target, known as Europe's effort sharing decision. Under this agreement Ireland faces significant mitigation challenges. Ireland has agreed a binding emission path; this begins in 2013 and decreases per annum until at 2020, emissions are 20% lower than 2005. Installations covered by the ETS are regulated on a EU-wide level, while mitigation policy in relation to non-ETS emissions must be addressed at a national level in accordance with the EU Effort Sharing Decision. Non-ETS sectors represent 72% of Ireland's emissions and within the national non-ETS emission profile agriculture is the largest emitter. Ireland faces a significant challenge in meeting its future EU emission targets for greenhouse gases under the EU Climate and Energy package for 2020. Effective action by all economic sectors is required in order to meet these targets. This study focuses on agricultures role in achieving the 20% reduction target (relative to 2005) and in identifying potential mitigation measures for Ireland's agriculture sector.

1.1 Problem Definition

The Climate and Energy Package, implemented in 2008, provides targets and legislative fundamentals for Europe's 2013-2020 plans. Under the terms of this European Union (EU) package, Ireland has committed to a 20% reduction in non-Emission Trading Scheme (ETS) emissions. ETS targets are regulated by the EU and establish the participation of European market players in order to reach assigned target, as such ETS targets are of less concern for Irish policy makers. Projections for the EU27 non-ETS emissions has shown that pre-recession data indicates that Ireland would fail to reach the 20% reduction target on the basis of existing policies (Harmsen, Eichhammer, & Wesselink, 2011). Harmsen exposed the inherent imbalance in the reduction effort among some member states. The principal target setting mechanism, GDP per capita, is obscured by the non-CO2 GHGs. The overall imbalance has created a low ambition level in some member states and a particularly high ambition level for other member states, including Ireland. Harmsen revealed that Ireland's national non-ETS emission target cannot be met with cost-effective energy savings alone. A review of Ireland's Climate policy published last year explained that, even with the full realization of Ireland's planned policy measures; Ireland would require a further 11% reduction in emissions in order to achieve the 20% reduction target (Environ, 2011).

This means that Ireland needs a further deepening of these policy measures in order to achieve compliance. Figures released in 2009 found that a variety of sectors in the Irish economy were forced to reduce their activities and greenhouse gas (GHG) emissions as a result of the economic recession experienced in Ireland at the end of 2008, which resulted in an overall reduction of emissions by 7.9% in 2008 (Anderson, 2010). It is hypothesized that, even with the impact of the recession, Ireland will still fall-short of reaching the 20% target; this is confirmed in Harmsen et al., 2011 (Harmsen, 2011, Fig 13). In the context of Europe, Ireland has a rather unusual emissions profile, with the majority of emissions originating from agriculture and transport. Ireland's annual emissions inventory has shown that highest national proportion of agricultural emissions among all EU member states resides in Ireland (EPA, 2008). It is within the agriculture sector that the potential for emission reduction will be examined and is where the recommendations for policy renewal will be based. When GHG emissions from installations participating in the ETS are excluded from the national emissions profile, the main sectors responsible for non-ETS emissions are the agriculture and transport sectors (Figure 1).

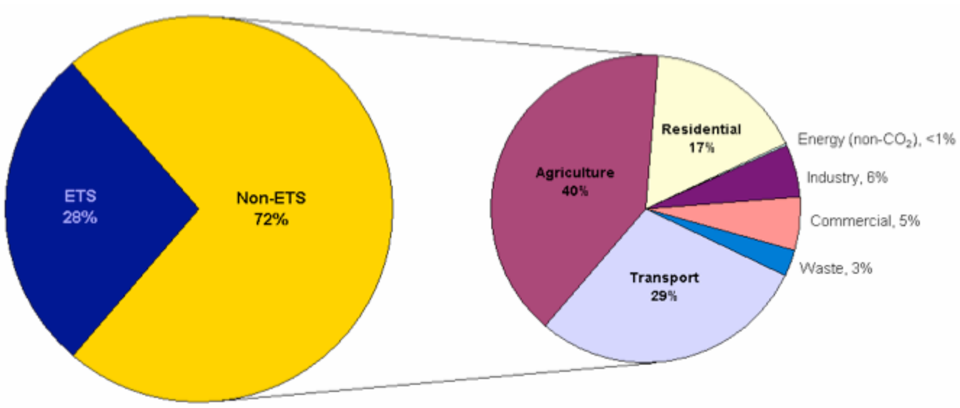

Figure 1 Non-ETS Sectorial Share 2011 (Environ, 2011)

1.2 Research Question

- What are the viable greenhouse gas abatement measures available to Ireland's agriculture sector that can be used to help bridge the non-ETS GHG emission gap arising from Ireland's non-ETS policy shortfall?

1.2.1 Sub-Questions

1. In terms of CO_2eq, what is Ireland's remaining 2020 policy gap, pre and post recession, for Ireland's national forecasts and European forecasts for Ireland's non-ETS's emissions?
2. What potential agricultural GHG abatement strategies are available to Ireland and how much greenhouse gas emissions, in $MtCO_2$eq, could be conceivably abated by 2020?
3. Can the agricultural GHG mitigation measures bridge Ireland's non-ETS emissions gap?
4. What barriers exist within Ireland's agricultural sector and how will the identified agricultural abatement measures address these barriers?
5. What viable policy instruments can be used to incentivize the adoption of the recommended agricultural abatement measures?

2. Background

2.1 The Effort Sharing Decision

The decision on Effort Sharing between Member States on greenhouse gas emission reductions became effective on the 25th of June 2009 (Decision No 406/2009/EC). The cost effective distribution resulted in two thirds of the emission reduction being apportioned to the ETS sectors and one third being allocated to non-ETS sectors. The overall emission reduction across the European Union, for non-ETS emissions, is 10% compared to 2005 levels. The European Commission decided that the cost-efficient distribution of emission reduction targets would be adjusted on the basis of the GDP per Capita method. This results in member states with low GDP per capita having less rigorous targets in comparison to countries who's GDP per capita is high. The government to government agreement was established to cap Member States emissions from various activities not covered by the EU emission trading scheme, sectors included are transport, buildings, services, small industrial installations, agriculture and waste, which as a whole represent around 60% of total GHG emissions in Europe. The greenhouse gases applicable to non-ETS emission reductions are briefly outlined below in Table 1. The various sources of non-ETS GHG gases are noted as well as their inherent global warming potential[1] (GWP).

In determining an emission target for Ireland's non-ETS GHG emissions, the EU assigned a goal requiring Ireland to reduce its non-traded sector greenhouse gas emissions by 20% relative to 2005 by 2020. Emission reductions for non-ETS sectors will take place between the years 2013 and 2020. The Emission reductions are subjected to annual monitoring and compliance checks to ensure EU greenhouse gas emissions gradually move downwards towards the agreed 2020 target (406/2009/EC). In the event that a member states non-ETS emissions are above their "effort sharing" emission budgets, then they will be forced to take corrective action in the following year. Underachievement of annual emission reductions will have to be fulfilled in the following year multiplied by a penalty factor of 1.08 (406/2009/EC). As well as this, Member States will have to submit a corrective action plan to the European Commission detailing the measures and timeframe for correcting the overshoot and remaining on track to reach 2020 target. There are a number of EU-wide measures that help member states to reduce emissions. The recent proposed regulation on CO_2 emissions from cars requires manufacturers to improve CO_2 efficiency of new cars. New efficiency criteria for boilers and water heaters, as well as improved labeling systems to inform consumers will also aid member states in reaching their non-ETS emission targets.

The European Commission is also promoting cost-effectiveness through the use of flexible mechanisms. Member states can avail of certified emission reductions, which result from Clean Development Mechanism (CDM) projects and Joint Implementation (JI) projects, under article 12 of the Protocol. CDM certified emission reductions are as a result of climate mitigation activities undertaken between Annex I countries and non-Annex 1 countries. Joint implementation projects are similar, however JI investments are between two Annex 1 countries. With these flexible

[1] GWP – Describes a greenhouse gases total warming impact relative to CO_2 over a

mechanisms, states can invest in greenhouse gas reductions in Annex 1 and non-Annex1 countries, where reductions are cheaper. These credits obtained through the reduction are used towards a states commitment target.

Table 1 Non-ETS Greenhouse Gases (EPA, 2012)

Gas	Sources	Global Warming Potential (100 Yrs)
Carbon Dioxide (CO_2)	Burning of fossil fuels	1
Methane (CH_4)	Agricultural activities Landfill sites Enteric fermentation Wastewater treatment Combustion engines	21
Nitrous Oxide (N_2O)	Agricultural soil Livestock waste Combustion engines Adipic acid production Nitric acid production	310
F-Gases - Hydrofluorocarbons (HFCs) - Perfluorocarbons (PFCs) - Sulphur hexafluoride (SF6)	Refrigeration and air-conditioning Aluminum production Semiconductor production Magnesium production	150 - 11700

2.2 Ireland's Agriculture Sector

2.2.1 Emissions

The Agriculture sector's emissions encompass emissions from enteric fermentation, manure management and nitrogen use on soils. The share of agricultural emissions varies greatly between European Union Member States. In 2010, agriculture represented 29.1% of total greenhouse gas emissions, which equates to 40% of the total national Non-ETS emissions (Breen, Westhoff, & Donnellan, 2010). Yearly national inventories show annual Non-ETS emissions pre-recession were on average 24% above 1990 levels, while after 2009, emissions decreased to 14.1% above 1990 levels (McGettigan, et al., 2012). Ireland's agricultural sector is quite distinctive in comparison to other European union member states. Ireland exports 80-90% of its beef production, which makes Ireland a net exporter of beef products (Enterprise Ireland, 2009).

Methane (CH_4) and nitrous oxide (N_2O) make up the majority of agricultural greenhouse gas emissions. This is due to the dominance of cattle and sheep livestock production in Irish agricultural output. Methane, from enteric fermentation, is the primary agricultural greenhouse gas and accounts for around 45% of the total agricultural emissions in 2010 (McGettigan, et al., 2012), while N_2O emissions, which arise from chemical/organic fertilizers, cover an additional 37% (EPA, 2012). The other major source of non-CO_2 emissions is associated with manure management, which accounts for 13% of agricultural emissions (Teagasc, 2012).

The trajectory of agricultural emissions has been in a downward direction since 2000. Enteric and nitrogen sourced emissions declined while N_2O emissions from synthetic fertilizers increased in 2010 due to an 18% increase in fertilizer sales between 2009 and 2010 (EPA, 2012). For Ireland's agricultural sector, Non-CO_2 emissions have been gradually declining since 2000; however, agriculture still remains the largest contributor of non-ETS GHG emissions (40%).

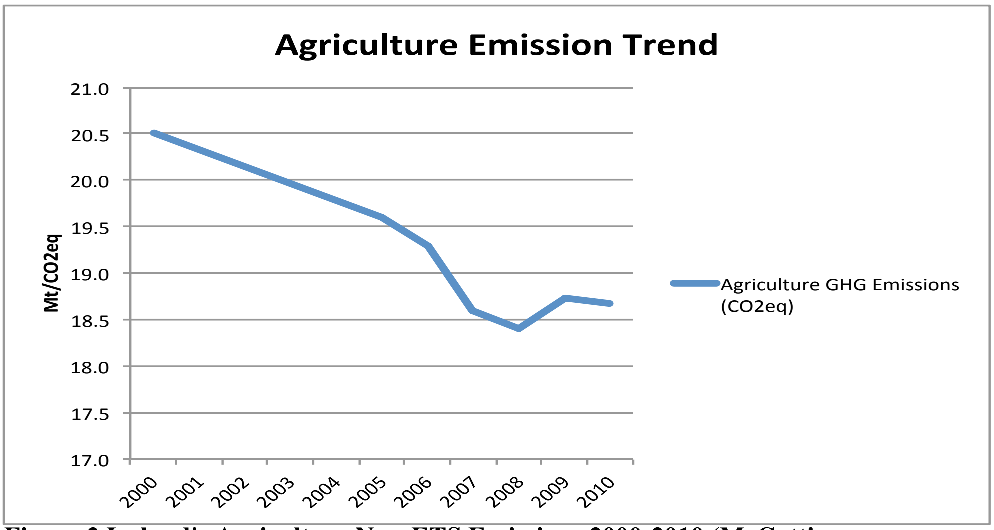

Figure 2 Ireland's Agriculture Non-ETS Emissions 2000-2010 (McGettigan, et al., 2012)

Ireland's annual UNFCCC emission inventory provides a breakdown of emissions per sector, which reveals Ireland's agricultural emissions with respect to methane, nitrous oxide and carbon dioxide (McGettigan, et al., 2012). Figure 3 shows a breakdown of emissions stemming from the agricultural sector, it is clear from this graph that methane emissions are the most dominant GHG released. Even though the volume of CO_2 emitted is greater compared to methane and nitrous oxide levels, when the emissions are converted to CO_2 equivalents, carbon dioxide becomes the least prominent greenhouse gas. The main sources of these GHG emissions have been graphed below (figure 3).

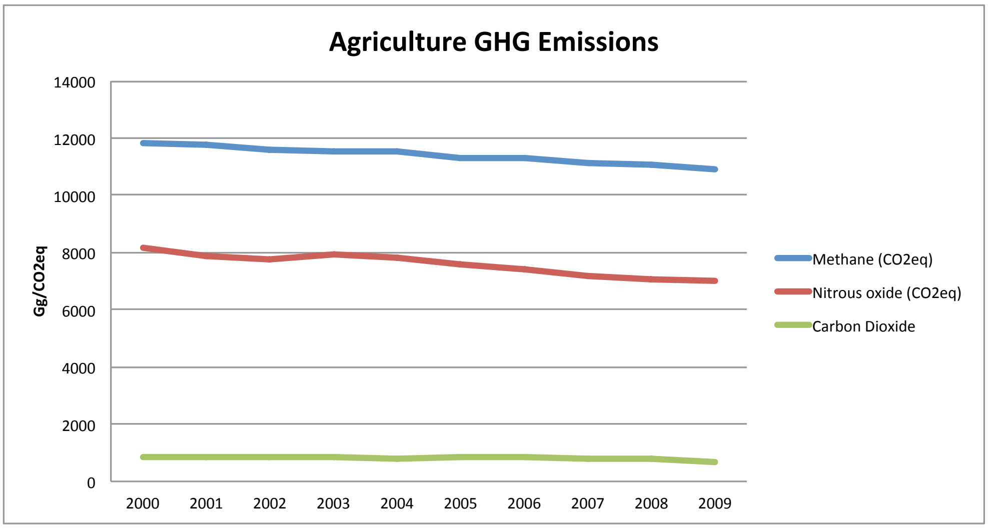

Figure 3 Most Prominent Agricultural Greenhouse Gases (McGettigan et al., 2012)

Methane emissions in the agriculture sector originate as a by-product of the livestock digestive process, in which microbes resident in the animals digestive system ferment the feed consumed by the animal (Gibbs, Conneely, Johnson, Lassey, & Ulyatt, 1999). This fermentation process is also known as enteric fermentation, where methane emissions are the primary by-product (Gibbs, Conneely, Johnson, Lassey, & Ulyatt, 1999). Figure 4 shows the type of GHG and quantity (Gigagram) of each for Ireland's agricultural sector in 2010. This data clearly shows that the primary emission activity is enteric fermentation (CH_4), as a result of Ireland's emissions from the national cattle stock.

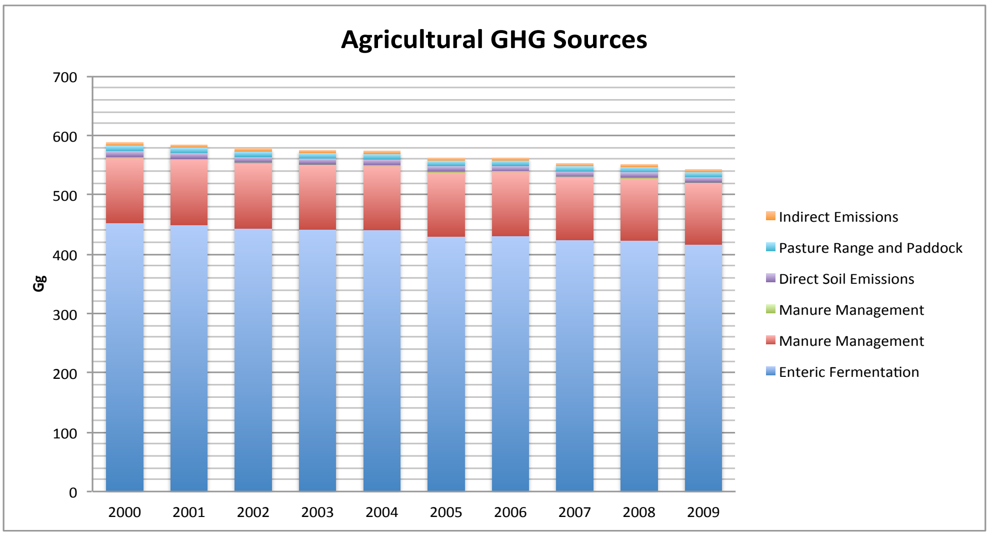

Figure 4 Sources of Agricultural Greenhouse Gas Emissions (McGettigan, et al., 2012)

The methane emissions from each of Ireland's particular set of livestock can be seen in Table 2. The variability of methane emission rates for individual animals in Ireland is shown to be quite significant. This variability offers the opportunity to reduce emissions by directing abatement measures towards high-emitting animals. Both non-dairy and dairy cattle represent the largest methane emitters in Ireland.

Table 2 Cattle numbers and emissions in 2010

Number of Cattle (2010)	Number	CH4 Emissions (kg/year)
Bulls	52000	4240600
Dairy cows	1092500	119311925
Other cows	1136700	42253034
Dairy heifers	233700	11722392
Other heifers	163100	8755208

2.2.2 Historical Agriculture Policy Measures

Ireland's agricultural GHG emissions have seen a sharp fall since 2000 (Figure 2). This reduction in emissions is as a result of Ireland's National Climate Change Strategy, 2000. In 1998, greenhouse emissions peaked at 21.097 Mt CO_2eq and as a result of this, a concerted effort to tackle emissions stemming from the agriculture sector was an important element of Ireland's response to its greenhouse gas emissions reduction target set by the Kyoto Protocol (McGettigan, et al., 2012). Emissions from the sector decreased by 17.1% to those in 2009 as a result of reductions in animal numbers and synthetic nitrogen fertilizer use, due to reforms in the Common Agricultural Policy. Emissions were closely linked to livestock numbers and sales of nitrogenous fertilizers and have historically correlated with GHG emissions. The need for emission reduction policies was made evident with the signing of the Kyoto protocol in 1997, and since ratification, Ireland has adopted many strategies to combat the rise in agricultural GHG emissions. These strategies are briefly outlined below.

Common Agricultural Policy (CAP)

In 2000, Ireland's National Climate Change Strategy (NCCS) proposed a reduction in methane equivalent by reducing livestock numbers by 10% below business as usual 2010 projections. As part of the CAP, the Single Payment Scheme (SPS) introduced by the EU in 2005, is an agriculture subsidy scheme, which allows farmers to farm to the demands of the market. Under this scheme, farmers who qualify for the subsidy are rewarded for adhering to certain rules and conditions set out by the European Union. The Single Payment Scheme adopted by the Irish government saw the decoupling of direct payments from production and has resulted in significant reductions in emissions. The subsidies, which Ireland could avail of, are outlined briefly below.

Livestock Emission Reduction Policies

A number of policy developments in the past have had an impact on livestock numbers and the age profile of agricultural animals, which in turn had a bearing on GHG emissions. These are:

⇒ *The Extensification Premium*: In order to qualify for this payment scheme, farmers were encouraged to lower their stocking rate in order to receive an increase rate of payment (Teagasc, 2004).

⇒ *The Special Beef Premium*: Eligibility to this scheme required farmers to adhere to strict criteria regarding stocking rate density limits (Teagasc, 2004).

⇒ *The Disadvantaged Areas Compensatory Allowances*: The payment basis for this scheme was based on headage (per animal), this was however changed and became based on area of farmland, thereby reducing the enticement for farmers to maximize stocking levels (Teagasc, 2004).

⇒ *Interim Commonage Framework Plan*: Introduced in 1998, this scheme reduced stock numbers by 30% in 6 western counties. Permanent destocking arrangements were put in plans for commonages in the final Commonage Framework Plans introduced in 2002 (Teagasc, 2004).

⇒ *Suckler Cow Premium*: The suckler cow premium facilitated the reduction in the average age of the suckler herd. New criteria allowed for an increasing number of heifers[2] to be eligible for payment (Teagasc, 2004).

⇒ *Research*: Research into improved animal husbandry techniques were carried out since 2000. Teagasc investigated techniques of maintaining high production yields without affecting animal fertility. Analysis also examined methods of improving grazing techniques, pasture management and animal dietary requirements in both dairy and beef systems. This research was aimed at identifying the best and most environmentally sustainable management systems.

Manure and Soil Emission Reduction Policies

As well as emission sourced from agricultural livestock, soil emission and manure management were targeted since 2000 in order to reduce GHG emissions.

⇒ *Rural Environmental Schemes (REPS)*: This voluntary scheme compensated and rewarded farmers for delivering environmental benefits. In 2005, 36% of all farmers in Ireland were registered to the scheme and consequently, each farm was required to implement a nutrient management plan. The plan establishes farming practices that have lead to greater efficiency in the use of nitrogenous fertilizer. REPS planners also identified areas, which are suitable for afforestation projects (Departement of Agriculture, Food and the MArine, 2012).

⇒ *Good Farming Practice*: All farms that were participating in theses schemes were also obliged to follow good farming practices in accordance with the environmental requirements set out in the “Good Farming Practice” booklet, published in 2001.

⇒ *EU Nitrates Directive*: The introduction of regulations (SI no. 788 of 2005) to implement the EU Nitrates Directive, places limits on the amount of the quantity of livestock manure which may be applied to the land.

[2] Heifers – Young Cattle.

The historical drop in GHG's has masked Ireland's underlying emission trends. In the past there has been an institutional failure to create a climate strategy, which manages various governmental departments in order to achieve cross-sectorial reductions in GHG emissions. Irelands National Climate Change Strategy was published in 2000 and outlined the measures that would be taken to reduce rising greenhouse emissions.
As well as misplacing budgetary expenditure, Ireland failed to commit to some of the measures targeted in the 2000 National Climate Change Strategy, such as not implementing plans to introduce a carbon tax for Ireland (Department of Finance, 2004). Opposition from the Department of Enterprise, Trade and Employment, believing that such a tax would undermine Ireland's competiveness and prospects of growth, caused the proposed application of a carbon tax to be postponed.
These historic policy decisions and failure to coordinated emission reduction measures across the sectors have had a significant bearing on Ireland's current and future policy decisions. Ireland's process of policy development involves a consultative process with the Social Partnership. As noted by Thomas Legge and Sue Scott, until 2006 the Social Partnership paid very little attention to climate change or GHG emissions (Legge & Scott, 2009). The current report on negotiations has a specific chapter on "environmental sustainability" while the previous agreement; "Partnership 2000", only contained a few references to the environment. This means that climate change policies were of little importance to members of the Social Partnership forum during the years of 2000-2006. There was little attention paid to national long-term investments whose true value for money might have been lower if the cost of their associated emissions had been taken into account.

2.2.3 Agriculture Policies 2009-2020

In recent years there has been a significant effort taken to thoroughly understand Ireland's agriculture emissions. Various authors have examined what the impact of changes in agricultural production methods on GHG emissions. Research has focused on:

- Improvement of genetic merit of cows - (O'Brien , Shalloo, Grainger, Buckley, Horan , & Wallace, 2010)
- Extension of the grazing season - (Lovett, Shalloo, Dillon , & O'Mara, 2008)
- Dietary supplementation - (Beauchemin, Kreuzer, O'Mara, & McAllister, 2008)

Despite the increased knowledge base developed by such research, Ireland has no plans to curb its agricultural emissions. In 2010, the government introduced the Food Harvest 2020 programme, which calls for an increase in agricultural outputs by 33%, with no policies to counteract the increase in emissions. The main objectives of the Food Harvest report are outlined below.

Food Harvest 2020

The Food Harvest 2020 report is an industry led initiative, which sets out a development strategy towards 2020. It identifies the opportunities and challenges, facing the Irish agri-food sector. The report specifies the following overall objectives to be achieved by 2020:

1. Increase the value of output in the agriculture, fisheries and forestry sector by €1.5 billion. This represents a 33% increase compared to the 2007-2009 average (Department of Agriculture, Fisheries and Food, 2010).
2. Increase the value added in the agri-food, fisheris and wood products by €3 billion. This represents a 40% increase compared to the 2008 average (Department of Agriculture, Fisheries and Food, 2010).
3. Achieve the target of €12 billion for the agricultural sector. This represents a 42% increase compared to the 2007-2009 average (Department of Agriculture, Fisheries and Food, 2010).

As well as these targets, the Food Harvest 2020 report includes two specific growth targets, these are:

1. A 50% increase in milk volume (Department of Agriculture, Fisheries and Food, 2010).
2. A 20% increase in the value of Ireland's beef produce (Department of Agriculture, Fisheries and Food, 2010).

The main challenge with these growth targets is, achieving these growth goals while still limiting the GHG emissions from this sector. The targets outlined within the Food Harvest 2020 report have meant that any potential agricultural GHG abatement measure selected, which reduces agricultural GHG emissions, cannot impede on future productivity. Suggestions to reduce livestock numbers in order to curb emissions, has been met with inherent complications. Reducing emissions by reducing food production would affect Ireland's food security and as well as that, there are a number of economic and social implications in lessening the number of livestock in Ireland (Teagasc, 2011). Data from the central statistics office indicates that Ireland's agri-food sector accounts for around 7% of GDP with primary agriculture accounting for 2.5% (Teagasc, 2012) and is set to remain an important aspect of Ireland's economy. This year Donnellan and Hanrahan estimated that achieving the objectives of this report would increase the projected agricultural GHG emissions (including fuel combustion emissions) from 18.7 $MtCO_2eq$ in 2010 to 20.0 $MtCO_2eq$ by 2020. This increase of 1.3 $MtCO_2eq$ equates to a 7% rise in emissions due in part to the projected increase in the number of ruminants. Given that agriculture represented 39% of total Non-ETS greenhouse gas emissions in 2010, it seems that some policy intervention is necessary within this sector in order to reduce Non-ETS GHG emissions (Department of Agriculture, Fisheries and Food, 2010). It is clear from examining Ireland's historical agricultural policy measures that the focus has been on reduction or management of bovine stocking rates in Ireland as well as controlling nitrates delivered to the soil. To best reduce emissions without damaging Agricultures profitability, the Department of Agriculture advises linking particular farming practices to the national emissions inventory, and using life cycle analysis to show the carbon intensity associated with Irish agricultural products. By reducing carbon intensity per unit of product, emissions can be reduced while retaining the profitability of the agriculture sector. Because of the relatively large proportion of emissions stemming for the agricultural sector, significant emission reductions are required during the period to 2013-2020. This is an opportunity for Ireland to develop the skills, expertise and knowledge base required for sustainable food production.

3. Methodology

This section describes the methodology used in this report to answer the research question:

- *What viable greenhouse gas abatement measures are available to Ireland's agriculture sector, which can be used to help bridge the non-ETS GHG emission gap arising from Ireland's non-ETS policy shortfall?*

Firstly, the methodology used to establish the gap between projected emissions and Ireland's effort sharing target is outlined. Secondly, the procedure used to select agricultural GHG abatement measures and to calculate their technical potential is also outlined. The approach used to assess the adoption potential of the selected measures is also summarized. Finally the method used to investigate feasible policy instruments is outlined.

3.1 Gap Analysis

This section describes the methodology used to answer the sub question:

- *In terms of CO_2eq, what is Ireland's remaining 2020 policy gap, pre and post recession, for Ireland's national forecasts and European forecasts for Ireland's non-ETS's emissions?*

Ireland's total non-ETS emission gap will be analyzed for both European and Irish projections. In order to evaluate Ireland's 2020 emission gap, it is first necessary to examine the 2020 CO_2eq target for both the EPA and European projections. The 2020 emission target for each projection is established through a 20% reduction in each of the base year emissions. So as to determine Ireland's current distance from these targets, projections towards 2020 were estimated from both Ireland's EPA and Europe's PRIMES and GAINS projections.

3.1.1 EU non-ETS GHG Emission Projection for Ireland

The European historical and projected greenhouse gas emissions for Ireland's non-ETS sectors, for both pre and post recession, are gathered using the Primes and GAINS emission projections (Capros et al., 2008/Amann et al., 2008/Capros et al., 2010/Hoglund-Isaksson et al., 2010).

1. Total per annum CO_2eq emissions are calculated through the sum of CO_2 and non-CO_2 emissions for each non-ETS sector.
2. Emission projections are plotted for both pre and post recession forecasts.
3. The effort-sharing target, for each forecast, is calculated through a 20% emission reduction in the 2005 base year.
4. Ireland's policy gap is established by subtracting the estimated total 2020 non-ETS emissions target from the projected 2020 emissions for both pre and post recession forecasts.

Table 3 Background to PRIMES/GAINS Projection

Model	Background	Greenhouse Gas(es) Examined
GAINS	- Explores interactions and trade-offs between the control of local and regional air pollution and the mitigation of global greenhouse gas emissions. - Covers 43 countries in Europe - Estimates emissions, mitigation potentials and costs for the major pollutants. - Used to assist policy debates on improving air quality in Europe.	- Methane (CH_4) - Nitrous Oxide (N_2O) - Hydrofluorocarbons (HFCs) - Perfluorocarbons (PFCs) - Sulphur Hexafluoride (SF_6)
PRIMES	- Simulates a market equilibrium for energy demand and supply within the European union and it focuses on market related mechanisms influencing the evolution of demand and supply - Covers 27 member states in the European Union - Used for forecasting, scenario construction and policy impact analysis.	- Carbon Dioxide CO_2

3.1.2 Ireland's non-ETS GHG emission projection

Historical and projected greenhouse gas emissions for Ireland's non-ETS sectors, for both pre and post recession, are established from Ireland's annual UNFCCC inventory report (McGettigan et (Sustainable Energy Authority of Ireland, 2011) al., 2011/McGettigan et al., 2008) and Ireland's environmental protection agency's 2020 emission forecast (EPA, 2008 / EPA, 2012).

1. Historical emissions for each GHG and non-tradable sector are summed to extrapolate Ireland's per annum non-ETS emissions between the years 2000-2010.
2. Emission projections were plotted for both businesses as usual and Ireland's policy forecast.
3. Ireland's policy gap was established by subtracting the estimated total 2020 non-ETS emissions from the relevant 2020 non-ETS emission target.

Table 4 Background to Ireland's EPA Projection

Source	Background	Greenhouse gas
Ireland's Environmental Protection Agency	- Agricultural emissions based on teagasc's FAPRI-Ireland model. - Energy forecasts are based on a set of macroeconomic projections for Ireland. - Business as usual forecasts and with policy forecasts are included in projections. - Projections based on a set of macroeconomic assumptions.	- Methane (CH_4) - Nitrous Oxide (N_2O) - Carbon Dioxide CO_2

3.1.3 Comparison between PRIMES/GAINS and Ireland's EPA forecast

Ireland and Europe's emission forecasts for Ireland's non-ETS sectors will be compared in relation to CO_2 and non-CO_2 emissions for post recession forecasts. Data gathered from Ireland's annual UNFCCC inventory report (McGettigan et al., 2011/McGettigan et al., 2008) provides historical emissions for both CO_2 and non-CO_2 emissions. Ireland's energy forecast (Sustainable Energy Authority of Ireland, 2011), for non-ETS sectors, is analyzed and converted to total emissions per sector ($MtCO_2$). European projections, for Ireland's non-ETS sectors, are gathered from the PRIMES and GAINS model forecasts, for both CO_2 and non-CO_2 sources respectively (Capros et al., 2008/Amann et al., 2008/Capros et al., 2010/Hoglund-Isaksson et al., 2010). The steps involved are outlined below:

1. Historical emission data (CO_2/non-CO_2) up to and including 2010 is gathered from Ireland's National Emission Inventory (McGettigan et al., 2011/McGettigan et al., 2008).
2. Energy projections (ktoe) towards 2020, for each non-ETS sector, are converted to Mt/CO_2 using the conversion factor, 41.87 (TJ/ktoe) and Ireland's environmental protection agencies emission factors, which are listed below in Table 5.
3. For Ireland's forecast, total per annum CO_2 emissions are then subtracted from total CO_2eq emission projections from Ireland's EPA forecast in order to distinguish non-CO_2 emissions.
4. For Europe's forecast of Ireland's non-ETS emissions, PRIMES (CO_2eq) and GAINS (non-CO_2eq) annual emission data are summed.
5. These emissions forecasts are then graphed and compared.

Table 5 Fossil Fuel Emission Factors (EPA, 2012)

Fuel	Emission Factor (t/CO_2/TJ)
Coal	94.6
Oil	73.3
Kerosene	71.4
Gasoline	70
Diesel	73.3
Gas	57.1
Peat (avg)	253.6

3.2 Potential Analyses

An investigation into the abatement potential that resides in Ireland's agriculture sector is undertaken in order to answer the following research question:

➢ What potential agricultural GHG abatement strategies are available to Ireland and how much greenhouse gas emissions, in $MtCO_2eq$, could be conceivably abated by 2020?

The abatement potential identifies measures that will build on Ireland's 2020 "with policy" emission forecast. A literature review accessing potential abatement measures is carried out and measures selected will target the prominent greenhouse gases and activities within the agricultural sector. A number of measures are selected and the technical and adoption potential for each strategy is estimated. A step-by-step outline of the methodology used for the potential analysis is summarized below.

3.2.1 Selection of Abatement Measures

A literature review examining potential agricultural emission abatement measures that will focus on reducing methane and Nitrous oxide gas is carried out. Individual measures were chosen on the basis of the following criteria:

- Measures must be relevant to agricultural systems in Ireland.
- Measures must be relevant for short term-deployment.
- Scientific data, from up-to-date research, must be available on the relative abatement potential of each measure.
- For each measure, activity data (actual and projections) must be available to assess the total national abatement potential.

3.2.2 Technical Abatement Potential

The technical potential examines the maximum potential, which is possible to reduce greenhouse gas emissions or improve energy efficiency by implementing a selected farm practice or technology. The agricultural abatement strategies target methane emissions from enteric fermentation and nitrous oxide emissions from nitrogen fertilizer application. For this the technical potential methodology is divided up into two types of agricultural abatement measures:

- Animal Nutrition Measures (Methane)
- Fertilizer Application Measures (Nitrous Oxide)

Animal Nutrition abatement Measures

The data used to calculate the technical potential of animal nutritional measures are presented in Table 6. Total emissions from Ireland's bovine herd and the steps taken in calculating the tchnical abatement potential of measures, are gathered and calculated as follows:

1. Total cattle herd numbers are obtained from Ireland's, 2010, agricultural census (CSO, 2012). Ireland's 2020 herd number estimates are derived from (French, 2010), where dairy herd numbers are projected to increase by 400,000. Only Dairy cow numbers are projected to increase, while the numbers of all other cattle types are assumed to remain constant towards 2020.
2. Emission factors ($kgCH_4$/head/year) for each variety of cattle herd are collected from Ireland's annual national inventory report (McGettigan, et al., 2012).
3. Ireland's dairy milk yield (liters/head/day) and emissions from milk production (CO_{2eq}/kgmilk) are collected from Teagasc's national dairy conferences' proceedings, 2011 (Teagasc, 2011).
4. Agricultural methane emissions are then calculated per cattle head per day.
5. Nutritional abatement measures target methane reductions per head/day or per kilogram of product/day (milk/beef).
6. From the literature review, measures are selected and the emission reduction potential of each strategy is then applied to Ireland's cattle herd in order to calculate the total technical reduction potential (Mt/CH_4) in 2020.
7. The technical methane reduction potential is then converted to CO_2 equivalents using methane's global warming potential (Table 2).

Table 6 Data for Animal Nutrition Abatement Calculations

Data	Value
Number of Cattle in 2010	
- Bulls	- 52,000
- Dairy Cows	- 1,092,500
- Other Cows	- 1,136,700
- Dairy Heifers	- 233,700
- Other Heifers	- 163,100
Total	2,678,000.00
Projected Number of Cattle in 2020	
- Increase in Dairy numbers	3,078,000.00
Cattle Emission Factors (kg/head/year)	
- Bulls	- 81.55
- Dairy	- 109.21
- Other Cows	- 37.17
- Dairy Heifers	- 50.16
- Other Heifers	- 53.68
Milk Yield (litres/cow/year)	4631.00

Fertilizer Application Abatement Measures

The data used to calculate the technical potential of fertilizer application measures are presented in Table 7. Total emissions from Ireland's annual fertilizer application and the steps taken to calculating the technical abatement potential of measures, are gathered and calculated as follows:

1. Fertilizer usages (kg/ha), on tillage crops, are obtained from Teagascs' survey of fertilizer use in Ireland from 2004-2008 from grassland and arable crops (Lalor, Coulter, Quinlan, & Connolly, 2010).
2. Ireland's projected fertilizer application rate, for 2020, is obtained from Donnellan's (2012) study of fertilizer use under the 2020 food harvest report.
3. Kindred (2008) estimated a value for nitrous oxide emissions per kg of nitrogen application, which is used in this study to calculate the total N_2O emissions per hectare of arable land in Ireland (Kindred, Berry, Burch, & Sylvester-Bradley, 2008).
4. Ireland's arable area for the crops, wheat and barley, is sourced from the central statistics office (CSO, 2011).
5. A qualitative literature study is conducted in order to identify fertilizer abatement measures, which target nitrous oxide reductions.
6. The emission reduction potentials, of each measure, are then applied to the wheat and barley farms of Ireland in order to calculate the total technical reduction potential (Mt/N_2O) of recommended measures in 2020.
7. The technical nitrous oxide reduction potential is then converted to CO_2 equivalents using nitrous oxides global warming potential.

Table 7 Data for Fertilizer Application Abatement Calculations

	Value
Fertilizer Application Rate per Crop (Kg/ha) - Winter wheat - Spring wheat - Winter barley - Spring barley Average	 - 179 - 139 - 163 - 118 149.75
Fertilizer Application Rate 2020 (kg/ha) - Increase of 17%	175.20
Nitrous Oxide Emissions (kg N2O per kg N)	0.0157
Area of Arable Farms (ha) - Wheat - Barley Total	 - 93800 - 180500 1,089,000

3.2.3 Adoption Potential

The objective of this section is to evaluate the adoption potential of the identified agricultural abatement measures. A qualitative study, to analyze the adoption rate of previous agricultural measures implemented in Ireland, is carried out.

Once the adoption rate has been established, the various factors that may influence this potential are identified and based on the evidence from historical adoption rates and the factors which may affect the up take of measures, adoption rates for each measure are assumed. The rate of adoption of each measure is assumed to develop linearly towards 2020. The new 2020 abatement potential will build on Ireland's 'with policy" forecast. Once an adoption rate for each measure has been recognized, a barrier analysis is conducted to identify obstacles, which may prevent the implementation of identified measures.

3.2.4 Effect of Agricultural Measures on Irelands non-ETS Emission Gap

This section will finally graph the deployment and abatement potential of the selected agricultural GHG mitigation measures towards 2020 in an attempt to answer the following sub-question:

- *Can the agricultural GHG mitigation measures bridge Ireland's non-ETS emissions gap?*

3.3 Barrier Analysis

A barrier analysis offers a structured way to visualize the obstacles related to the implementation of abatement strategies in Irish agriculture. This section attempts to answer the following research question:

- *What barriers exist within Ireland's agricultural sector and how will the identified agricultural abatement measures address these barriers?*

A qualitative analysis of agricultural literature will be conducted to identify the possible barriers. These identified barriers are then screened and a list of the most essential obstacles is constructed. The developed abatement measures selected are then assessed with respect to the list of identified barriers. The three steps involved in conducting the barrier analysis are as follows:

1. Identify all possible barriers through literature survey.
2. Screen the gross list of barriers to select the most essential.
3. Show how identified abatement measures selected, overcome barriers.

3.4 Policy Evaluation

In this section, the methodology used to answer the below research question is outlined:

- *What viable policy instruments can be used to incentivize the adoption of the recommended agricultural abatement measures?*

The selected measures will require varying types of incentivisation. Behavioral change measures and measures that require investment will need policy instruments that entice famers to adopt the selected abatement measures. A literature review will be conducted to identify viable policy instruments that can aid in the up-take of the agricultural abatement strategies. The policy choices will be categorized into the following four types:

- Control and Regulatory instruments
- Economic and market-based instruments
- Fiscal instruments and incentives
- Support, information and voluntary action.

From a qualitative analysis of possible policy instruments, a list of promising mechanisms is made and from this, practical policy instruments are selected for each abatement strategy.

4. Results

Findings for each analysis are outlined below. Firstly Ireland's policy gap is identified, followed by the results of the potential analysis, barrier analysis and policy evaluation.

4.1 Gap Analysis

The gap analysis results ascertain the gap between Ireland's effort sharing decisions' target and forecasted non-ETS emissions towards 2020, for both pre and post recession. The gap investigation identifies the effort, which will be required to meet Ireland's 20% non-ETS emission reduction target, relative to 2005 emissions. Firstly European projections for Ireland's non-ETS emission are displayed. Following this, Ireland's national forecast is graphed for both the business as usual and Ireland's "with policy" scenario. Each established gap will be based on "with policy" forecasts and not on business-as-usual projections.

4.1.1 European Projections and Ireland's Policy Gap

The PRIMES and GAINS scenarios examine CO2 and non-CO2 emissions, respectively. Figure 4 shows the ration between CO_2 and non-CO_2 as forecast by PRIMES and GAINS towards 2020. Figure 5 presents pre-recession forecasts towards 2020; these are used as a source of comparison so as to understand the impact of the recession on non-ETS GHG emissions. The graphed results of the PRIMES/GAINS projections are shown below (Figures 5/6). Table 9 displays the results of the gap analysis.

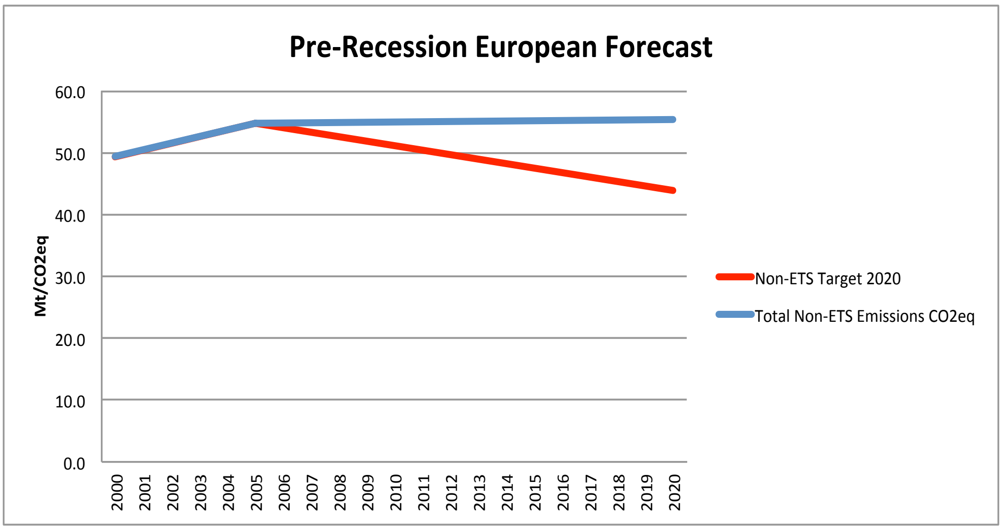

Figure 5 European forecast for Ireland's Pre-Recession Non-ETS Emissions (Capros et al., 2008/ Amann et al., 2008)

The European Pre-recession forecast for Ireland's non-ETS emissions shows a shortfall of 11.4 $MtCO_{2eq}$. Pre-recession projections display an increase in non-ETS emissions relative to the base year.

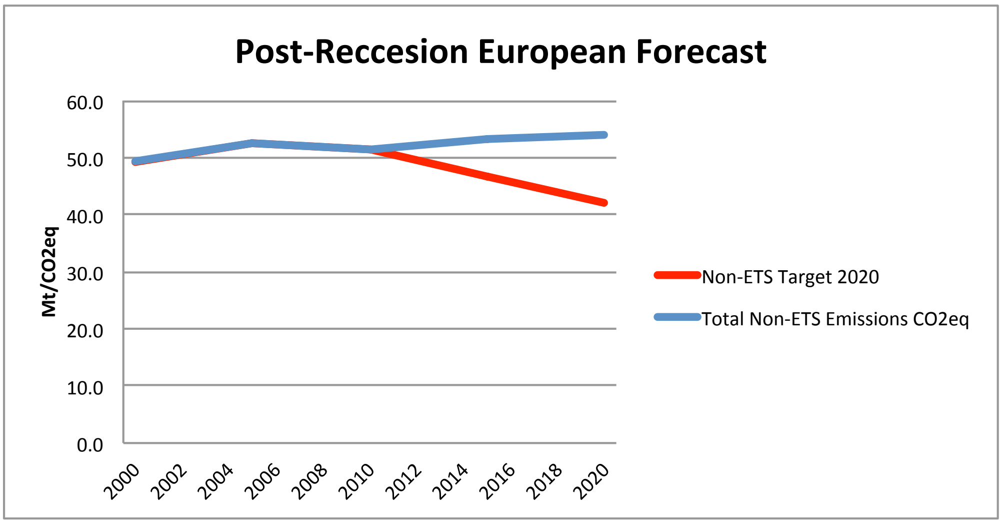

Figure 6 European forecast for Ireland's Post-Recession Non-ETS Emissions (Capros et al., 2009/Hoglund-Isaksson et al., 2010)

Baseline non-ETS emissions show an overall increase of 3.8% in the policy gap after the Irish recession. The post recession European forecast for Ireland shows the emission gap to be 11.9 Mt/CO_{2eq}. The revised projections showed differences in Ireland's historical emissions, for example, pre recession figures for 2005 indicated that Ireland's total non-ETS emissions for that year to be 54.7Mt/CO2eq, while in 2009 this figure was revised to 51.3MtCO2eq. In order to further understand this variance, the ratio between CO_2 and non-CO_2 emission will be outlined in section 4.1.3.

4.1.2 Ireland's National Projected Policy Gap

Graphed beneath are Ireland's non-ETS greenhouse gas emission projections towards 2020. Figure 7 shows, Ireland's pre recession business as usual trajectory and "with policy" scenario, towards 2020, while figure 8 shows non-ETS projections post recession.

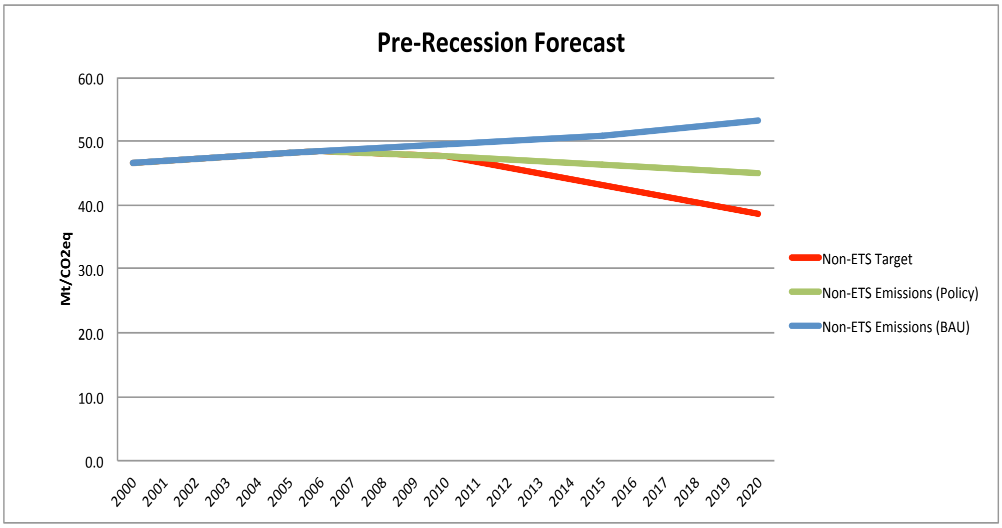

Figure 7 Ireland's National Pre-Recession non-ETS forecast (EPA, 2008)

Ireland's pre-recessionary projections show that even with all existing and planned policy measures, Ireland would come up substantially short of the 20% non-ETS reduction target. This pre-recession shortfall equates to 6.3 Mt CO_{2eq}.

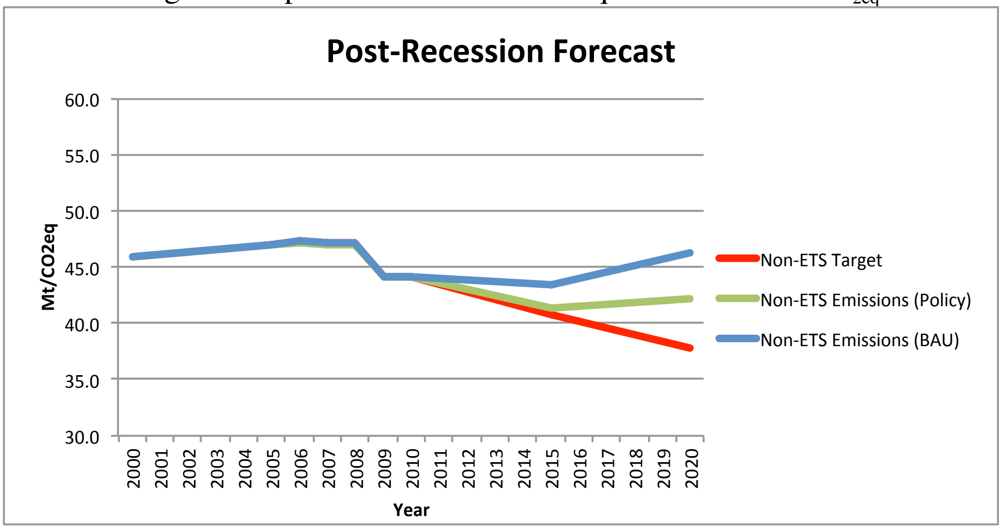

Figure 8 Ireland's National Post Recession non-ETS forecast (EPA, 2012)

Initial observations of Ireland's post-recession non-ETS emissions between the years 2007 and 2010, shows the significant impact the recession had on Ireland's non-ETS greenhouse gas emissions. Post-recession data displayed a 68% decrease in Ireland's 2020 policy gap, when compared to the pre-recession outlook. The impact of the recession can also be seen in Table 8**,** where Ireland's GDP and GNP fell by 9.8% and 13.5% respectively. The EPA's reviewed 2020 forecast now estimates that Ireland will come up short of achieving the 20% reduction target by 4.1MtCO_2eq. This decline in the policy gap can be explained by the economic regression Ireland experienced between 2008-2009.

Table 8 Ireland's trend in GDP/GNP (CSO, 2011)

	2006	2007	2008	2009	2010	2011	Recession 2008-2009 (%)
GDP	117,729	188,729	178,882	161,275	156,487	158,993	**- 9.84**
GNP	154,465	162,209	153,565	132,911	130,202	127,016	**- 13.45**

A complete review of the Ireland's gap analysis is displayed in Table 9**.** A selection of agricultural abatement measures will build on Ireland's post-recession "with policy" forecast and the gap from target of 4.1Mt/CO_2eq in 2020.

Table 9 Comparison Between EU and Irish Forecasts for Ireland's 2020 non-ETS Emissions

Forecast	**2005 Emissions (Mt/CO_{2eq})**	**2020 Emissions (Mt/CO_2eq)**	**20% Reduction Target (2005)**	**Gap to Target (Mt/CO_2eq)**
Ireland EPA Pre-Recession (WAM)	48.3	44.9	38.6	6.3
Ireland EPA Post-Recession (WAM)	46.9	41.6	37.5	4.1
PRIMES/GAINS Pre-Recession	54.7	55.2	43.8	11.4
PRIMES/GAINS Post-Recession	52.6	54.0	42.1	11.9

4.1.3 Comparison Between Emission Forecasts

It is clear from Table 9 that there are sizable differences between Irish projections and European projections for Ireland's non-ETS greenhouse gas emissions. The 2005 base year emission values show differences in emissions for each pre/post forecast as a result of re-calculations in the base year for both the European outlook and Ireland's national forecast. The large difference in emission levels between European forecasts for Ireland and Ireland's national forecast could not be explained within this report. Sectoral activity from the energy use is largely consistent between PRIMES/GAINS and Ireland's National Inventory, however it has been reported that there are differences between the emission factors used. The Integrated Modelling Project of Ireland has shown that on average, there is approximately a 20% difference recorded in emission factors, but this can also be as high as 158% (Kelly, Redmond, & Amarenda , 2009). In order to explore the differences further, it is necessary to examine the disparities between CO_2 and non-CO_2 emissions, for both forecasts. For the purpose of this investigation, post recession figures are compared at 5-year intervals due to the unavailability of per annum CO_2/non-CO_2 emission projections towards 2020.

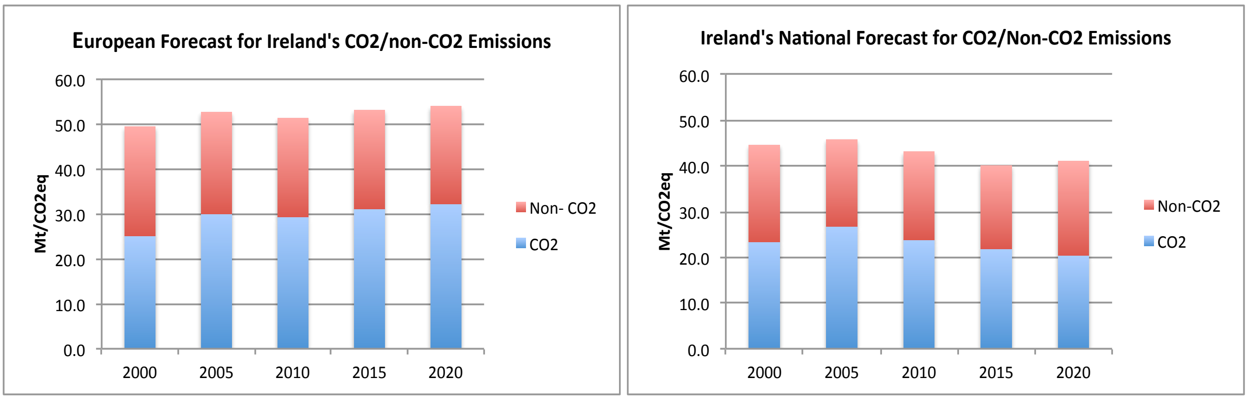

Figure 9 Comparison between CO2/non-CO2 Emissions for both the national forecasts and EU forecast for Ireland's non-ETS Sectors

The European projection for Irish non-ETS emissions shows a higher forecast for each five-year interval when compared to Ireland's national projection. Initially, both projections show similar per annum CO_2 emissions, in 2000 and 2005. Non-CO_2 emissions are more prevalent in the European forecast compared to Ireland's national projection. Between 2005 and 2010, Ireland's national forecast shows a decline of 3.2 $MtCO_2eq$. This fall in total emissions shows the significant impact the recession had on Ireland's non-ETS emissions. European projections for Ireland, on the other hand, only indicate a decline of 0.6$MtCO_2eq$ during this time. Therefore the impact of the recession is far more pronounced in Irish forecasts. For post 2010 emissions, European projections indicate that both CO_2 and non-CO_2 emissions gradually increase, while for Ireland's national projection, CO_2 emissions are shown to decline while non-CO_2 emissions rise post 2015. This increase in non-CO_2 emissions will mainly be driven by Ireland's agricultural sector and the removal of the European Union milk quota and Ireland's national Food Harvest 2020 targets. The 2020 emission gap in Europe's projection for Ireland is substantially larger when compared to Ireland's national forecasted gap (Table 9). Irish data from Europe's GAINS model scenario is quite similar to Ireland's national non-CO_2 emissions, while for CO_2 emissions, Europe's PRIMES data displays substantially more CO_2 emissions post recession (Table 10).

Table 10 CO2 and Non-CO2 Emissions for both Ireland's national Forecast and Europe's Forecast for Ireland's non-ETS Sectors

		2000	2005	2010	2015	2020
Ireland's National Forecast	CO_2	23.4	26.76	23.87	21.82	20.40
	Non-CO_2	21.23	19.03	19.31	18.33	20.70
Europe's Forecast for Ireland	CO_2	25.09	30.00	29.32	31.10	32.17
	Non-CO_2	24.30	22.60	22.00	22.00	21.80

Table 11 compares the ratios between CO_2 and non-CO_2 emissions from the above information. Ratios are similar in the years 2000, 2005 and 2010. However projections vary substantially in 2015 and 2020. It is not known why such a difference is present between Ireland's national forecast and Europe's forecast for Ireland.

Table 11 Ratio Between CO2 and Non-CO2 GHG Emissions

Forecast	**2000**	**2005**	**2010**	**2015**	**2020**
EU	1:1.03	1:1.33	1:1.33	1:1.41	1:1.48
Ireland	1:1.10	1:1.40	1:1.23	1:1.19	1:0.98

Ireland's 2012 nation emission inventory report shows that emission trends are in line with Ireland's national forecasts (McGettigan, et al., 2012). The next section identifies the possible agricultural abatement measures which could be used tackle Ireland's 2020 "with policy" emission gap of 4.1 MtCO_2eq.

4.2 Potential Analyses

Agricultural and transport emissions are forecasted to represent 75% of Irelands total non-ETS greenhouse gas emissions in 2020, with agriculture representing the largest share. With such a high proportion of emissions projected to stem from the agricultural sector, the need to identify feasible strategies for the agriculture sector in the coming years is ever more important. This section will firstly identify viable measures, then the technical potential of each measure will be calculated followed by the adoption potential of each measure.

4.2.1 Reducing Agricultural Emissions

Numerous agricultural mitigation measures for GHG abatement have been reported in international literature (see e.g. Moran et al., 2009/ Johnson et al., 2009/ Bates et al 2009). The selected options are not a comprehensive list, other mitigation measures may have the potential to reduce GHG emissions from agriculture, nevertheless some of those options are subject to continuing research.
Individual measures were chosen and included for Irish agriculture on the basis of the criteria outlined:

- Measures must be relevant to agricultural systems in Ireland.
- Measures must be relevant for short term-deployment.
- Scientific data, from up-to-date research, must be available on the relative abatement potential of each measure.
- For each measure, activity data (actual and projections) must be available to assess the total national abatement potential and associated cost/benefit.

From section 2**,** it's clear that methane and nitrous oxide are the most prominent GHG's arising from agriculture. For methane, reducing emissions from enteric fermentation is dependent on emissions per head of livestock and the total number of animals. Enteric emissions can be simply reduced through reducing the total head of livestock in Ireland, however this solution does not comply with Ireland's Food Harvest 2020 targets (Section 2.2.2). Reducing enteric emissions can however be tackled by improving the productivity of ruminants, which means reducing methane emissions per animal or per unit of animal product (O'Mara, 2004). Practices for reducing CH_4 emissions from enteric fermentation can be grouped into two general categories, improved feeding practices and alteration of dietary practices (Bates, Brophy, Harfoot, & Webb, 2009).
Nitrous oxide emissions can be reduced through various agricultural management strategies (Mosier et al., 1998). Emissions as a result of the application of mineral nitrogen and organic nitrogen can be decreased through the optimization of a crop's

ability to compete with processes whereby nitrogen available to the plant is lost in the soil-plant system and by lowering the rate and duration of the processes by which nitrogen is lost (leaching etc.), reduces the amount of N_2O loss from the soil (Mosier et al., 1998). Other measures increase the overall efficiency with which nitrogen is used by crops (Dawson, Huggins, & Jones, 2008). This is largely based around accurately controlling the supply of nitrogen and matching this to the crops needs. Preventing the formation of N_2O can also be a mitigation measure, through the drainage of soils or the use of nitrification inhibitors (DC Edmeades (agKnowledge Ltd), 2004). Measures must be inline with Ireland's current agricultural system, which is dominated by cattle farming, as well as this, measures must be suitable for quick deployment as a result of the short time available for reaching the target of 37.5Mt/CO_2eq. Options for reducing agriculture GHG emissions are taken from up to date research papers, where the relative abatement potential of each measure is discussed. Options, which could reduce methane and nitrous oxide emissions, are listed and discussed below.

4.2.2 Measures to Reduce Agricultural Emissions

From the qualitative literature review, the following abatement measures have been selected and examined for Ireland's agricultural sector (Table 12).

Table 12 Selected Agricultural GHG Abatement Measures

Measure	Targeted Greenhouse Gas
Feeding Oils	CH_4
Extension of Grazing Season	CH_4
Replace Roughage with Concentrates	CH_4
Spreader Maintenance	N_2O
Precision Farming	N_2O

Animal Nutritional Abatement Measures

Enteric fermentation is a natural digestive process for many ruminant animals. The process involves anaerobic bacteria, called methanogens that decompose and ferment the food present in the digestive tract. Because the digestive process is not 100% efficient, some of the food energy is lost in the form of methane. It is estimated that 7-10% of a ruminants energy intake is lost to enteric fermentation (Moss et al., 1993). Mitigating enteric fermentation would not only reduce emissions, it may also raise animal productivity by improving digestive efficiency. Three potential strategies to reduce methane emissions from enteric fermentation are outlined below.

1) Feeding Oils

Based on the work of Beauchemin et al. 2008, which identified feed additives that reduce enteric fermentation from cattle livestock. Beauchemin showed that with the supplementation of diets with unsaturated lipid* sources, can reduce enteric methane emissions. Her study examined diets containing tallow oil (saturated) and sunflower oil (unsaturated). Feeding 4% oil in the diet would decrease enteric emissions per cow per day by 23% (Beauchemin, Kreuzer, O'Mara, & McAllister, 2008). Other studies have also shown, that by using a lipid feed additive, methane reductions can be substantially reduced (Jordan, Lovett, Monahan , Callan, Flynn, & O'Mara, 2006). This reduction is based on a reduction of rumen protozoa within the digestive tract of the animal.

2) Extension of Grazing Season

This measure is based on the work of Lovett et al. 2008. The study compared a farm in Fermoy North Cork to a farm in Kilmaley West Clare, with different soil composition, permeability and average annual rainfall. Both farming systems adjusted their grazing season length to 149 and 250 days per year. Results from the study showed that for every one-day increase in the grazing season, the emissions reduced on average by 0.14% and 0.17% (Lovett, Shalloo, Dillon , & O'Mara, 2008). Increasing the percentage of grazed grass in the cattle's feed budget and minimizing the proportion of silage in the livestock's diet increases feed digestibility (Kennedy, Curran, Murphy, & O'Donovan , 2009). By minimizing the time cattle spend feeding on grass silage, reduces the proportion of dietary energy lost as methane.

3) Replace Roughage with Concentrates

Ruminants have the ability to utilize low energy fibrous roots, also called roughage, which forms a large proportion of the typical livestock diet. Roughage contains a high proportion of structural carbohydrates, replacing this roughage with high starch concentrates improves propionate generation in the rumen (Bates, 2001). Moran, 2009 reported that by replacing the grass silage with high starch concentrate led to a 7% drop in Methane emissions and a 14% increase in milk yield. This drop in methane emissions is due to the greater proportion of propionate in the rumen volatile fatty acids and as a result there is less H_2 for methane synthesis (Moran, et al., 2009).

Fertilizer Application Abatement Measures

Nitrogenous fertilizers are important for increasing crop yields in agriculture, however the use of nitrogen based fertilizers increases nitrous oxide emissions from the soil and water through nitrification and denitrification processes. For Agriculture, the primary anthropogenic source of N_2O emissions is agricultural soil management.
Two potential strategies that could be utilized so as to maximize fertilizer use are discussed below. These measures reduce the risk of exceeding crop nitrogen requirements improved farming practice and through monitoring fertilizer application.

1) Spreader Maintenance

On-site farm management practices have the potential to reduce nitrogen losses from the agricultural system through improved farming techniques. The progression of the CAP, which has now moved away from direct price support to crops, encourages the trend of increasing farming efficiency. This measure is likely to complement other measures to reduce nitrate leaching and pollution, such as the European Nitrates Directive. In order to improve fertilizer practice, the amount of nitrogen, which exceeds crop nitrogen needs, must be reduced. The improving spreader maintenance has been shown to save approximately 50kg N/ha per 228 kg N/ha.

2) Precision Farming

Precision farming involves whole farm management in order to optimize returns on farm inputs. Precision farming uses technologies such as Global Positioning System (GPS), automatic crop and soil sensors, satellites and aircraft so that crop performance and output can be accurately measured (Schmerler & Basten M, 1999). Farmers can actively vary inputs across the field in order to improve soil nitrogen efficiency and improved management of crops. Precision farming also involves taking account of on-site soil type and soil nitrogen supply; this ensures that crop fertilization is balanced across the farm. Precision farming has been shown to save 20 kg N/ha for wheat, 10 kg N/ha for barley and 15 kg N/ha for maize farming (Bates, Brophy, Harfoot, & Webb, 2009).

Table 13 below shows the selected measures and how each relates to the criteria established in section 3.2.1. All measures, for the most part, adhere to the criteria outlined. Only precision farming's will be an issue for short-term deployment. Time consuming geological soil surveys are needed, which must be carried out to analyze the soil nitrogen content and the residual nitrogen present on each farm.

Table 13 Selected Agriculture GHG Abatement Measures and Criteria for Selection

	Relevant to Irish Agriculture	Short-Term Deployment	Up-to-Date Research	Activity data
Feeding Oils	✓	✓	✓	✓
Extension of Grazing Season	✓	✓	✓	✓
Replace Roughage with Concentrates	✓	✓	✓	✓
Spreader Maintenance	✓	✓	✓	✓
Precision Farming	✓	✗	✓	✓

4.2.3 Technical Abatement Potential

The technical potential of the measures, outlined beneath, shows the amount by which it is possible to reduce greenhouse gas emissions or improve energy efficiency by implementing a farm practice or technologies that has already been demonstrated to reduce emissions. The reduction potential of each measure is outlined in Table 14 followed by the results of the technical potential analysis for each measure.

Table 14 Abatement Potential of Agriculture GHG Abatement Measures

Abatement Measure	Measurement	Potential
Feeding Oils (Beauchemin et al., 2008)	% Saved per cow per day	23 %
Replace Roughage with Concentrates (Moran, et al., 2009)	% Saved per cow per day	7 %
Extension of Grazing Season (Lovett et al., 2008)	% Saved per unit of milk product	0.14%
Precision Farming (Bates et al., 2009) - Wheat - Barley	kg of Nitrogen saved per hectare	- 20 kg N/ha - 10 kg N/ha
Spreader Maintenance (Bates et al., 2009)	kg of Nitrogen saved per hectare	38.4 kg N/ha

The reduction potential of each measure shown above is then applied to Ireland's agricultural sector in order to deduce the impact of 100% deployment of each measure. The results are outlined in Table 15.

Table 15 Technical Potential of Selected Agricultural Measures

Category	Measure	Technical Potential ($MtCO_2eq$)
Animal Nutritional Abatement Measures	Feeding Oils for Dairy Cattle	7.87
	Replace Roughage with Concentrates	1.55
	Extension of Grazing Season	0.01
Fertilizer Application Abatement Measures	Precision Farming (Wheat & Barley)	0.01
	Spreader Maintenance	0.29
	Total	**8.92**

The results in Table 15 show that with 100% deployment of the selected measures, the potential of GHG reduction within the agricultural sector is 8.92 Mt CO_2eq. The effectiveness of these measures will be influenced by interactions between measures and the environment. Since this limit is not informed by the reality of non-adoption or likely policy or social constraints, realizing this potential between the years 2013-

2020 is unlikely. So as to gain a more representative abatement potential achievable by 2020, it is necessary to analyze the adoption potential of these measures towards the year 2020.

4.2.3.1 Technical Potential Assumptions
A list of assumptions inherent within the above calculations is briefly outlined below. The assumptions are divided into nutritional abatement measures' assumptions and Fertilizer abatement measures' assumptions.

Animal Nutritional Abatement Measures
In order to calculate the technical potential of each nutritional abatement measure, the following assumptions are made:

1. The number of dairy cattle is set to increase by 400,000 towards 2020. This is in line with Teagascs' forecast and is inbuilt within Irelands "with policy" projection (Teagasc, 2011/EPA,2012).
2. The length of the average annual grazing days is assumed to increase from 227 to 250, under the extension of grazing days' abatement strategy.
3. Milk yield is assumed to remain constant to the year 2020.

Fertilizer Application Abatement Measures
So as to calculate the technical potential of each fertilizer application abatement measure, the following assumptions are made:

1. Arable farm areas are assumed to remain constant towards 2020.
2. Arable fertilization rates are assumed to increase by 17% towards 2020, in line with the EPA's forecast for Ireland's arable agriculture (EPA,2012).

4.2.4 Adoption Potential
There is no Irish literature available that examines the adoption rates of previous historical agricultural measures. The information has neither been specifically collected through agricultural census nor officially published. Therefore there is a knowledge gap in the understanding of the state of adoption of agricultural measures in Ireland. As well as this, there are many factors that can influence the up-take of abatement measures, which makes accurately predicting viable adoption rates difficult. Ireland also has an average farm size of 32 hectares, which makes the successful large-scale deployment of GHG mitgation strategies difficult, given that almost all farms do not have necessary economies of scale. In order to understand the adoption potential of the recommended measures, the uptake of Ireland's Rural Environmental Protection Scheme (REPS1) is examined. This environmental initiative is funded by the European Union and rewards farmers for carrying out their farming activities in an environmentally friendly manner and to bring about improvement on existing farms. The REPS1 was introduced in 1994 and ran till 1999, where the REPS2, REPS3 and REPS 4 replaced it.

Table 16 Rural Environmental Protection Scheme (1991-1994)

Average No. of farms in Ireland (1994-1999)	No. of Farms involved in REPS1 (1994-1999)	Percentage of Total No. of Farms (%)
149050	45500	30.5

Between the years 1994 and 1999, 30% of Irish farms were involved in the REPS1 initiative. From this, the adoption rate for the selected measures is assumed to be 5% per annum with linear development. However, the five measures differ and can be divided up into two types, those requiring investment and those requiring behavioral change on the part of the farmer. Behavioral change measures do not required investment, therefore it is expected that those measures will be adopted at an increased rate compared to the measures that require financing. The annual projected uptake of either behavioral change measures is chosen to be 6.5%.
Financing has and will become an increasingly important factor in the adoption of agricultural measures. Recently a report was published, which revealed that in the last few years only one-third of farms are economically viable farm businesses and almost 37,000 farm households are economically vulnerable (Finfacts Team, 2012). For this reason a conservative annual uptake of 5% per annum is assumed. The short time-scale available for the deployment of measures is another reason behind the choice of the selected adoption rates, with only 7 years left until the 2020 non-ETS emission target must be reached. Table 17 displays the adoption rate anticipated for all measures and the total expected 2020 abatement potential of each.

Table 17 Selected Adoption Rates and Abatement Potential for Each Measure

	Measure	Adoption Rate (Per annum)	Total 2020 Penetration (%)	2020 Abatement (Mt/CO2eq)
Behavioral Change	Extension of Grazing Season	6.5%	45.5	0.0067
	Spreader Maintenance	6.5%	45.5	0.1059
Investment	Feeding Oils (Dairy)	5%	35	3.1491
	Replace Roughage with Concentrates (Dairy/Beef)	5%	35	0.6219
	Precision Farming	5%	35	0.0072
Total				**3.42**

The 2020 abatement figure of 3.42Mt/CO_2eq is however, dependent on a number of barriers, which must be overcome. These barriers are listed and discussed in section 4.3 below.

4.2.5 Effect of Agricultural Measures on Irelands non-ETS Emission Gap

The impact of the chosen agricultural measures is graphed below. From this projection it is clear to see that even with the additional agricultural abatement measures, Ireland will fail to bridge the gap towards achieving the 20% reduction in non-ETS emissions by 2020. Ireland's national "with policy" projection shows an increased decline post 2015, this further fall in emissions is due to the removal of the EU milk quota and the increase number of Irish dairy cattle stock, which positively impacts on the emission reduction potential across Ireland's dairy herd. Ireland's remaining emission gap towards the 2020 Effort Sharing Decision target, equates to be just 0.7Mt/CO_2eq in 2020.

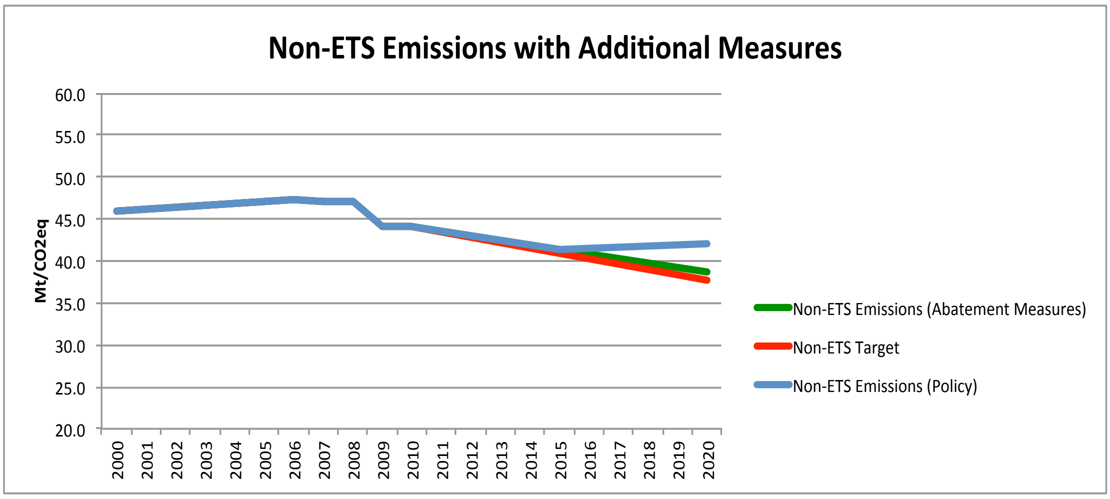

Figure 10 Non-ETS Emission Forecast with Additional Agricultural GHG Abatement Measures

To close, under the selected adoption rates and calculated technical potential, the influence of all five agriculture GHG abatement measures reduces the Ireland's effort sharing decision's emission gap to just 0.7Mt/CO_2eq, however these measures alone are not enough to bridge the gap fully.

4.3 Barrier Analysis

With Ireland forecasting a growth in production from that agriculture sector by 2020, potential measures that reduce non-ETS GHG emissions need to understand what barriers are involved for the uptake of theses measures in Ireland's Agricultural sector. The barriers inherent within the agriculture sector are outlined below.

4.3.1 Barriers in Agriculture

There are many barriers within the agricultural sector that prevent or hamper the adoption of agricultural GHG abatement strategies. With the majority of GHG emissions stemming from various natural processes, it can be difficult to successfully abate emissions, which occur naturally within a farming system. A number of studies outline various constraints that discourage the uptake of measures. Cary et al., 2001 identified a number of barriers related to information and knowledge transfer in sustainable agriculture (Cary, Webb, & Barr, 2001). It is necessary to understand the barriers connected to the generation and diffusion of knowledge within the agriculture sector. Some measures may require a need for improved education, as certain strategies require further understanding of farm and crop systems. As a result farmers may not be attracted to changes, which require intellectual investments (Vanclay &

Lawrence, 1994). Economic factors are often mentioned as barriers to adoption of GHG abatement measures. The cost of adoption, the doubt of profitability, potential loss of production, labor demands and short-term economic necessities are all factors, which have been noted to affect adoption (Pederson, Nielsen, Christensen, & Hasler, 2012). Farmers in Ireland are also carrying large debt. Poor product prices and recent high investment on farm facilities means that many farmers are unable to make large ventures (Punch & Gilmartin, 2010). This means that for some of the selected measures to be adopted by Irish farmers, they are likely to require policy and economic incentives and other programmes, so as to reduced the risks associated with the adoption of certain measures. A farmers personal characteristics and traditional farming practices has been noted as being a barrier to adoption of conservation tillage with farmers from Ontario. Uncertainty to change was the most regular barrier (Wandel & Smithers, 2000). A change in farming technique may be rejected because of a farmer's resistance to change (Vanclay & Lawrence, 1994). New farming practices are not part of the various farming subcultures across Ireland and are less likely to be rapidly adopted.

Table 18 Most Prominent Agricultural Barriers

Barrier	Description
Risk Attitudes (United Nations Framework Convention on Climate Change, 2008)	A change in farming practices can be seen as a threat to productivity and competitiveness without considering the possible benefit of GHG mitigation measures.
Transaction Costs (Punch & Gilmartin, 2010)	Measures requiring investment will be difficult to impose due to the large debt accumulated by Irish famers in recent years.
Traditional Farming Practices (United Nations Framework Convention on Climate Change, 2008)	Measures must be consistent with traditional Irish farming practices; a significant change would be met with rejection from farmers.
Knowledge (Teagasc, 2011)	Decision-making of farmers whose practices are mostly informed by inter-generational learning process, which may hamper the uptake of new measures. Need for more in depth research into site-specific mitigation potential for various areas of Ireland. Need to enhance the transfer of knowledge to farmers. There is also high uncertainty in Irish agricultural emissions estimates and lack of information for their assessment.

4.3.2 Abatement Measures and Identified Barriers

Methane and nitrous oxide are the most prevalent GHG emitted from Ireland's agricultural sector and the measures selected are aimed at reducing these specific gases. The abatement measures have been selected to address the barriers, which have been identified for Ireland's agricultural sector.

Dietary Manipulation

One of the central barrier to the adoption of agricultural GHG abatement strategies is the Food Harvests' 2020 production targets, which are outlined in section 2.2.2. This report has not outlined any agricultural emission abatement strategy aimed at reducing or controlling emissions as a result of an increase in production. With this in mind, measures that reduce agricultural GHG emissions must not impede productivity.

The chosen dietary manipulation measures of feeding oils and replacing roughage with concentrates have the potential to benefit the productivity of dairy and suckler cows. The potential for implementing feeding oils on commercial farms as a methane mitigation strategy is high because lipids represent "natural" rather than chemical intervention. Lipid sources can have other benefits such as altering the fatty acids composition of milk and meat, reducing the dustiness of feed, and increasing the absorption of fat-soluble nutrients (National Research Council, 2001). With the inherent benefits for meat and milk production, feeding oils are also predicted to be a cost effective means of reducing methane emissions from cattle (Beauchemin, Kreuzer, O'Mara, & McAllister, 2008). The use of concentrates as a replacement to roughage intake has been shown to increase milk yield by 14% per animal (Anon, 2005). This predicted benefit to production should also help with the barrier of transaction costs. Increasing quality and yield of produce in dairy farming could convince farmers to adopt such dietary manipulating measures, particularly when the milk quota is removed in 2015. Extending the grazing season has also been mentioned to have positive implications for profit margins, as grazed grass is the most inexpensive feed available (Chilibroste, Soca, Mattiauda, Bentancur, & Robinson, 2007). The benefits of dietary adjustment to productivity will also remove the barrier of risk, as productivity and competitiveness will not be affected. The measures are also non-intrusive, as traditional farming practices are not challenged with sizeable change. This will make these on-farm strategies much more attractive for Irish farmers to adopt.

Fertilizer Management

The two land management strategies selected are spreader maintenance and precision farming. Improving fertilizer spreader maintenance through correct spreader calibration is a simple, cost effective and non-invasive strategy of reducing on farm N2O emissions. The use of fertilizer management practices to reduce nitrogen loses from agricultural systems can maximize crop productivity, improve profitability of farms and also reduces leaching or nitrate (Bates, Brophy, Harfoot, & Webb, 2009). Precision farming is the most cost intensive measure recommended as this strategy requires the purchase of computer mapping software, decision support software, monitoring and recording facility for tracer and yield mapping and GPS systems (Schmerler & Basten M, 1999). Precision farming as a management tool improves crop yields and can achieve greater efficiencies in input usage and costs. There is a need for investment as well as the need for improved transfer of knowledge. Such a measure may be more attractive to younger famers whose farming practices are not as ingrained within the farming subculture. Small farm holders will not view this measure as a legitimate option and may require incentivisation to encourage adoption. Economics is the main force behind precision farming, as the farms increase in size, economies of scale allow one farmer to manage more land in less time, producing more arable products at lower costs (McBratney & Whelan, 2005). By choosing spreader maintenance and precision farming at measures to reduce GHG emissions from agricultural sources, it is hoped that all farming operations and farmer situations can be catered for. Table 19 shows the impact assessment of each abatement measure on the barriers identified above.

Table 19 Barrier-Analysis of Selected Agricultural Abatement Measures

	Feeding Oils (Dairy Cattle)	*Replace Roughage with Concentrates (Beef/Dairy)*	*Precision Farming (Wheat & Barley)*	*Spreader Maintenance (Arable Land)*	*Extension of Grazing Season (Dairy)*
Risk Attitudes	✔	✔	✔	✔	✔
Transaction Costs	✔ ✗*	✔ ✗*	✗	✔	✔
Traditional Farming Practices	✔	✔	✗	✔	✗
Knowledge	✔	✔	✗	✔	✔

✔: A tick indicates that the barrier of the agricultural GHG abatement measure has been addressed
✗ : A cross indicates that the barrier of the agricultural GHG abatement measure has not been addressed
* : Both a cross and a tick indicate that these measures are potentially profitable although initial start up investment is needed

4.4 Policy Evaluation

As said in section 2.2.2, Ireland does not have any domestic agricultural policies aimed at reducing emissions from the agricultural sector. Agricultural GHG abatement policies are a relatively young and dynamic area of public policy making. However, its development has attracted far more attention than the results it delivers in practice, which of course is a concern for Irish policy makers. Due to the complex nature of emissions from agriculture, agreeing on the strategies and policy instruments has been difficult. The 3.45 Mt/CO_2eq abatement potential for the recommended measures represents what can be realistically achieved by 2020. However, these measures will only be adopted with incentivisation, research and advisory programmes to facilitate the adoption of measures and the transfer of knowledge to Irish farmers. Policy instruments take a variety of forms, a number of which are outlined below.

4.4.1 Policy Instruments

Policy instruments can be categorized into four types, regulatory, market-based, fiscal and informative measures. The categories and some examples of the type of instruments available are outlined in Table 20.

Table 20 Categories and Types of Policy Instruments

Control and regulatory instruments		**Economic and market-based instruments**	**Fiscal instruments and incentives**	**Support, information and voluntary action**
Normative **1**. Appliance Standards **2**. Procurement Regulations	*Informative* **1**. Mandatory audits **2**. Mandatory labeling and certification programs	**1**. Cooperative procurement **2**. Certificate Schemes	**1**. Taxes/Tax Exemptions **2**. Capital subsidies, grants, subsidized loans	**1**. Voluntary certification and labeling **2**. Trade agreements **3**. Awareness raising, education, information campaigns

If enforcement can be secured, regulatory and control instruments were revealed as the most effective and cost-effective category of instruments (United Nations Environment Programme, 2007). Examples of such regulatory instruments are Quotas, which are used to regulate product output; an example of such a measure is the European milk quota. Contracts are another example of a control and regulatory instrument. Contracts can be used to guarantee a specific action is undertaken. A Cross compliance instrument outlines regulations on the environment, which must be followed in order to participate in a particular program (Varela-Ortega & Calatrava, 2004). An example of a cross compliance instrument is Europe's Single Payment Scheme for Farmers. Fiscal policy measures and incentives use government spending and taxation to influence the pattern of an activity. Incentive-based policy instruments have historically gained favor with policy makers (Speck , Anderson, Nielsen , Ryelund, & Smith, 2006).

Subsidies are also often used when the focus is to encourage a particular response, such as the provision of trees for farm planting or to support a farmer's income such as the European Common Agricultural Policy. Lastly, support and the supply of information to farmers is an essential policy instrument to stimulate the adoption of abatement measures. Trade agreements are increasing in popularity and many require environmental provisions to be established within the agreement. Bilateral trade agreements can achieve an easier entry into other countries markets with varying types of trade preferences concerning low carbon intensive products, low emission technologies and inputs to low emission agricultural process. For Ireland, Teagasc is the main agricultural research institution. Teagasc will have a key role in knowledge transfer and in supporting innovations for farmers towards 2020. Teagasc provides a platform for the access to technologies, that Irish farmers can apply so as to improve farms competitiveness. Teagascs' knowledge transfer advisory programme will be key to the success of any greenhouse gas abatement measure and in order to achieve the most potential. In order to achieve the best possible deployment potential the current transfer advisory programme must be expanded.

The various instruments shown above have been used in the past to enable the goals of policies to be accomplished. Some have been more effective than others, for this reason choosing the right policy instrument becomes important. The instruments mentioned do not represent a complete list of those available. Additionally, the function of the various instruments can differ widely. What is required for Ireland is the choice of an instrument or combination of instruments, which can achieve the desired objective of increasing the adoption rate of the selected greenhouse gas abatement strategies, with minimum delay and with acceptable cost. Pedersen et al., 2011 analyzed how to optimize the effect of policy instruments in the Danish agricultural sector and found some farmers to be more economically motivated while other farmers are more focused on optimizing yield and pay less attention to expenditures and crop prices. Farming groups in Denmark differed in their response to economic policy instruments and the results implied the need for a broad array of policy instruments to match different farmer rationales (Penderson, Nielsen, Christensen, & Hasler, 2012). For the purpose of this study policy instruments will be recommended for each abatement measure suggested. The policy instruments recommended for each of the chosen abatement measures can be seen in Table 21.

Table 21 Policy Instruments for Agricultural Measures

Measure	Policy Instrument	Details
Feeding Oils	- Grants - Awareness raising, education, information campaigns	Supply of grants to cover marginal costs to farmers and to incentivize uptake of measure. Transfer of knowledge and techniques improved through education and information campaigns.
Extension of Grazing Season	- Research funding - Awareness raising, education, information campaigns	Research for farm specific potential. Information campaigns for farmers to improve the transfer of knowledge.
Replace Roughage with Concentrates	- Grants - Awareness raising, education, information campaigns	Grants cover marginal costs to farmers Transfer of knowledge and techniques improved through education and information campaigns.
Spreader Maintenance	- Mandatory audits - Awareness raising, education, information campaigns	Audits on the quality of spreader calibration across Ireland. Education and information campaigns
Precision Farming	- Subsidized Loans - Awareness raising, education, information campaigns	Subsidized loans to purchase precision farming machinery. Agricultural co-operatives to pool farming resources and share equipment. Information campaigns needed to educate farmers on precision farming.

5. Discussion

Under the current non-ETS emission trend, Ireland will not adhere to the 20% reduction (relative to 2005) target agreed upon under the European Effort Sharing Decision. Even with the achievement of all non-ETS policy measures towards 2020, Ireland will overshoot the 20% reduction target by 4.1MtCO_2eq. The agricultural GHG abatement measures, identified in this report, have shown a combined technical abatement potential of 8.9MtCO_2eq. However, the realistic 2020 deployment potential shows that these measures have the potential to abate 3.42Mt/CO_2eq from Ireland's agricultural sector emissions. This however is insufficient to successfully bridge the gap in Ireland's effort sharing decision, with a gap of 0.7MtCO_2eq remaining.

There are a number of points, which must be raised when examining the results. Firstly, the gap analysis showed sizable differences between Europe's projection for Ireland's non-ETS sector and Ireland's national projection. This difference seems to stem from Europe's PRIMES (CO_2) data. In order to rectify these differences and improve the accuracy of European projections for Ireland, both Ireland's EPA and the PRIMES/GAINS teams must examine the parameters used by each, so as to coordinate future forecasts and improve their accuracy to aid in future policy making. Secondly, individual mitigation measures operate at farm level, which impact on many aspects of farm management. This means that measures may interact with one another and as a result may increase or decrease the abatement potential of the combined measures. Research is required to examine these complex interactions further as well as furthering Ireland's understanding of the climate and soil variability, which exists across the country.

The future of Ireland's agricultural policy is firmly set on the side of boosting productivity, with little regard for the abatement of GHG's from this sector. This report identifies the need for agriculture policy intervention towards 2020 and suggests five potential agriculture GHG abatement measures, which have been proven to have the potential to reduce GHG emissions. As agriculture is the largest sector within Ireland's non-ETS sectors, concerted effort should be made to improve national agricultural policy in Ireland, so as to address the issue of Ireland's agricultural emissions. This paper has shown the potential for GHG abatement within Ireland's agricultural sector, however, the abatement potential of the selected agricultural measures, in 2020, is based upon the premise that Ireland will successfully achieve all policy objectives by 2020. Any deviation from successfully achieving these goals will change the results outlined in this paper.

Under the current structure of the effort sharing decision, the gap of 0.7MtCO_2eq will require the use of the Kyoto Protocol flexible mechanism, either through the purchase of emission allowances from other member states (from unused allocations) or through the purchase of credits from projects that reduce emissions in developing countries. This solution is not ideal, as relying on purchasing credits from overseas may be an expensive way to delay national action.

The impacts of the recession may have contributed to the reduction in emissions, but it may also have inhibited future investment resources and disputably may have altered the political priorities of the Irish government. Ireland cannot trust on the recession to meet the national effort sharing decision target. In order to ensure that future economic growth within the Irish agriculture sector is sustainable, agriculture

must be more resource efficient. Future progress in the abatement of GHG emissions from Ireland's agriculture sector will only be achievable through incentivisation, investment in R&D projects and through information campaigns.
A final point to make is that currently under the Effort Sharing decision, carbon sinks are not permitted to contribute to meeting national targets for non-ETS sectors. If this were the case, Ireland's environmental protection agency has forecasted that carbon sinks could potentially offset 4.8MtCO_2 in 2020 (EPA, 2012). However, the Council and European Parliament have asked the European Commission to assess modalities for the inclusion of associated emissions and removals in the reduction commitment (European Commission, 2012). If forestry sinks were allowed to contribute to Ireland's effort sharing decision, the 20% reduction target could be achieved. As it stands omitting sinks from contributing to the effort sharing decision target does not suit Ireland's situation. Ireland requires a more flexible approach so as to adhere to the 20% reduction (relative to 2005).

6. Conclusion

To conclude, Ireland's 2020 effort sharing decision's emission gap is projected to be 4.3Mt/CO_2eq in 2020, relative to 2005. The agricultural GHG mitigation measures selected have the potential to abate 3.2MtCO_2eq. The remaining gap towards achieving Ireland's effort sharing decision is calculated to be 0.7Mt/CO_2eq with the additional recommended agriculture measures. These measures will only be successfully adopted through incentivisation and advisory programmes. Further research is needed in order to understand the interactions of the various mitigation measures as well as the potential variability of GHG abatement potential across Ireland's farming system.

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