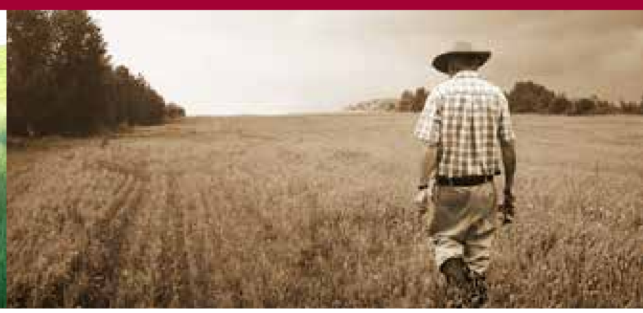
national rural network

Farm Level Actions to Reduce Climate Change Impacts

A NATIONAL RURAL NETWORK REPORT

DECEMBER 2013



The European Agricultural Fund for Rural Development: Europe investing in Rural Areas.

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

LEADER

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government

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The recommendations in the report are the considered opinion of the author based on the consultations undertaken with stakeholders and the input of the members of the Working Group. However, there may be specific elements in the recommendations that may not fully represent the views of all participating organisations.

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Table Of Contents

Executive Summary

Climate change will impact significantly on farming in future in terms of actual climatic conditions and the measures which may be implemented to limit the greenhouse gas emissions. Climate change is defined by the EPA as a significant change in climate (e.g. temperature, rain, wind) for an extended period of decades or longer. Climate change can be attributed directly or indirectly to human activity. Climate change can occur as a result of increased emissions of greenhouse gases from human activities. Greenhouse gases are part of the atmosphere (both natural and those resulting from human activity) that absorb and re-emit infrared radiation which contributes to trapping heat. At farm level, there is a lack of knowledge and understanding of the impact that farm practices have on greenhouse gas emissions or on how practices can be changed in order to reduce the negative climatic impacts. In Ireland, the *Food Harvest 2020* report has set ambitious targets for increased production/output across all of the main farm enterprises. While the *Food Harvest 2020* report takes account of the greenhouse gas and other environmental implications of increased output, it also reflects the reality of conflicting economic and environmental objectives.

This research report was guided by a National Rural Network (NRN) working group which explored actions which could be undertaken at farm level. The specific aim of the research was to explore ***'farm level actions to reduce climate change impacts (taking account of the Food Harvest 2020 production targets)'***. The scope of the report did not allow for conducting primary research and therefore the report was informed by national and international research and by the input, knowledge, experience and expertise of the members of the working group (and their respective organisations). The focus was kept deliberately narrow on the farm level actions to reduce emissions. While farmers will also need to adapt their practices to cope with the impacts of climate, this aspect is not addressed in this report.

The purpose of the report is to inform the Department of Agriculture, Food and the Marine, other agencies and farmers on specific actions which could be taken to reduce greenhouse gas emissions at farm level. This report is one of a series undertaken by the NRN to develop the discussion around key issues of concern and importance in rural areas and propose practical changes to current policies/programmes/measures.

FOOD HARVEST 2020 – THE CONTEXT

The *Food Harvest 2020* report has established ambitious targets for Irish agricultural production. The basic premise of the *Food Harvest 2020* report is that the period to 2020 is one of opportunity for agriculture. The achievement by farmers of these targets on their own farms will require support, advice and the adoption of new technology. However, the greenhouse gas implications of achieving increased production may be less obvious or readily identifiable for many farmers. The *Food Harvest 2020* report identifies a major opportunity for Ireland to find ways to differentiate itself and take the lead in developing low carbon food products. The future prosperity of Irish agriculture depends on the extent to which the industry merges the demand for food with the need to limit greenhouse gas emissions (*Food Harvest 2020* production targets recognised as having the potential to increase greenhouse gas emissions from agriculture).

THE CHALLENGE OF CLIMATE CHANGE

Climate change poses a major challenge for the agricultural industry and farmers, however, many farmers do not fully understand the contribution of agriculture to greenhouse gas or the consequences and impact that climate change will have on their business (climatic and/or regulatory/policy). Many farmers are sceptical about the concept but fearful that it will bring further negative environmental pressures on farm practices.

What is certain, is that the world population is increasing. As a result, food demand is increasing, placing additional pressure on land and other resources which ultimately are creating environmental pressures. Therefore, the challenge for farmers (and policy makers) is to produce adequate food to feed the world without further damaging the natural environment. While farmers will produce the food, the responsibility of sustainable production rests with everyone, not just farmers.

Based on the distribution of emissions in the national climate change strategy (different measurement to the UN/EU measure), agriculture accounted for 32% of national total greenhouse gas emissions in 2011. The high Irish figure reflects the relative importance of agriculture to the economy and the significance of ruminant livestock. This is the highest share of national total emissions across the EU and is the second highest (New Zealand has the highest share at 47.2% in 2011) amongst parties to the United Nations Framework Convention on Climate Change (UNFCCC).

RESEARCH CONCLUSIONS

Climate change is impacting and will impact further on Irish farmers and farming systems over the coming decades due to climatic conditions but also due to policies implemented to reduce the greenhouse gas emissions from agriculture. While Irish beef and dairy production systems are efficient in terms of carbon, agriculture accounts for a large proportion of overall emissions in Ireland and therefore needs to be addressed. It is important to balance the reduction targets with a focus on how to achieve those reductions, working with farmers to achieve improvements rather than simply setting out targets to be achieved.

The NESC report (2012) *Ireland and the Climate Change Challenge: Connecting 'How Much' with 'How to'* suggested that it was necessary to balance the emphasis on 'how much' emissions reduction to target with more focus on 'how to' achieve the reductions. The findings from this research endorse those conclusions and highlight the importance of working with farmers to achieve improvements rather than simply setting out targets which they must achieve.

There is confusion among farmers and others about climate change and the terms used to describe it, the range of greenhouse gases and the different units/methods of measurements. A greater understanding may lead to a greater adoption of changes at farm level.

A major challenge is the lack of knowledge and understanding of the impact that farm practices have on greenhouse gases or on how practices can be changed in order to reduce the negative impacts. Farmers have not considered how policy measures or regulations which may be introduced to address greenhouse gas reductions might impact on their farming operations, impose restrictions on their production systems or lead to additional costs.

Due to the small carbon footprint relative to other countries, there are opportunities for Irish agriculture to prosper from the focus on climate change and greenhouse gas emissions. The increasing demands for low carbon food products offers potential to promote and market Irish food as such.

The confusion with regard to greenhouse gases and the lack of understanding of how to address the issue at farm level is now being addressed by the development of the Carbon Navigator by Teagasc and Bord Bia and the initiation of farm carbon audits. Evidence from the carbon audits show that there is considerable potential to further improve the carbon efficiency of farms which will also potentially lead to improvements in management and productive efficiency.

Extensive research has been undertaken nationally and internationally on farm level actions to address greenhouse gases. Many of the outcomes highlight practical measures relating to management practices and efficiency which could be adopted at farm level. The big gap appears to be in the communication and explanation to farmers of what they can do on their own farms to reduce their own greenhouse gas emissions and contribute to reducing overall emissions from Irish agriculture.

While agriculture production practices contribute to greenhouse gas emissions, it is evident that there is potential to reduce emissions by: sequestering CO_2 in biomass and soil; increasing efficiency in the utilisation of inputs such as fuel, fertiliser and pesticides; producing biofuels to replace fossil fuel; improving the efficiency of usage of nitrogen; and reducing emissions from manure.

Evidence from research shows potential for reducing emissions by: improvement in livestock genetics; reducing age at first calving and length in the herd; extended grazing; reducing beef finishing times; improved nitrogen efficiency; increased use of clover; use of nitrogen inhibitors; minimum tillage; anaerobic digestion; renewal fuels; and changes in management practices. The benefits of adopting these practices extend beyond environmental improvements as they are generally worthwhile in terms of production efficiency and as result have the potential to enhance profitability. Forestry also has significant potential to sequester CO_2.

Farmers have the potential and the capacity to work to address the impact of climate change and reduce greenhouse gas emissions at their own farm level and ultimately national level. However, they need advice and guidance on the most appropriate actions to take. Advisory services, discussion groups and other mechanisms need to be explored for ways of communicating the messages to farmers. In addition, farmers will need reassurance that the actions they have taken are worthwhile both environmentally and financially.

RECOMMENDATIONS

The focus of this report is on *'farm level actions to reduce climate change impacts'* and therefore the recommendations specifically address aspects at farm level. It is evident from the research that there is considerable uncertainty among farmers regarding climate change, the impacts, the causes and how to reduce the impact. The most important recommendations relate to information and communication with farmers.

The process of information and communication should involve a multi-agency/stakeholder approach which is structured, based on presentation of clear facts and grounded in science. Therefore emission targets need to be clearly presented to farmers and explained in terms of what they mean at farm level. Farmers react negatively when measures appear to be imposed without due consultation and explanation whereas balanced and incentivised measures generate a more positive response.

The first stage of the information campaign needs to explain in simple terms: what the impact of climate change is; how it is developing; the extent to which farmers contribute to climate change both positively and negatively; and how farmers can play a role in adapting practices for their own benefit and the overall environmental benefit. Critically important is the presentation in a balanced way of the consequences of not voluntarily taking action to address greenhouse gases at farm level and ultimately being forced to do so by policy measures/legislation.

A simple guide should be produced for farmers on greenhouse gas emissions and climate change: clear facts; causes; impacts; and the actions that can be taken to reduce emissions.

As a mechanism to reduce greenhouse gas emissions from agriculture, all farms should undertake a carbon audit and the carbon navigator used to both measure and produce practical recommendations for all farms. A series of information meetings should be organised which seek to explain the results of the audits, interpret the findings and discuss the actions that can be taken at farm level (and wider benefits of taking those actions).

The potential of developing the carbon navigator further should be encouraged in order to explore further beneficial productivity factors which could then be addressed by farmers.

Case studies (similar to those included in this report) are a useful and interesting approach to communicating the message to farm families. In particular, the case studies could also explain the concept of carbon audits, the aspects that contribute to emissions, and the actions that can be taken to reduce emissions. The agricultural media have a role to play in information provision and enhancing the knowledge about greenhouse gas emissions, climate change and the impacts at farm level. This role could be undertaken by general information articles focused on farm level actions and could utilise real farm scenarios to illustrate this.

National greenhouse gas emission reduction targets need to be combined with associated measures/incentives which would encourage farmers to adopt management practices which would lead to reduced emissions. Farmers should be consulted on the development of policy measures addressing climate change and greenhouse gas emissions so that there is understanding about the need for the measures, the approach undertaken and the design of the measures. In order to achieve progress on reducing emissions, there is a need to focus on appropriate mitigation measures which provide tangible benefits for farm families as well as for the environment. Measures should be considered in tandem with an information campaign.

It is important to continue to provide resources for research in this area to generate ongoing information on further reducing emissions and improving the environment. Demonstration/monitor farms focused on addressing greenhouse gas emissions should be developed which could demonstrate the research findings (incl. costs and benefits) in a real farm situation. It should be possible to include a greenhouse gas focus onto existing monitor farms and to specifically observe these farms with this intention in addition to their original focus.

The discussion group programme (dairy, beef, sheep and tillage) should be utilised to disseminate information and provide advice to farmers on management practices to reduce greenhouse gas emissions. There is an opportunity within these programmes to demonstrate actions and to focus on achieving best practice.

Advisors and consultants providing advice to farmers may need upskilling in the area of climate change and greenhouse gas mitigation. General farm management advice needs to take account of the carbon/greenhouse gas implications of taking particular actions on the farm. Where farmers are expanding production/increasing output, they need to be advised on the approach which minimises any increase in emissions or leads to a reduction in emissions.

The low carbon nature of Irish agriculture and food can be potentially exploited as a marketing tool for Irish food. This can only be adequately exploited when accurate measurement is available at farm level, which can be verified and audited, with products labelled and marketed accordingly.

1. Introduction to report and the National Rural Network

The past decade in particular has seen much debate about climate change, the impact it is having on day-to-day life (farming and all other), the challenge of addressing it and in particular the difficulty of reducing the negative consequences. The causes and impacts of climate change can either be explored at a global (macro) scale or at a local (micro) farm/household scale.

At farm level, there is a lack of knowledge and understanding of the impact that farm practices have on greenhouse gases or on how practices can be changed in order to reduce the negative impacts. In Ireland, the *Food Harvest 2020* report has set ambitious targets for increased production/output across all of the main farm enterprises. While the *Food Harvest 2020* report takes account of the environmental implications of increased output, it also reflects the reality of the conflicting economic and environmental objectives.

The research in this report was guided by the NRN Climate Change Working Group (see Appendix for membership). The specific aim of the research was to explore *'farm level actions to reduce climate change impacts (taking account of the Food Harvest 2020 production targets)'*. The scope of the research brief did not allow for conducting primary research and therefore the report was informed by national and international research and by the input, knowledge, experience and expertise of the members of the working group (and their respective organisations). The topic is vast and there are a wide range of dimensions which could have been explored however, the focus was kept deliberately narrow on the farm level actions to reduce emissions. While farmers will also need to adapt their practices to cope with the impacts of climate, this aspect is not addressed in this report.

The purpose of the report is to inform the Department of Agriculture, Food and the Marine, other agencies/organisations and farmers on specific farm level actions which could be taken at farm level. The National Rural Network (NRN) assists in the efficient and effective implementation of the Rural Development Programme (RDP). The Network is facilitated by the Rural Development Support Unit within Limerick Institute of Technology. The NRN embraces all four axes of the programme and seeks to promote synergies across measures, encouraging individuals and organisations to work together and expand the possibilities available to those involved in the delivery of the programme and beneficiaries. The NRN seeks to support stakeholders in addressing important issues of concern and focus on practical opportunities and responses. Strategic Issues Working Groups have been established by the NRN in order to develop the discussion around key issues of concern and importance in rural areas. The focus of these groups is to draw together existing policies and research in a coherent manner and following debate to develop practical proposals for changes to current policies/programmes/measures.

2. *Food Harvest 2020* – The Context

The *Food Harvest 2020* report has established ambitious targets for agricultural production over the next decade. The *Food Harvest 2020* report therefore provides the context for farm development production targets until 2020.

The basic premise of the *Food Harvest 2020* report is that the decade ahead (2010-2020) is one of opportunity for agriculture, through the delivery of high quality, safe and naturally based produce (DAFF, 2010). While there is considerable potential for growth in the market for Irish food from increasing world population and rapid economic development in countries which had a low level of development prior to this, the *Food Harvest 2020* report identifies that improving competitiveness must be priority for Irish Agriculture. In order to do so, producers must use new systems of sustainable production (economies of scale, production efficiency & reduced costs) (DAFF, 2010).

In order to achieve growth in output, value added and exports, the *Food Harvest 2020* vision sets out that the industry needs to *act smart* and *think green*. *'Thinking Green'* includes: prioritising environmental protection; capitalising on natural advantages and resources; building environmental credibility through research and actions; conserving biodiversity; and aligning sustainability across the supply chain (DAFF, 2010). While farmers may agree with these aims, achievement on their own farm may need support, advice and the adoption of new technology. However, the implications of achieving increased production may be less obvious or readily identifiable for many farmers.

The *Food Harvest 2020* report (DAFF, 2010) identifies a major opportunity for Ireland to find ways to differentiate itself and take the lead in a market increasingly demanding low carbon food products and recognising that environmental sustainability is not only a worthwhile goal but a powerful marketing tool. The future prosperity of Irish agriculture depends on the extent to which the industry merges the demand for food with the need to limit environmental impacts.

The *Food Harvest 2020* (DAFF, 2010) vision is for an Irish food industry that is innovative, efficient and a global leader in environmentally sustainable production. The report recognises that the achievement of this vision will require meeting environmental challenges head on and reducing the carbon intensity of agriculture.

The achievement of the increased output value and production targets set in the *Food Harvest 2020* report was recognised as having the potential to increase greenhouse gas emissions from agriculture by 2020. The increased output from dairying was estimated in the *Food Harvest 2020* report to lead to a 12% increase in greenhouse gas emissions (DAFF, 2010). Investment in research and technology transfer could identify management practices to reduce the negative impacts. The need for advice and information for farmers was considered to be crucial to reducing the carbon intensity of production and enhancing their profitability. Research in the area of greenhouse gas emissions from agricultural systems presents a business opportunity for Ireland in the development of new technologies that will be required to measure and reduce emissions from the sector (DAFF, 2010).

3.The Challenge Of Climate Change

Climate change poses a major challenge for the agricultural industry and farmers, however, many farmers do not fully understand the contribution of agriculture to climate change or the consequences and impact that it will have on their business (climatic and/or regulatory/ policy). Grubinger (2010) stated that some farmers, just like some of the general public, are sceptical that climate change is even real. Others are doubtful it will affect agriculture, and some don't even want to bring it up for fear it might generate yet another concern about the environmental impact of farming.

The OECD (2012) estimates that by 2050, the world population will reach 9 billion (approximately 7 billion currently), 70% of whom will live in urban areas. This population level will increase the demand for food and productivity per hectare and also place further pressures on the environment. The OECD estimates that by 2050: energy usage will be 80% higher than 2010; global water demand will have increased by 55%; and there will be increased pressure on agricultural land.

However, the former EU Commissioner for Agriculture and Rural Development, Ms Marian Fischer Boel, described the challenge of climate change and food production in 2009:

When it comes to food production and climate change... are we caught between the devil and the deep blue sea?... are we forced to make an impossible choice between one kind of disaster and another? The devil is the fear that, a few years from now, we will no longer be able to feed ourselves (need to double food production by 2050 to keep up with expected changes in population and diet)...the deep blue sea is climate change. While we raise agricultural production, we must bring climate change under control... this means cutting greenhouse gas emissions...agriculture is an emitter of greenhouse gases. So we have a dilemma... our problem is more complex and more difficult...because farming not only contributes to climate change but will also be very seriously affected by it.

Unlike other sectors such as energy and transport, global mitigation in agriculture cannot be addressed through one-off technological fixes. Mitigation in agriculture will require the sustained application of processes or management practices by millions of individual farmers. In order to be effective in the long term, food production, food security and mitigation objectives must be complementary and support or enhance each other (Montgomery, 2010).

3.1 Climate Change Defined and Key Terms Explained

The Environmental Protection Agency (2011) defines climate change as a significant change in the measures of climate, such as temperature, rainfall or wind, lasting for an extended period of decades or longer.

The United Nations Framework Convention on Climate Change (1992) defines the process as *'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'.*

The term climate change is often used interchangeably with the term global warming. Global warming refers to an average increase in the temperature of the atmosphere near the Earth's surface, which can contribute to changes in global climate patterns. However, rising temperatures are just one aspect of climate change (USEPA, 2011). Global warming can occur from a variety of causes, both natural and human induced. In common usage, *'global warming'* often refers to the warming that can occur as a result of increased emissions of greenhouse gases from human activities (Global Warming Information, 2011).

A number of relevant definitions relating to aspects of climate change include:

Emissions: Release of greenhouse gases and/or other precursors into the atmosphere over a specified area and period of time (UN, 1992).

Greenhouse Gases: Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation (contributes to trapping heat e.g. water vapour, carbon dioxide, methane, nitrous oxide, ozone (UN, 1992; O'Mara, 2011)).

Reservoir: Component(s) of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored (UN, 1992).

Sink: Any process, activity or mechanism which removes a greenhouse gas, an aerosol, or a precursor of a greenhouse gas from the atmosphere (UN, 1992).

Carbon Sequestration: Storage of carbon in a biological or geographical sink (soil, trees and the ocean). For carbon sequestration to have a meaningful impact on the atmosphere it is necessary to ensure that the carbon remains sequestered and is not released back into the atmosphere through other biological processes (Wightman, 2010).

Carbon Footprint: Measure of the impact activities or products have on greenhouse gas emissions taking into account the whole lifecycle of the product (O'Mara, 2011).

Carbon Leakage: Results from agricultural production moving to less carbon efficient countries that are outside of binding agreements (resulting in production in countries with higher greenhouse gas emissions per unit product) (Gibson and Lanigan, 2010).

3.2 Concern About Climate Change

Scientists have suggested that the current changes in climate are different to those in the past (long periods of warmth and ice ages) because human activities are contributing significantly to natural climate change through the emissions of greenhouse gases (EPA, 2011; USEPA, 2011a).

Climate change is a natural phenomenon as weather and weather patterns are constantly changing. Climate change can result from natural processes and factors and human activities through the emission of greenhouse gases. The natural processes include: changes in the sun's intensity; volcanic eruptions; changes in the Earth's orbit around the sun; and changes in the ocean current circulation. However, it is the changes which are resulting from human activities which are changing the composition of the earth's atmosphere that are causing most concern at the moment. Human activities contributing to climate change include: carbon dioxide emissions through burning fossil fuels such as coal, oil, gas and peat; methane and nitrous oxide emissions from agriculture; and emissions through land use changes such as deforestation, urbanisation and desertification (EPA, 2011). The increased concentrations of heat-trapping greenhouse gases prevent heat from escaping to space.

The extent of the concern about the contribution of humans to climate change is highlighted by the Intergovernmental Panel on Climate Change (IPCC) (2011): *'most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic (produced by humans) greenhouse gas emissions'.*

Gilliland (2010) highlighted that the concern for agriculture from climate change is twofold: the large proportion of Irish food which is exported (80%); and 60% of Irish exports are bought by UK retailers. The challenge is compounded by the fact that UK retailers are greatly influenced by the media. Retailers are positioning themselves in response to consumer and media demands or perceived demands. Gilliland added that Tesco has pledged to *'Zero Carbon'* business by 2050 with a 30% reduction over the next decade. As a result, agriculture must respond and meet the challenges presented by climate change. If not, they will not only damage the environment but even more significantly in the short term, damage their markets and profitability.

Agriculture and forestry which account for 90% of Europe's land surface are exposed to the direct effects of climate change. Changes in climate from year to year impact on crop yields and this variability will increase as a result of climate change. The impact may not be only negative, it can lead to an increase in yield and a longer growing season in certain parts (EU, 2010).

3.3 Impacts of Climate Change

The concern about climate change is due to the profound current and future impacts. No different to other parts of the world, the climate in Ireland is changing (particularly rapidly over the past century). Dwyer (2012) in a report for the EPA stated that the rate of change over recent decades has been much higher than that for many tens of thousands of years, due to the enhanced greenhouse effect, caused by human activities which emit a range of greenhouse gases, including carbon dioxide and methane into the atmosphere. Some key climate changes which have occurred include (EPA, 2012; McElwain and Sweeney, 2007):

- Annual average surface air temperature has increased by approximately 0.8°C over the last 110 years. The number of warm days has increased and the number of frost days has decreased over the last 50 years and the length of the frost season decreased. Warming is evident in 2 periods, 1910 to the mid-1940s and 1980 to 2004 (at a greater rate than global temperature increases). Six out of the ten warmest years have occurred since 1990. From 1961 to 2005, the minimum temperatures generally increased at a faster rate than maximum temperatures;
- An increase in average annual rainfall of approximately 60 mm or 5% in the period 1981 to 2010, compared to the 30-year period 1961 to 1990. Four out of five of the wettest years on record at Malin Head have occurred since 1990;
- Current carbon dioxide (CO_2) concentrations of more than 390 ppm (270 ppm before industrial revolution) are higher than at any time over at least the last 400 thousand years;
- Current average global methane (CH_4) concentrations of more than 1800 ppm are 140% higher than pre-industrial concentrations and concentrations of nitrous oxide (N_20) are approximately 20% higher than pre-industrial levels;
- Gases which replaced those which deplete ozone are increasing steadily and are contributing significantly to the enhanced greenhouse effect. Damage to the ozone means that more harmful ultraviolet radiation can reach the Earth's surface;
- It is estimated that Ireland's soil carbon stock

decreased by 27 million tonnes between 1990 and 2000 due mainly to drainage and extraction of peat and to a lesser extent to changes in patterns of agricultural land use and urban development;

- Sea surface temperature in Irish waters has increased at a rate of approximately 0.6°C per decade since 1994; and
- In terms of land use there has been a significant change in the distribution of land-cover type across Ireland in recent decades. The major changes have been an increase in urban areas and the conversion of grassland and peatland to forest. The expansion of forest area has seen the amount of carbon stored or sequestered in forest areas increase by 40% since.

McElwain and Sweeney (2006) in their report for the EPA, further outlined the impacts of climate changes for a number of sectors.

Impacts on Water Resources
Water supply and quality are highly sensitive to climate change. A reduction in soil moisture storage could have serious implications for agriculture both in terms of drought and flood risk. Beyond agriculture, there are serious implications for meeting the water demands of the wider population.

Impacts on Agriculture and Food Production
Increases in temperature and CO_2 levels provide opportunities for increased production of grass and cereals. However, the potential may be limited by moisture deficits in summer. The warmer climate may also increase the potential for crops such as maize and soyabean. In contrast crops such as potatoes could suffer from lack of water. Total grass growth is also expected to increase. While minor increases in temperature could be beneficial in terms of yield, greater increases could lead to reduced yields in crops.

Impacts on Ecosystems and Biodiversity
Climate change is likely to have positive and negative impacts on ecosystems and biodiversity. If the changes are gradual many species should be able to adapt but those at risk will be those who are unable to adapt fast enough.

McElwain and Sweeney (2006) summarised key impacts of increased temperatures in Table 1. Benefits could be achieved if global mean temperatures are limited to a 1°C increase, however, above this level, there are significant negative impacts.

Table 1: Summary of Potential Impacts and Vulnerabilities for Ireland of Increased Temperatures

Up to 1°C	Up to 2°C	Greater than 2°C
Longer growing season	Increased likelihood and magnitude of river flooding	Sea level rise due to thermal expansion of oceans, melting of ice
Potential for new crops, e.g. soybean	Reduced soil moisture and groundwater storage	Loss of coastal habitats due to inundation and increased erosion
Increased production of existing cereal and grass crops	Water shortages in summer which will impact upon reservoirs and soil management	Increased incidence of coastal flooding
Earlier breeding and arrival of birds	Increased demand for irrigation	More intense cyclonic and extreme precipitation events
Heat stress will have an impact on human and animal health	Change in distribution of plants and animals, e.g. decline and possible extinction of Arctic species	
Negative impact upon water quality, e.g. reduction in quantity of water to dilute pollution	Fisheries could be affected as fish stocks are sensitive to small changes in temperature	
	Increased frequency of forest fires and pest infection	

If climate change occurs smoothly and linear, there is time to adapt and possibly manage the impact. However, if less predictable and unstable, adjustment can be more difficult and impacts more severe. Climate change impacts could be more severe for Ireland than other parts of Europe (McElwain and Sweeney, 2006).

4. Measuring Greenhouse Gases

To measure and compare greenhouse gases, they are given weighted values according to their potency as a greenhouse gas. This potency is referred to as a Global Warming Potential (GWP) and the common unit of measurement is referred to as a carbon dioxide equivalent or CO_2e:
Carbon dioxide (CO_2) = 1 CO_2e;
Methane (CH_4) = 21 CO_2e; and
Nitrous Oxide (N_2O) = 310 CO_2e (IPPC, 1996).

There are two common approaches to greenhouse gas emission quantification: Intergovernmental Panel on Climate Change (IPCC Method); and Life Cycle Analysis (LCA). The Intergovernmental Panel on Climate Change is an intergovernmental body that produces guidelines for calculating the national inventories of greenhouse gases (utilised by EPA) (O'Mara, 2011). This is the approach that is required in reporting national greenhouse gas emissions to the EU and the UNFCCC. The LCA approach is a technique to assess environmental impacts associated with all stages of a product's life from cradle to grave (raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling), (Table 2) (O'Mara, 2011).

Table 2: Main Sources of Greenhouse Gas Emissions from Agriculture

Methane from animals	These are counted in national inventory – IPCC
Methane and nitrous oxide from animal manures	
Nitrous oxide from fertiliser	
Nitrous oxide from urine patches	
CO_2 from fuel use on farm	Additionally counted when completing LCA
CO_2 from generation of electricity for use on farms	
CO_2 embedded in input brought onto farm (fertiliser, feed)	
Possibly release of or build up of carbon stores in soils	

Source: O'Mara, 2011

4.1 Carbon Leakage

Carbon leakage results from agricultural production moving to less carbon efficient production in other countries. In order to minimise the projected increase in global agricultural emissions, it is imperative that agricultural production is maximised in regions where the associated emissions are lowest. In relative terms the greenhouse gas efficiency (unit product per unit greenhouse gases emitted) of Irish agriculture is relatively high, so reducing production in Ireland (to reduce emissions) could lead to a global increase in emissions if demand is met from a country with a less efficient system (IIEA, 2009).

Emissions from South America and South Asia were almost double those of Irish, EU and New Zealand emissions, even without taking into account the effects of land use change, i.e. expansion of the agricultural area at the expense of natural habitat. If land-use change emissions were to be included (with only residue burning and soils emissions allocated to the land-use change), the emissions per unit product would double for South America. Leakage of dairy production from temperate grass based systems to tropical or arid grasslands will double or treble the emissions associated with the same amount of product (Schulte et al., 2011).

It was estimated that the displacement of 50% of current Irish beef exports to South America would result in a net annual increase of global emissions by c. 3.6 MT CO_2e per annum, equivalent to c. 20% of total current Irish agricultural emissions (disregards emissions associated with land-use change; if these emissions were to be taken into consideration, the estimated value would be two to three times higher) (Schulte et al., 2011).

4.2 Carbon Footprint of Irish Farms

Bord Bia is working with Teagasc and the Carbon Trust in Britain to achieve accreditation for a carbon footprint calculation model for Irish farms. This work was initially focused on beef farms with the intention of integrating it into the Bord Bia Quality Assurance Scheme. Initial pilot audits were carried out on more than 200 beef farms, the aim of which was to develop an approach to quantify the greenhouse gas emissions associated with Irish beef production, and to identify ways of improving their performance. As a result, a calculation model was developed in conjunction with Teagasc and the Carbon Trust which can assess the carbon footprint associated with the production of a kilo of beef. The results of the pilot showed a variation of up to 40% in the carbon footprint across farms, indicating potential for significant improvements in efficiency and profitability while also reducing the carbon footprint.

Following the completion of the initial pilot, Bord Bia intends to roll out the carbon footprint initiative to over 32,000 farms involved in the Bord Bia Quality Assurance Scheme. The data collected from these farms will be matched with the information from the detailed audits and an assessment of the carbon footprint for each farm calculated. Feedback will be provided to all farms on how cost saving measures can be adopted which will also lead to lower emissions.

Bord Bia is also undertaking an assessment of the processing and packaging stages of production to develop a processing footprint. There is also a pilot programme on 100 dairy farms being undertaken in conjunction with Glanbia (Bord Bia, 2011; Brennan et al., 2011). The case studies outlined in Section 9 of this report are examples of the carbon audits undertaken by Bord Bia.

4.3 Greenhouse Gas Targets for Ireland

The objective of the UN Framework Convention on Climate Change (1992) is the `stabilisation of atmospheric greenhouse gas concentrations at level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. '

The European Union's (EU) agreed objective is to limit global temperature increase to less than 2°C compared with pre-industrial levels, beyond this threshold irreversible changes, such as the breakdown of the Greenland and/or West Antarctic ice sheets, become more likely (EPA, 2011).

As a party to the Kyoto Protocol and a member state of the EU, Ireland agreed to limit the increase in greenhouse gas emissions in the period 2008-2012 to 13 percent above base year emissions (the base year being 1990) as determined by Decision 2005/166/EC.

In 2007, the EU agreed a series of targets to be reached by 2020 under the Climate and Energy Package. These are: a reduction in EU greenhouse gas emissions of a least 20% below 1990 levels; 20% of EU energy consumption to come from renewable resources; and a 20% reduction in primary energy use compared with projected levels (EPA, 2012). The target for Ireland's non-ETS (Emissions Trading Sectors i.e. agriculture, transport, waste, residential and commercial energy use) sectors as a result is to reduce emissions by 20% in 2020 relative to 2005 levels.

5. Greenhouse Gas Emissions From Agriculture

Greenhouse Gas emissions from the agricultural sector in Ireland are derived from three major sources: enteric fermentation in ruminants (48%); manure management (14%); and nitrogen application in the form of manures and fertilizer to agricultural soils (38%). They are accounted for by two key greenhouse gases: methane (CH_4) and nitrous oxide (N_2O) (Table 3) (EPA, 2013a).

Table 3: Historical and Projected Agricultural Emissions (Gg CO_2e)

	$C0_2e$ in gg	1990	2011	2008-2012*	2015**	2020**
Agriculture	Enteric fermentation	9574	8,543	8,652	8,753	9,203
	Manure management	2789	2,570	2,619	2,661	2,804
	Soils & indirect emission	7271	6,682	6,622	7,042	7,426
	Total	19,634	17,691	17,894	18,456	19,433

*Average per annum emission over the five year Kyoto protocol commitment period
** Assumes full implementation of FH2020 targets
Source: EPA (2013a)

In Ireland (2011) agriculture accounted for 32% of the national total emissions, followed by energy (power generation & oil refining) at 20.8% and transport at 19.7%. The remainder is made up by the residential sector at 11.5%, industry and commercial at 14%, and waste at 1.8% (EPA, 2012a). The EU average for agriculture is 9% of total emissions. The Irish figure reflects the relative importance of agriculture to the economy and the significance of ruminants. Among developed economies, only New Zealand has a higher level of national greenhouse gas emissions associated with agriculture (Schulte et al., 2011). In global terms, Ireland is a small country with a relatively small population. However, Ireland's greenhouse gas emissions per person are amongst the highest of any country in the world (EPA, 2011).

6. Role Of Agriculture in addressing Climate Change

The NESC report (2012) *Ireland and the Climate Change Challenge: Connecting 'How Much' with 'How to'* concludes that in order to achieve carbon neutrality in Ireland by 2050, one of the actions is the creation of a world-class agri-food sector working within a carbon-neutral system of agriculture, forestry and land use. The report suggests that Ireland can become a world leader in the production of low carbon, high quality, sustainable food. This can be achieved by research and exploring ways in which farm practices can be changed to further reduce emissions.

The EU Commissioner for Agriculture and Rural Development, Mr Dacian Ciolos (2010) highlighted that farmers and other rural stakeholders can play a role in mitigation (protecting important environmental resources) and the adaptation to climate change (maintaining the viability of rural areas in changing environmental circumstances). He stated that there is a significant scope for carbon sequestration in rural areas. Therefore, land use is important for both climate mitigation and adaptation as land is both a source and sink for emissions. There are also opportunities to limit the impacts of climate change on agriculture and water availability. Agriculture has a crucial role to play due to its dual role of both a source and a sink and also the critical role of agriculture in producing the world's food. It is estimated that food and feed production will need to increase by 70% in order to be able to feed the world population by 2050 (EU, 2010). Increasing agricultural production will place pressures on the environment and could lead to increased emissions.

While most of the capacity for increased food productivity and carbon mitigation measures in agriculture lies outside the EU, especially in relation to soil carbon and the land pressures linked to agriculture and deforestation. Nevertheless, agricultural mitigation in the EU will be very important because non-CO_2 emissions from agriculture (mainly nitrous oxide from soils and methane from livestock digestive processes) accounts for approximately 10% of total EU emissions.

Gilliland (2010) outlined a number of reasons why agriculture needs to engage with climate change:

- Security of the European & global food chains;
- More extreme weather (droughts, floods, snow & ice);
- More pests & diseases (Blue Tongue, Brown Rot, etc);
- Saving money & efficient agriculture;
- New legislation & policies;
- New market place developments; and
- Energy security & jobs in the 'Green Economy'.

Due to the relatively carbon efficient nature of Irish agriculture (despite the contribution of agriculture to overall emissions), it may appear that there are limited opportunities to reduce agricultural emissions, particularly in the light of expectations for increased emissions alongside increased production. NESC (2012a) argues that there is not only an opportunity to reduce emissions from agriculture but that a low-carbon footprint is a necessity for the competitiveness of our food industry. The report suggests that *'far from being at odds with the farming and business dynamic of Irish agriculture, the climate change agenda can be complementary to the existing achievements and ambitions of the sector'*. The report recommends: pushing scientific knowledge; focusing on what is happening in practice; and greater efforts to develop biomass as an energy source.

Reducing the size of the national herd has been suggested as an option to reduce greenhouse gases. However, such an option would have a significant negative impact on food exports, the economy and rural communities. In global terms, Ireland is an efficient food producer in terms of converting grass, cereals into milk, meat and other products. There is currently significant pressure to increase food production in response to growing populations. Breen et al. (2010) concluded that reducing food production in Ireland may result in an increase in food production elsewhere which could globally cause more emissions particularly if it involved deforestation or the cultivation of previously unutilised areas. Therefore reducing livestock in one part of the world could be counteracted by an increase in another area which is much more damaging. Teagasc (Breen et al., 2010) believes that the approach to addressing climate change should focus on improved management practices and technologies.

Gilliland (2010) while obviously coming from his perspective as a farmer, warns against the easy option of destocking to reduce greenhouse gases as ruminant livestock production in Ireland is grass-based and permanent grass is an excellent carbon sink and good for biodiversity. Uncontrolled ploughing of permanent grass could lead to excessive greenhouse gas emissions and a reduction in biodiversity.

Given that the main sources of agricultural greenhouse gas emissions in Ireland relate to animal production systems, achievement of the output targets in the *Food Harvest 2020* report would be expected, other things being equal, to lead to an increase in the emissions of greenhouse gases from Irish agriculture. Teagasc prepared a briefing paper which explored the consequences of achieving the production targets set out in the *Food Harvest 2020* report (Donnellan and Hanrahan, 2011). The achievement of the Food Harvest 2020 targets will result in changes in the production intensity, composition and size of the Irish cattle herd. The emissions will depend on the relative mix of dairy and beef cows, the level of productivity, fertiliser usage, stocking densities among other factors. The Teagasc briefing paper explored different scenarios relating to emissions and the achievement of the *Food Harvest 2020* production targets. When the achievement of the Food Harvest targets were considered, planting of forestry and bioenergy crops and no major external policy changes,

6. Role Of Agriculture in addressing Climate Change

(Continued)

greenhouse gas emissions were predicted to increase due to the anticipated increase in dairy cow numbers and a decline in the size of the suckler herd. By 2020, the level of greenhouse gas emissions would be almost 18.1 million tonnes CO_2 equivalent (not assuming any reductions associated with the adoption of abatement technologies) (Donnellan and Hanrahan, 2011). Schulte et al. (2011) estimated that in the absence of the *Food Harvest 2020* targets, greenhouse gas emissions from agriculture could be expected to reduce by 5% by 2020, compared to 2008. However, agricultural emissions are expected to increase by 3% taking account of the production targets in the Food Harvest 2020 report. This shows the difficulty for the agri-food sector to achieve significant further absolute reductions on current emissions. However, the EPA (2013a) have a more recent estimate that total emissions from agriculture are projected to increase by 12% over the period 2011-2020 to 21 million tonnes CO_2 equivalent. While the projections differ, the expectation is for an increase in emissions.

The NESC Interim Report on Climate Change (NESC, 2012a) provided a worthwhile analysis on the complexity of the challenge of reducing emissions in agriculture. The complexity is due to a number of related factors:

- The agriculture sector has ambitious plans for growth: growth and emissions targets viewed as conflicting;
- The CAP is being reformed: not clear of the impact on Irish agriculture and the environment/climate change;
- The world is facing a food security crisis: due to population increase, changing diets, land availability and negative impacts of climate change on the ability to produce food;
- There are two accounting systems, IPCC and Life Cycle Analysis (LCA), which can rank potential measures differently;
- Many farming activities are not economically viable and this must be considered in the adoption of changes;
- The question of emissions reduction, particularly in agriculture, impacts on other aspects of environmental sustainability and biodiversity e.g. extended grazing may increase risk of soil compaction with associated risks to water quality and nitrous oxide emissions; and
- Farmer attitudes and behaviours have an important and often poorly understood bearing on decision-making and practice adoption.
- Nonetheless, NESC (2012a) concludes that these challenges should not stifle the thinking on new ways of reducing the emissions from agriculture.

6.1. EU Agricultural Policy Changes

In March 2012, the EU Commission adopted a new proposal on accounting of greenhouse gas emissions from forests and agriculture which is a first step towards incorporating removal and emissions from forests and agriculture into the EU's climate policy (EU, 2012). The Land Use, Land Use Change and Forestry Sector (LULUCF) refers to the exchange (emissions and removals) of greenhouse gases between the atmosphere and plants and soils (all human activities on agricultural land, forested land, wetland and peat). The term LULUCF is used in relation to the forestry and agriculture sector in the international climate negotiations under the United Nations Framework Convention on Climate Change (EU 2012a).

Forests and agricultural land trap and store large quantities of carbon, preventing the release into the atmosphere. However, it was difficult to assess the exact benefit of agriculture and forestry in storing carbon as it was challenging to collect adequate data and a lack of common rules for measurement. The new EU proposal aims to address the measurement challenges and provide new opportunities to recognise the role that farmers play in mitigating against climate change (EU, 2012).

The Kyoto protocol recognised the importance of all sectors to contribute to addressing climate change, however, at this stage there was insufficient processes or knowledge to measure emissions and removals from the agricultural and forestry sector. The LULUCF rules aim to address this gap in accounting (EU, 2012a).

From a farmer perspective, the LULUCF framework which is now being developed could bring both benefits (carbon sink more visible and measureable) and drawbacks (possible controls and restrictions in the management and utilisation of land and land use change).

The new CAP proposals respond to environmental and climate change concerns with the introduction of the mandatory 'greening measures'. The EU Commission is determined to introduce payments for agricultural practices which are beneficial to the climate and the environment (Matthews, 2012). In order to meet the requirements of the basic single payment, farmers must adhere to greening practices and 30% of the single farm payment is conditional on meeting these practices.

"One of the objectives of the new CAP is the enhancement of environmental performance through a mandatory "greening" component of direct payments which will support agricultural practices beneficial for the climate and the environment applicable throughout the Union. For that purpose, Member States must use part of their national ceilings for direct payments to grant an annual payment, on top of the basic payment, for compulsory practices to be followed by farmers addressing, as a priority, both climate and environment policy goals. Those practises should take the form of simple, generalised, non-contractual and annual actions that go beyond cross compliance and are linked to agriculture such as crop diversification, maintenance of permanent grassland and ecological focus areas" (European Commission, 2011).

7. Agricultural Strategies To Address Climate Change

Agriculture has a role to play in the broader effort to reduce greenhouse gas concentrations by (CAST, 2004):

- Taking CO_2 from the atmosphere and sequestering it in biomass and soils;
- Decreasing the rate of land clearing for agriculture and taking marginal lands out of production;
- Changing agricultural practices on productive, established agricultural lands;
- Increasing efficiency of farm inputs such as fuel, fertilizers and pesticides;
- Increasing production of agricultural biofuels (renewable biological-based energy fuels) to replace fossil energy emissions (however this should not be done at the expense of food production);
- Improving N-use efficiency as the primary means of decreasing N_2O emissions; and
- Decreasing methane emissions by capturing or preventing emissions from animal manure storage and by increasing livestock production efficiency.

The Environmental Protection Agency (EPA) states that addressing climate change requires two types of responses: mitigation (defined as an anthropogenic intervention to reduce anthropogenic forcing of the climate system (IPCC, 2007)) and adaptation (defined as: the *'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects that moderates harm or exploits beneficial opportunities'* (IPCC, 2007)).

The *'From Farm to Fork'* report (IIEA, 2009) states that a *'whole farm-scale strategy'* involving a mosaic of practices and technologies, rather than individual measures in isolation, offers the most promise.

Factors which could be addressed at farm level to have a positive impact on emissions include (IIEA, 2009; EUCJRC, 2010; Wightman, 2010; Rees *et al.,* 2010; Soil Association, 2009; Wulf *et al.,* 2002):

- Livestock genetic improvement (breeding for improved efficiency of the animal (indirect); breeding for improved efficiency of the system (indirect); and breeding for reduced greenhouse gas emissions (selection on improved feed efficiency and beneficial effect on reducing the emissions);
- Extended grazing (less stored manure and lower enteric methane emissions on grazed diets);
- Reduced beef finishing times (increased daily weight gains);
- Dietary manipulation (optimizing the diet not only improves the efficiency and reduces the methane emissions);
- Nitrification inhibitors (nitrification inhibitors can be added to fertilisers to reduce N_2O emissions, however the efficiency of different inhibitors varies);
- Slurry management (timing and application method of slurry/manure impacts on the extent of uptake and the level of losses to the atmosphere);
- Nutrient management (reduced nitrogen use, N_2O emissions are sensitive to fertiliser application rates, therefore, adherence to best practice and fertiliser recommendations can reduce emissions);
- Nutrient leaching (could be reduced by using catch crops, such as energy crops as buffer strips along open streams);
- Tillage (optimising N timing and application, cover cropping and minimum tilling. Minimum till methods can provide small increases in soil carbon however these can be offset by increased losses of N_2O);
- Improved sward quality (existing crop varieties vary in their N use efficiency, further screening and enhancements in plant breeding could exploit this);
- Increased use of clover (sequester CO_2 and reduced enteric emissions) (increased use of clover results in reduced need for nitrogen fertiliser);
- Anaerobic digestion (captures CH_4 from manure/ slurry to generate biogas for heat and for injection to the grid or for use as a transport fuel);
- Drainage (improved drainage reduces N_2O emissions, but probably increases CO_2 emissions and improves crop production);
- Organic farming (it is suggested that action to raise soil carbon levels through organic farming practices and grass based mixed farming can make a significant contribution to greenhouse gas mitigation); and
- Forestry (significant potential opportunity to offset greenhouse gas emissions from the agricultural sector through carbon sequestration. Use of biofuel and bioenergy has potential to offset national greenhouse gas emissions by displacement of fossil fuels).

Specific mitigation measures impact on different types of emissions:

- Reducing Methane Emissions:
    - Increasing genetic merit;
    - Extending the grazing season;
    - Reducing beef finishing times;
    - Replacing roughage with concentrates;
    - Improving pasture quality;
    - Dietary manipulation (grass to maize, supplementation with oils, crude fibre, crude protein);
    - Alteration of bacterial flora;
    - An increase of lactations per cow;
    - Composting and transforming biogas into heat and/or electricity; and
    - Anaerobic Digestion (Gibson and Lanigan, 2010; EUCJRC, 2010).

- Reducing Nitrous Oxide Emissions:
    - Diet manipulation;
    - Nitrification inhibitors;
    - Increasing clover in swards;
    - Altering timing of fertilizer application; and
    - Altering slurry spreading techniques (Gibson and Lanigan, 2010).

Mitigation of nitrous oxide from agricultural soils and methane from manure management are generally considered to be more achievable in the period to 2020 as measures to reduce enteric methane are often technically and economically challenging (IIEA, 2009).

7.1 Specific Mitigation Strategies for Greenhouse Gas Emissions from Irish Agriculture

Teagasc in collaboration with other institutions are undertaking ongoing research on mitigation measures including:

- Improvement of genetic merit of cow;
- Reducing age at first calving and increasing longevity in the herd;
- Extension of the grazing season;
- Reducing beef finishing times;
- Improvement of nitrogen efficiency;
- Increased use of clover;
- Use of nitrification inhibitors;
- Minimum tillage techniques;
- Renewable energy crops;
- Forestry; and
- Organic production.

7.1.1 Improvement of Genetic Merit of Cows

O'Brien *et al.* (2010) demonstrated that selection of cow breed, based on a combination of fertility and milk performance, reduced emissions per kg of milk solids by up to a maximum of 15%, relative to cows selected for milk only. It is also expected that the EBI (Economic Breeding Index) will be the key component in increasing milk solids production per cow. These increases in efficiency will be important component in reducing emissions per kg of milk solids and improving farm profitability.

7.1.2 Reducing Age at First Calving and Increasing Longevity in the Herd

Reducing the age at first calving is related to lower feed, enteric fermentation and manure management emissions for first calving heifers (prior to them becoming productive in terms or milk +/or beef). The longer a cow remains in the herd, the lower the level of replacements required which reduces the overall greenhouse gas emissions per cow calving (Crosson *et al.,* 2013).

7.1.3 Extension of the Grazing Season

Extension of the grazing season (the number of days that animals spend on grass outdoors) reduces emission intensities by reducing the quantity of stored manure, and by lowering direct enteric methane emissions from animals. Lovett et al. (2008) quantified that, for every extra day dairy cows graze grass, emissions per unit of product decreased by 0.14%, using IPCC emission factors. For every one day increase in the length of the grazing season, there is an increase in profitability of €2.70 for every dairy cow in the herd.

7.1.4 Reducing Beef Finishing Times

The most important source of greenhouse gas emissions from beef production systems is methane from enteric fermentation. Most of these strategies involve the use of enteric fermentation modifiers i.e. dietary supplementation (Beauchemin *et al.,* 2008). These strategies are less suited to Irish grazing systems where grazed grass represents over 60% of the diet. Increasing daily liveweight gains reduces the finishing time and this results in lower absolute enteric fermentation emissions and lower enteric fermentation emissions per kg of beef carcass produced (Foley *et al.,* 2011) (higher efficiency and profitability).

Research carried out by Teagasc on calf-to-steer beef and calf-to-bull beef systems indicated that best practice performance compared to average production resulted in higher levels of animal performance and lower emissions (Drennan and McGee, 2009). When combined with improved nutrient use efficiency, direct (those produced on-farm) and total (on-farm emissions plus emissions associated with purchases, ammonia volatilization and nitrate leaching) emissions were 15% and 18% lower for steer and bull systems, respectively.

7.1.5 Improvement of Nitrogen Efficiency

Major changes in N-efficiency have occurred in the past decade, with average fertilizer nitrogen use on grassland falling by over 40%, from 145 kg/ha in 1999 to 86 kg/ha in 2008 (Lalor *et al.,* 2010). Further gains in fertilizer nitrogen use efficiency will be increasingly difficult to achieve.

Teagasc research has shown that there is still potential to further improve on the efficient use of organic nitrogen in animal manures. Low emission spreading techniques can be used to reduce the gaseous losses of ammonia from land-spreading of animal slurries, relative to the splash-plate method, most commonly used at present. Methods available include: band-spreading; trailing hose; trailing shoe; and shallow injection. For application to grassland, the trailing shoe is considered to be the method that is most suitable to Irish conditions to reduce ammonia emissions, although similar results can also be expected using band-spreader or trailing hose methods. Targeting cooler and moist weather conditions also result in lower ammonia volatilisation. These conditions are generally more prevalent in the spring period but land-spreading can be restricted by soil trafficability (Bourdin *et al.*, 2010; Lalor & Lanigan, 2010; Lalor & Schulte, 2008).

Encouraging more slurry application in the spring period will also reduce the length of the slurry storage period (McGettigan *et al.,* 2010a). Teagasc has estimated that, at national level, the combined effect of changing the slurry management practices on methane emissions from slurry storage and on nitrous oxide emissions following slurry application, amounts to a maximum of 0.12 Mt CO_2eq. The economics of low emission spreading technologies, however restrict their usage to contractors or large-scale farmers (Lalor, 2008).

7.1.6 Increased Use of Clover

White clover can supply biologically fixed nitrogen in grassland through a symbiotic relationship with *Rhizobium* bacteria. As a result, clover-based systems can reduce the requirement for mineral fertiliser application (Ledgard *et al.,* 2001). At low rates of fertiliser application there is believed to be a greater reduction in pastoral N_2O emissions, as sward N utilisation is improved (Klumpp *et al.,* 2010; Kirwan *et al.,* cited in Schulte *et al.,* 2011). A limitation is that not all soil types are suitable for clover.

7.1.7 Use of Nitrification Inhibitors

Nitrous oxide originating from grazing animals comprises 37% of agricultural N_2O emissions (Duffy *et al.,* 2013). Urine patches have been identified as a major source of nitrogen loss in grazing systems via leaching and gaseous emissions. One potential mitigation method to reduce the associated N_2O emissions is the use of the nitrification inhibitor dicyandiamide (DCD). DCD has been shown to reduce nitrous oxide and nitrate leaching losses and, in some cases, increase pasture production (Di & Cameron, 2002) in grazed pasture systems in New Zealand. On a per hectare basis, inhibitors are extremely effective, with reductions in N_2O emissions of between 47% - 71%, depending on the amount of N applied and on the soil type (Di & Cameron 2002, 2004, 2005; Zaman & Blennerhasset, 2010). The effectiveness of nitrification inhibitors is dependent on soil type and local climate. The cost of inhibitor application is high (circa €30 per hectare per application). It is likely that the technology will only be justifiable on soils where stocking rates are high and where the potential for reductions in N_2O emissions is large (Schulte *et al.,* 2011).

7.1.8 Minimum Tillage Techniques

Minimum tillage techniques typically increase storage of soil organic matter (SOC), relative to conventional till practices, as these techniques reduce soil erosion. In addition, they enhance aggregate stability in the soil which slows decomposition of organic matter (Six *et al.,* 2000; Lanigan *et al.,* 2008).

Unlike the livestock sector, where 85% of emissions are field-based, almost 50% of tillage greenhouse gas emissions result from power and fuel usage when quantified using LCA. These emissions are lowest for minimum tillage, provided no extra weed intervention or harrowing of headlands is required. Moving from conventional inversion ploughing to non-inversion tillage will reduce costs but are not suitable to all soil types, are more suitable for large scale growers and are more difficult to manage.

7.1.9 Renewable Energy Crops

Renewable energy crops such as willow, miscanthus and other crops provide an opportunity to address climate change. These biomass crops can be used to produce bioenergy for domestic and industrial use. The potential of these crops is that they can replace energy from high greenhouse gas emission fossil fuel sources. The mitigation potential of biofuels is due to the fact that during growth they capture the carbon dioxide which is re-released during combustion and this makes them close to carbon neutral (Caslin, 2012). He also states that these crops have the advantage that the CO_2 released in burning was captured from the atmosphere in recent times as opposed to fossil fuels which release carbon which has been stored in the earth for millions of years.

Teagasc research (cited in NESC, 2012a) suggests that 15,000 ha of land could be used for willow and miscanthus production without a reduction in agricultural activity (increased stocking rates on lowly stocked farms). However, there is also a potential for replacement of other agricultural activities which would bring about a direct reduction in emissions. The main challenge for farmers growing renewable energy crops is the ability to make an economic return in practice. Similarly with anaerobic digestion, it is generally not economically feasible for farmers to engage in it.

7.1.10 Forestry

Forestry is included in reporting of emissions/removals, however it is not accounted as part of the Effort Sharing Decision. If forestry was included in the effort sharing decision, it could potentially be used as a mechanism to reduce overall emission reduction targets. However, forestry makes an important contribution at a number of levels (NESC, 2012a): forestry contributes to the supply of bioenergy for heating; supplies materials for use in construction and manufacturing which acts as a further carbon store; and reduces use of energy intensive materials, which provide an incentive to plant more forestry.

Teagasc (Schulte *et al.,* 2011) highlighted that forestry contributes to the reduction of GHG emissions by: afforesting land; forest management; optimising forest productivity; and by using forest products for generation of bioenergy.

- Increasing rates of afforestation increase the CO_2 sequestration capacity of Irish forests. Therefore, it is important to continue to encourage farmers to plant forests in order to maintain the forest sector as a net carbon sink.
- In order to reduce GHG emissions, careful forest management is required in terms of reforestation, sustainable forest management, annual harvest levels and other management practices. As forests mature and are felled, it is important to reforest so that forests continue to mitigate climate change.
- Targeted species selection offers the potential to improve afforestation schemes in order to increase their carbon sequestration potential (productivity can be increased by targeting specific species on specific sites). Increased productivity leads to increased CO_2 sequestration per hectare.
- The use of forestry products for bioenergy has the potential to replace fossil fuels. Evidence from the SEAI (2012) shows that wood fuels (range of

products) are significant contributors to renewable energy in Ireland (second only to wind energy). Much of the wood fuel comes from early stage forests and therefore it is significantly dependent on an ongoing plant regime.

7.1.11 Organic Production

Organic farming provides environmental benefits through the sequestration of carbon in soil organic matter. Evidence from the FIBL (2012) suggested that soil organic stocks were higher in organic farming systems and that these systems sequestered more carbon per hectare annually. However, the differences seemed to be mainly influenced by practices typical of mixed farming. It concluded that soil carbon levels are likely to be improved if measures intrinsic to organic farming are applied to any agricultural production system.

Lindenthal et al. (2012) suggest that due to the fact that organic farming does not involve the use of chemical fertilisers, nitrogen is less readily available and results in lower N_2O emissions. However, while organic farming may reduce emissions per hectare compared to conventional systems, due to lower stocking rates, the emissions per unit of output may not decease as significantly.

7.1.12 Overview of Mitigation Strategies

Teagasc research shows that selection using Economic Breeding Index has the most significant effect on reducing emissions per kg of product, followed by increasing grazing season length and a reduction in N fertilizer application. Shalloo (2010) suggested that some of the mitigation strategies for dairy farmers could be described as *'win-win'* benefiting climate change and farmers. Changes in practices/technologies (earlier calving, reduced replacement rate, improved composition, longer grazing season, higher stocking rates and inclusion of white clover) would result in increased milk solids per hectare (which increases profitability) and the potential to reduce current greenhouse gas emissions from 16.06 kg to 13.53 kg CO_2 equivalent per kg milk solids produced. Teagasc estimates that emissions per kg milk solids could be reduced as much as 40 per cent from the current national average performance (O'Brien *et al.,* 2011). Further research indicates that in the long-term (2018), that there is potential to further reduce emissions by up to 11% (11.7 kg of CO_2eq per kg of milk solids) (Schulte *et al.,* 2011).

Teagasc (Schulte *et al.,* 2011) estimates that combinations of mitigation measures have the *technical* potential to reduce the emission intensity (i.e. rate of emissions *per kg product*), of beef production by up to 15-20%. At national level, this has the potential to translate into emission intensities between 18 and 19 kg of CO_2eq per kg beef carcass for suckler beef systems and between 11 and 12 kg of CO_2eq per kg beef carcass for dairy beef systems.

While the science and research suggest that there is potential to reduce emissions through the adoption of changed practices, farmers take time to implement changes on their own farms and need support and encouragement to do so. The NESC report (2012) *Ireland and the Climate Change Challenge: Connecting 'How Much' with 'How to'* highlights the importance of balancing the reduction targets with a focus on 'how to' achieve reductions in practice. This is particularly relevant in the context of farmers adopting new or changed practices.

7.1.13 Cost Benefit Analysis of Mitigation Measures

The NESC Interim Report on Climate Change (2012a) presented findings of work carried out by the Department of Agriculture, Food and the Marine and Teagasc (2012) which explored the scope of some of the measures (outlined earlier) to reduce emissions. Teagasc produced a Marginal Abatement Cost Curve (MACC) for Irish Agriculture in 2012. The MACC quantifies the current opportunities for abatement of agricultural greenhouse gases, as well as the associated costs/ benefits. Three areas were specifically considered as part of a cost benefit analysis: lengthening the grazing season; changing nitrogen use; and changing slurry spreading practices. The details are presented in Table 4.

Table 4: Cost Benefit Analysis of Emission Mitigation Measures

	Measure	Benefit 2020 Mt	Cost
Grazing Season*	Extension of grazing season by 25 days per annum	.275	Training and advisory costs but economically beneficial to farmers
Nitrogen Use	Increased use of clover aimed at reducing fertiliser use	.40	Limitation is land suitability for planting of clover and time required for adoption of methods.
Slurry	Increase proportion of slurry spread in spring from 35% in 2005 to 50% in 2020 using splash plate only	.68	€.6m
	OR 33% with trailing shoe;	.101	€3.2m
	OR 60% in spring, trailing shoe used to spread 33% of total slurry.	.244	€2.6m

Source: NESC, 2012a & Teagasc 2012
* Weather is a variable factor which will continue to impact on this aspect irrespective of the progress made by farmers.

The MACC analysis assumes that a number of measures would take place as part of the implementation of Food Harvest 2020 targets. Using the IPCC methodology, Teagasc explored a number of further measures and found that there is potential to cost-beneficially reduce emissions by 1.102 Mt CO_2 eq per annum in 2020 (NESC, 2012a; & Teagasc, 2012). There are four areas, in Table 5, where reducing emissions can have the effect of improving efficiency on farms: EBI-based genetic improvement, earlier finishing of bull beef, extension to the grazing season and nitrogen use (clover and management).

Table 5: Cost Benefit Analysis of Additional Measures

	Measure	Benefit 2020 Mt	Cost (Per Mt CO_2 eq)
Genetics	Continuing to improve genetic merit of dairy herd by increasing EBI by a further €32/cow to €140.	.596	- €483
Weight Gain	Use of finishing bulls to improve average lifetime daily gain. To gain of 0.75kg per day from 0.68.	.122	-€575
Grazing Season *	Extend grazing season to 248 days for dairy and 238 for beef over FH2020 of 227 days and 224.	.264 + .040	-€334 - €662
Nitrogen	Nitrification Inhibitors (use of DCD). Limit N fertiliser increases under FH2020 (includes clover and nutrient management).	Zero .08	n/a -€361

Source: NESC, 2012a & Teagasc 2012
* Weather is a variable factor which will continue to impact on this aspect irrespective of the progress made by farmers.

The MACC for Irish Agriculture (Teagasc, 2012), based on IPCC analysis is presented visually in (Figure 1). The green measures relate to increased efficiency, yellow measures relate to land use change and blue measures relate to technology interventions. The green measures are cost-beneficial, gains in efficiency reduce the carbon footprint but also reduce the costs. Yellow measures are generally cost-neutral or slightly beneficial while the blue measures are generally cost-negative (cost associated to implementing them).

Marginal Abatement Cost Curve (IPCC)

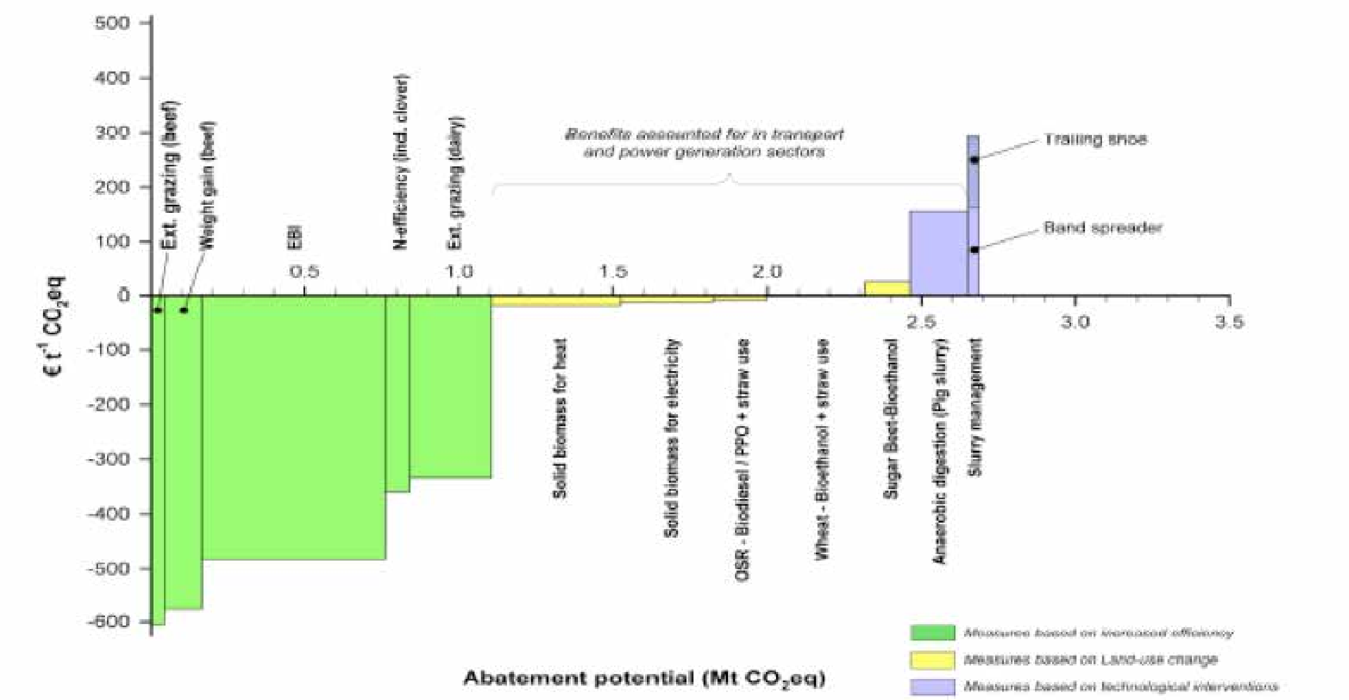

Figure 1: Marginal Abatement Cost Curve for Irish Agriculture, using IPCC Analysis. Colours Indicate Measures Based on Efficiency (green), Land Use Change (yellow) and Technological Interventions (blue)
Source: Teagasc (2012)

7.1.14 Ongoing Research

To continue to achieve reductions in emissions requires ongoing research and exploration of new farm practices and aspects of management. The NESC Interim Report on Climate Change (2012a) summarised some ongoing research papers which may present further potential in the future (Table 6).

Table 6: Ongoing Research Which Could Contribute to Reduce Emissions

Area	Potential Measure
Diets	Improving the quality of grass offered to cattle reduces methane emissions: 16% difference in methane per kg average daily gain for beef; 20 per cent per kg milk is achievable. Changes to physical qualities of diet associated with feed conversion efficiency improvements of between 8 and 17 per cent.
Beef and Diary	Integration of beef and dairy farm systems linked to 30 per cent reduction in greenhouse gas emissions. Challenge is to maintain supply of calves in numbers and quality to meet demands of the beef industry and maintaining the productivity targets of the dairy industry.
Urea replacing CAN	Emissions of N_2O over 50 per cent lower. Limitation is that application will have to be spring or autumn unless urease inhibitors can be used. These are compounds that coat the surface of urea to reduce NH3 volatilisation during warm weather (at a fraction of the cost of DCD). Effects may be variable and further understanding of the biological mechanism is required. Commercial products may be available in the next 2–3 years.
Pasture Sequestration and Land-use	Land management changes impact on carbon stocks though few countries include this in reporting because while initial stocks can be measured it is very difficult to assess impact of changes. In addition, management practices need to be in place for 10 years before changes are detected. Teagasc is currently working to model the impact of management on sequestration. Develop an Irish Soil Information system to formally account for land-use interactions. Teagasc, Cranfield and UCD (with EPA funding) finalising 1:250,000 scale next-generation soil map by 2014.
Bioenergy: Anaerobic digestion of biomass (grass)	Potential to meet Ireland biofuel and greenhouse gas reduction target. Key issue is energy targets, which place it in competition with other renewables. Research, ongoing to quantify the opportunities and issues around size and sites of AD plants (Teagasc, UCC and MTT Finland).
Disease prevention and control Health	Improvements in health increase productivity and therefore reduce emissions per unit of production. Improvements will be included in future MACC once more detail is available on their overall extent and impact. Improvement in herd health is also a product of improvements in EBI.

Source: NESC, 2012a

7.2 Carbon Sequestration

(Schulte et al., 2011) stated that forestry has significant potential to sequester carbon dioxide, thereby offsetting greenhouse gas emissions from other sectors and contributing to greenhouse gas abatement. Currently, most afforestation takes place on private land, the majority of which is owned by farmers; as a result, forestry and agriculture are intimately intertwined. Farmers have proven to be the overwhelming and predominant sector, who consistently convert their land to forestry. It is notable that in 2011 and 2012, 94% of all new planting took place on land owned by farmers. In an Irish context, these statistics demonstrate that forestry is essentially an agricultural land use activity rather than a general private sector endeavour. It is therefore appropriate that the positive outputs arising from the forestry sector activities should be ring fenced towards netting off against the overall agriculture sector targets.

Soil carbon sequestration represents 89% of agriculture's greenhouse gas global mitigation potential (Smith et al. cited in Soil Association, 2009). Soil carbon losses caused by agriculture account for a tenth of total CO_2 emissions attributable to human activity since 1850. Unlike the carbon released from fossil fuels, the soil carbon store has the potential to be recreated to a substantial degree, if appropriate farming practices are adopted (Soil Association, 2009). Therefore carbon sequestration by grassland has significant potential to offset greenhouse gas emissions from agriculture. Permanent grassland soils may continue to sequester carbon for many decades, particularly following adoption of improved grazing management strategies. When grassland sequestration is taken into account, reductions in the emission intensities of grass-based produce could be between 30% and 70% of the total emission intensities (Pelletier et al., 2010; Veysset et al., 2010).

The production of biofuel and bioenergy has substantial potential to offset greenhouse gas emissions in Ireland. Displacement of fossil fuels by biofuel / bioenergy can be achieved through three pathways by: domestic production of biofuel and bioenergy crops; increased utilisation of forest products; increased use of bioenergy feedstock's; and land-use change associated with increased biofuel and bioenergy crops and forests, will result in lower emissions of N_2O and increased rates of carbon sequestration (Schulte et al., 2011).

8. Consultation with Farmers

In order to assess the views of farmers on greenhouse gases and climate change, two groups of farmers were consulted (a multi-enterprise group of farmers and a drystock organic farmer discussion group). Their views are summarised with regard to three specific questions:

- Meaning of climate change to farmers;
- Concern about climate change; and
- Actions to address climate change.

8.1 Meaning of Climate Change to Farmers

Climate change is generally a concept that most farmers do not fully understand or indeed most have not engaged with the idea. As a result, the main concerns were about climate change at a global level rather than at a local level. The global perspective on climate change means that many have not considered climate change as an issue of direct concern to them, particularly as it was out of their direct control and influence.

There was no significant grasp of the fact that climate change could bring policy and regulatory impacts on farmers in the short-term. Therefore, the perception was that climate change was *'out there in the distance'* and not really an immediate concern for farmers. On the other hand, there was limited knowledge of how Irish farm practices impacted on greenhouse gas emissions or the consequences of taking particular actions or following specific management practices.

There was also the view that a certain level of emissions was a cost of food production and consumers and the wider public need to accept this. Similarly in this regard, the increased production/output targets in the *Food Harvest 2020* report were considered as inevitably leading to increased emissions. Therefore the contradiction is that the benefit to the economy conflicts with efforts to control and reduce greenhouse gas emissions.

8.2 Concern about Climate Change

The main concern about climate change was at a global level in terms of altered weather patterns and large scale destruction in the vegetation in developing countries. There was uncertainty over whether this was due to human and agricultural activity or part of a larger natural cycle of warming and cooling.

The changing weather patterns were exasperated by the efficiency drive which means that the most efficient and profitable farmers tend to be operating on the edge, small changes in weather can have significant consequences e.g. efficient grassland management.

However, many farmers were not specifically concerned about the climate change impacts of their own farming activity as they felt that the concept of climate change was *'out there in the distance'* from them and as a result was not an immediate concern to them.

Farmers were concerned to a certain extent that they were contributing to climate change by their farm practices but they do not know what practices were damaging the environment or exactly how the damage was being caused. Therefore, many felt powerless in terms of what they could do to reduce the impact on the environment.

Much of the concern was due to a lack of real or informed insights into greenhouse gases and climate change and the interplay with farming which could be addressed by an information campaign.

8.3 Actions to Address Climate Change

Due to the overall lack of understanding about greenhouse gases and climate change, there was limited knowledge of how farmers could address climate change on their farms and change practices to reduce the overall level of emissions. However, there was a view that organic farming was more positive and led to a lower level of overall emissions than conventional farming.

Some farmers were concerned that the only option to seriously address greenhouse gases was to reduce the size of the national herd. There was concern about how this would impact on individual farmers and also on the overall agricultural and national economy. There was a fear that this could be imposed on farmers if other actions were not taken.

Farmers were generally unaware of the extent of the greenhouse gases generated from their systems of production. As a result, they were unable to make judgements on changes which could lead to reduced greenhouse gas emissions. The Bord Bia audits were considered as an important step in determining the extent of greenhouse gas emissions on farms. In order to take action, farmers require information, the impacts of their practices and management changes which would lead to reduced emissions.

The areas considered worthy in terms of reducing greenhouse gas emissions included: reducing livestock numbers; mainstreaming the lessons learned from environmental schemes; promotion of forestry; and renewable energy. Overall, the most important aspect was to inform and educate farmers on, the concerns, the consequences and the actions that they could take to address greenhouse gas emissions.

9. Farm Case Studies

In order to explore what farmers can do to reduce greenhouse gas emissions on their own farms, a number of case studies are presented. These case studies presented were prepared utilising information provided by Bord Bia, Teagasc and the content of articles prepared by the Irish Farmers Journal (Justin McCarthy and Darren Carty). The beef farmers were farmers who participated in the Sustainable Quality Beef Producer Awards. The information presented includes the outcomes from the use of the carbon navigator tool. The farms are all involved in beef production, it was intended to also include dairy farmer case studies but these were not available at the time of publication.

9.1 Carbon Navigator

The Carbon Navigator was developed by Teagasc and Bord Bia as a management tool which allows farmers to set improvement targets in key management areas and see the results for their enterprise in terms of environmental and economic performance. More than 32,000 Bord Bia quality assured farms provided information that allowed the environmental performance of their farms to be assessed. The Carbon Navigator assesses key areas and allows guidance to be provided to farmers on the actions they should take to improve their environmental performance. The focus is on reducing greenhouse gas emissions while improving efficiency leading to benefits for the farmers and the environment.

The Carbon Navigator for beef focuses on six main areas of production:

- Length of grazing season;
- Calving rate;
- Age at first calving;
- Liveweight gain;
- Nitrogen fertiliser usage; and
- Management of animal manure.

9.1.1 Length of Grazing Season

For every extra day at grass during the year, there is the potential to increase profitability by €1.54 per day for suckler cows and €0.95 for yearlings.

The length of grazing seasons impacts on greenhouse gas efficiency in four main ways:

- Emissions from direct deposition of manure on pasture are greater during grazing but;
- Reduced slurry storage and applications emissions (lower quantities stored);
- Lower enteric fermentation emissions since the digestibility of grazed forages is greater than that of conserved forage; and
- Lower fuel emissions as a result of reduced forage harvesting and feeding.

9.1.2 Calving Rate

For every percentage unit increase in calving rate, there is a potential increase in profitability of €8.60.

Higher calving rates reduce the carbon footprint by increasing output per cow and therefore diluting the greenhouse gas footprint over a greater quantity of beef.

9.1.3 Age at First Calving

There is a potential reduction in profitability of €1.65 for every day increase in age at first calving.

Age at first calving impacts on greenhouse gas efficiency in three main ways:

- Heifers consume greater quantities of feed (with associated feed production emissions) prior to first calving;
- Heifers produce greater quantities of methane (enteric fermentation) prior to first calving; and
- Heifers produce greater quantities of manure prior to first calving.

9.1.4 Live Weight Gain

For every gram/day increase in weight for age, there is a potential increase in profitability of €0.63 per head for steer/heifer systems and €1.01 per head for bull systems.

There are two opposing implications of higher lifetime live weight gain performance with regard to greenhouse gas emissions:

- Absolute greenhouse gas emissions increase since the quantities of feed consumed and manure produced are greater; and
- Greenhouse gas emissions per unit of beef produced are reduced since the greater quantities of beef produced more than off-set the increase in greenhouse gas emissions.

9.1.5 Nitrogen Fertiliser Usage

Reducing the quantity of nitrogen required per kg of beef produced, leads to increased technical efficiency and as a result, economic efficiency is improved.

Reducing nitrogen fertiliser use improves greenhouse gas emissions efficiency by:

- Reducing direct N_20 emissions associated with fertiliser application;
- Reducing CO_2 emissions associated with the manufacturing of nitrogenous fertiliser; and
- The use of white clover has the potential to substantially reduce inorganic nitrogen fertiliser requirements on grassland farms, particularly at low or moderate stocking rates. The reduction in inorganic nitrogen fertiliser usage improves production efficiency, thus improving profitability and reducing greenhouse gas emissions.

9.1.6 Management of Animal Manure

Increasing the amount of slurry spread in the spring, increases the utilisation of the nitrogen component in the slurry. This means that less chemical nitrogen has to be applied and/or higher grass output can be achieved.

- Increased spring application of slurry use improves greenhouse gas emissions efficiency by:
- Achieving higher levels of uptake of the N in slurry thereby reducing the amount lost to the atmosphere as NH_3;

Reducing the storage period and thereby reducing losses of greenhouse gases during storage; and
The use of trailing shoe or band spreading also reduces the greenhouse gas losses and improves nitrogen uptake by plants.

9.2 Case Study No. 1 – Suckler to Beef

David and Joanne Kinsella, New Ross, Co. Wexford

David and Joanne run a 42 hectare suckler to beef enterprise in Co. Wexford. They have 4 young children.

The farm is all in grassland and is primarily dry, free draining land. The farm carries 60 suckler cows and their progeny. The spring calving herd are a mixture of Simmental, Charolais and Limousin cows. The stocking rate is approximately 2.2 LU/ha.

Compact calving is achieved by using AI for the first 3 weeks of the breeding season followed by a Charolais stock bull. Replacements are bred from selected mature cows using AI sires (Charolais and Simmental). Replacement heifers are bred to an easy calving Limousin AI sire and calved down at 24 months. Replacements are maintained on high quality grass throughout the grazing season and turned out to grass as soon as possible after calving, with the intention of getting them back in calf as quickly as possible. Compact calving and breeding management has helped to achieve a weaning rate of one calf/cow/year with a 372 day calving interval.

Male calves are finished as young bulls at 17 months at an average carcase weight of 456 kg (in 2011) (86% U-grade) and females are finished at 19 months at an average carcase weight of 348 kg (88% U-grade). The heifers are finished off grass while the bulls are grazed until June and then housed on ad-lib concentrates for 70-80 days. In the past, males were finished as bullocks at 20-22 months. The system was changed to finishing bulls in order to take advantage of the efficiency gains and also to finish the bulls before the cows are housed.

Early turnout of all stock is a target on the farm with proper autumn management to ensure that adequate grazing is available for spring (10th February). This is achieved by a rotational closing of paddocks in October which facilitates early turnout, considered to be more efficient than grazing later in the autumn. Weanlings are wintered on quality silage (70+ DMD) and 2 kg concentrates. Cows are wintered on a restricted diet of 25kg silage and straw.

Table 7: Outcomes from the Carbon Navigator for the Kinsella Farm

Aspect	Achievement	Score (1-10)	Target	Comparison
Length of Grazing Season	263 days for cows and yearlings	9.8	263 days for cows & 276 for yearlings	• Higher than average • Increases profitability by €4,295 compared to average • By achieving the target, potential to reduce greenhouse gas emissions by 0.5% and to increase profitability by €1,457
Calving Rate	1	10	On Target	• Higher than average • Increases profitability by €8,256 compared to average
Age at First Calving	24.8 months	10	24 months	• Lower than average • Increases profitability by €3,433 compared to average • By achieving the target, potential to reduce greenhouse gas emissions by 0.24% and to increase profitability by €482
Liveweight gain per day of age (g)	1,500	10	On Target	• Higher than average • Increases profitability by €55,755 compared to average
Nitrogen Usage (kg N/kg live weight beef)	0.16	10	On Target	• Lower than average • Top 10% of farmers – 0.16 kg N per kg beef produced
Slurry Application and Method	• 50% spring and 50% summer after 1st cut silage by splash plate • Average storage of 98 days • 1.519 kg CO_2e/kg live weight (greenhouse gases)	6.2	• 65% spring & 35% summer after 1st cut silage by splash plate • Average storage of 86 days • 1.402 kg CO_2e/kg live weight (greenhouse gases)	• Average storage days lower than average • By achieving the target, potential to reduce greenhouse gas emissions by 0.8% and to increase profitability by €46

The scores, targets and comparisons are presented in line with national averages. Factors such as land type and location impact on the extent to which the national average can be achieved on specific farms. As a result, the targets change for different farms and national average performance levels are not possible on all farms. The figures presented should be taken as indicators on performance and GHG emissions reduction.

The carbon footprint for the farm is around a third better than the average for suckler to beef systems. The overall benefit of achieving all greenhouse gas targets would be to reduce emissions by 2% and increase profitability by €1,985.

9.3 Case Study No. 2 – Suckler to Weanling/Stores

Raymond and Margaret Palmer, Castlefinn, Co. Donegal

Raymond and Margaret operate a 53 ha grassland farm (21 ha owned and 33 ha rented) in Co. Donegal. They have 2 sons and a daughter. The farm is described as well drained grassland.

They operate a 60 cow suckler herd, 60% spring calving and 40% autumn calving. The cows are a mixture of Simmental, Limousin and Charolais. Compact calving is a feature of the farm system, and in 2011, a weaning rate averaged 0.98 calves/cow with a 379 day calving interval. A combination of AI and stock bulls are used for breeding. A Charolais stock bull is used on cows and a Simmental bull is used for the breeding of replacements. Additional replacements are also purchased as required. Bulls are selected for ease of calving and muscle. The priorities are good growth and muscle which allows stock to be finished at a younger age at good weights.

Males are reared for sale as yearling bulls at an average of 500 kg at one year (both autumn and spring born). This ambitious target weight is achieved through grassland management, breeding and milk yield. Heifers are retained on farm and finished at 20-26 months of age (either off grass or out of the shed) at an average carcase weight of 340 kg, along with 20 bought-in heifers.

The Palmers have changed their system of grassland management to incorporate rotational grazing, which is being undertaken in order to improve the quality of grass and increase the overall amount of grass grown on the farm. The farm has not got conventional paddocks but has field sizes of 3-4 ha. The fields are divided into 1 ha sections with temporary electric fences. This facilitates the creation of suitable divisions to accommodate different groups of stock and it also allows grazing fields to be cut for silage.

The split calving season facilitates more balanced labour demands and cashflow throughout the year. Spring born (January to March) calves are suckled until October/ November and then wintered on ad-lib silage and 2-3 kg concentrates. Autumn born calves receive 1-2 kgs of concentrates during the winter. Future plans are for more compact calving (12 weeks spring and autumn) and continued maximisation of grassland management.

Table 8: Outcomes from the Carbon Navigator for the Palmer Farm

Aspect	Achievement	Score (1-10)	Target	Comparison
Length of Grazing Season	223 days for cows and 230 yearlings	3.4	On target for cows 238 for yearlings	• Decreases profitability by €5,318 compared to average • By achieving the target, potential to reduce greenhouse gas emissions by 0.5% and to increase profitability by €996
Calving Rate	0.9	9.7	On target	• Higher than average • Increases profitability by €2,683 compared to average
Age at First Calving	29.3 months	6.9	27 months	• Lower than average • Increases profitability by €626 compared to average • By achieving the target, potential to reduce greenhouse gas emissions by 0.7% and to increase profitability by €1,201
Liveweight gain per day of age (g)	1,040	10	1,050	• Higher than average • Increases profitability by €23,934 compared to average • By achieving the target, potential to reduce greenhouse gas emissions by 0.05% and to increase profitability by €825
Nitrogen Usage (kg N/kg live weight beef)	0.05	10	On target	• Lower than average • Top 10% of farmers – 0.16 kg N per kg beef produced
Slurry Application and Method	• 50% spring and 50% summer following 1st cut by splash plate • Average storage of 98 days • 1.760 kg CO_2e/ kg live weight (greenhouse gas)	6.2	• 60% spring and 40% summer following 1st cut by splash plate • Average storage of 90 days • 1.679 kg CO_2e/ kg live weight (greenhouse gas)	• Average storage days lower than average • By achieving the target, potential to reduce greenhouse gas emissions by 0.6% and to increase profitability by €54

The carbon footprint for the farm is more than 30% better than the average for similar systems. The overall benefit of achieving all greenhouse gas targets would be to reduce emissions by 1.9% and increase profitability by €3,075.

9.4 Case Study 3: Weanlings/Store to Beef

Bourns Family, Ballinasloe, Co. Galway

The Bourns Family run a 250 hectare mixed drystock and tillage farm in Co. Galway (94 ha grassland). The farm is described as well drained arable and grassland.

They finish over 1000 cattle every year (the unit has a capacity to feed 800 cattle) including young bulls, steers and heifers. They also carry 1,200 mid-season lambing ewes.

The cattle are finished on a diet which includes: grass silage; maize silage; wholecrop wheat; urea treated wheat; popcorn treated barley; and fodder beet. Up to 90% of the total diet is grown on the farm. While the tillage enterprise on the farm provides feed for the beef and sheep enterprises, they are run financially as separate enterprises. This is necessary to ensure that all enterprises are run and managed as efficiently as possible.

The increasing cost of concentrates has focused the Bourns' on achieving the maximum rate of daily liveweight gain from grazed grass.

All stock are purchased, none are born on the farm. The majority are purchased in spring and autumn but this depends on prevailing prices at the time. Spring purchased weanlings are generally between 360-380kgs with a target weight gain of 180-200kg over the grazing season. Autumn purchased cattle are either finished directly from the shed or off grass in the following season. Different finishing regimes are pursued depending on the weight of the animal.

Priority on the farm has been given in recent years to achieving a greater liveweight gain from grazed grass which has involved reseeding and greater use of paddocks for rotational grazing. The use of smaller paddocks has increased weight gain. Mixed grazing is also practiced to maximise grass utilisation. The use of a trailing shoe for slurry spreading is reducing the level of artificial fertiliser used and allows for greater utilisation of grazed grass after the spreading.

The large numbers of animals which are finished on the farm has required close attention to the diet and ensuring efficient feed conversion. Upon housing cattle are gradually introduced to a high energy diet. The use of a range of different feeds requires careful attention to balanced nutrition and maximising performance. Technology is used to ensure that performance is maximised, diets are mixed using a diet feeder. This also allows close monitoring of the feed costs. Liveweight gain is monitored by regular weighing throughout the finishing period. A liveweight gain of 1.5kg per day is targeted for bulls over the finishing period and 1.2 kg per day for steers.

Bulls are brought to a weight of 320-420kg (16-22 months) depending on market requirements. Young bull carcases average 371kg at 19 months, steers 363kg at 26 months and heifers 312kg at 21 months.

Health is another critical issue on this farm due to the fact that all stock are purchased and disease is a potential threat. They aim to purchase as much stock as possible directly from farms. They have a health plan in place to deal with problems including the taking of regular dung samples for more efficient and targeted use of dosing in parasite control.

Table 9: Outcomes from the Carbon Navigator for the Bourns Farm

Aspect	Achievement	Score (1-10)	Target	Comparison
Length of Grazing Season	243 days	3.3	250 days	• Lower than average • Decreases profitability by €14,672 compared to average • By achieving the target, potential to reduce greenhouse gas emissions by 0.5% and to increase profitability by €8,559
Liveweight gain per day of age (g)	1240	9.1	On target	• Higher than average
Nitrogen Usage (kg N/kg live weight beef)	0.15	9.9	0.14	• Lower than average • Top 10% of farmers – 0.16kg N per kg beef produced
Slurry Application and Method	• 100% summer following 1st cut by trailing shoe • Average storage of 135 days • 2.037 kg CO_2e/ kg live weight (greenhouse gas)	5	• 30% spring, 60% summer following 1st cut and 10% late summer/ autumn by trailing shoe • Average storage of 120 days • 1.868 kg CO_2e/ kg live weight (greenhouse gas)	• Average storage days higher than average • By achieving the target, potential to reduce greenhouse gas emissions by 1.2% and to increase profitability by €185

The carbon footprint for the farm is a third better than the average for this production system. The overall benefit of achieving all greenhouse gas targets would be to reduce emissions by 2.3% and increase profitability by €8,744.

9.5 Case Study 4: Dairy Calf to Beef

Michael Murphy, Nenagh, Co. Tipperary

Michael and Olivia Murphy run a 92 ha (82 ha owned and 10 ha rented) dairy and beef farm. They have four children. The farm is described as well drained.

They purchase over 300 dairy bull calves (autumn and spring born) annually which are reared and finished as steers (20-22 months) and young bulls (16 months). The calves are reared in groups of 35 using automatic feeders in order to reduce workload and improve efficiency. They found that feeding higher levels of milk replacer provided a performance benefit for calves. During rearing, calves have access by day to small paddocks near the sheds. Stock are weighed regularly in order to monitor performance and ensure that a consistent performance and weight gain is achieved. The target weight at housing for January/ February born bull calves is 270kg. His target is to finish bulls at 16 months. Those not on target to achieve this goal may be castrated. The difficulty of managing bulls at grazing in the second season is one of the main reasons for not grazing them, they can be dangerous and unpredictable. The average daily lifetime weight gain is 1.1kg/day for bulls and 0.98 kg/day for steers. Steers average 300kg carcase weight at 23 months at an average grade of O3 and young bulls slaughtered under 16 months at 280kg carcase weight, grading O2+, on average.

Table 10: Outcomes from the Carbon Navigator for the Murphy Farm

Aspect	Achievement	Score (1-10)	Target	Comparison
Length of Grazing Season	228 days	2.8	233 days	• Lower than average • Reduces profitability by €68,799 compared to average • By achieving the target, potential to reduce greenhouse gas emissions by 0.3% and to increase profitability by €1,349
Liveweight gain per day of age (g)	810	6.7	820	• Lower than average • Reduces profitability by €10,735 compared to average • By achieving the target, potential to reduce greenhouse gas emissions by 0.05% and to increase profitability by €1,789
Nitrogen Usage (kg N/kg live weight beef)	0.11	10	On target	• Lower than average • Top 10% of farmers – 0.16 kg N per kg beef produced
Slurry Application and Method	• 100% summer following 1st cut by splash plate • Average storage of 135 days • 3.608 kg CO_2e/ kg live weight (greenhouse gas)	3.2	• 35% spring, 55% summer following 1st cut and 10% late summer/ autumn by splash plate • Average storage of 116 days • 3.328 kg CO_2e/ kg live weight (greenhouse gas)	• Average storage days longer than average • By achieving the target, potential to reduce greenhouse gas emissions by 2% and to increase profitability by €837

The carbon footprint for the farm is more than 30% better than the average for similar systems. The overall benefit of achieving all greenhouse gas targets would be to reduce emissions by 1.9% and increase profitability by €3,075.

9.6 Case Study 5: Dairy and Calf to Beef

Timmy Hannon, Kilmore, Co. Clare

Timmy Hannon runs a mixed dairy and calf to beef enterprise in Kilmore Co. Clare. He farms a total of 109 ha (97 ha owned and 12 ha rented) of grassland and dairying is the predominant enterprise (approximately 28 ha designated as being for beef production). The land is heavy and some only capable of summer grazing.

He is currently milking 85 pedigree British Friesian cows (increased from 50 over the past number of years). He has maintained British Friesian breeding because it produces stock with good confirmation which are easier to finish. This was necessary when he was trying to build the dairy cow numbers and generate additional replacements. However, Friesian sires have been maintained as it allows him to finish them without turnout for a second season. The surplus heifers produced in the system are sold as replacement in-calf heifers.

Cows are calved from January and impressive fertility and management is evident in a 362 day calving interval. Early calving provides for earlier calves with a longer grazing season and maximum weight gain from grazed grass. Early calves are targeted for release to grass from mid-March onwards. Calves are taken off meals in mid April, late born calves are continued on 1-3 kg of concentrates for a longer period. Similarly in the dairy herd, the emphasis is on efficient use of concentrates, cows receive an average of 750-800 kg per cow to support a yield of 5,900 – 6,400 litres.

Weanlings are generally housed in early November on ad-lib silage and an average of 2.5 kgs of concentrate. In mid-January bulls are transferred onto a high concentrate diet until slaughter. Aberdeen Angus and Hereford sires were previously used on the dairy herd and stock finished at 20-23 months at an average carcase weight of 335 kg. All British Friesian sires are now used and young bulls are finished at 14-15 months (after one grazing season). These averaged 254 kg carcase weight in 2011, graded O+/R- at fat scores of 2+ and 3-. The bulls achieved a daily liveweight gain of 0.9 kg to 1 kg per head per day.

Overall grassland management is critical to the financial efficiency of the farm as high levels of concentrates are required to finish the bulls early. The dairy beef system is viewed as maximising the use of labour and facilities and provides a boost to cashflow early in the year.

Table11: Outcomes from the Carbon Navigator for the Hannon Farm

Aspect	Achievement	Score (1-10)	Target	Comparison
Length of Grazing Season	214 days	-	221 days	• Lower than average • Reduces profitability by €48,784 compared to average • By achieving the target, potential to reduce greenhouse gas emissions by 0.5% and to increase profitability by €1,303
Liveweight gain per day of age (g)	800	6.5	810	• Lower than average • Reduces profitability by €6,174 compared to average • By achieving the target, potential to reduce greenhouse gas emissions by 0.05% and to increase profitability by €1,235
Nitrogen Usage (kg N/kg live weight beef)	0.15	10	On target	• Lower than average • Top 10% of farmers – 0.16 kg N per kg beef produced
Slurry Application and Method	• 100% summer following 1st cut by splash plate • Average storage of 135 days • 3.608 kg CO_2e/ kg live weight (greenhouse gas)	3.2	• 35% spring, 55% summer following 1st cut and 10% late summer/ autumn by splash plate • Average storage of 116 days • 3.328 kg CO_2e/ kg live weight (greenhouse gas)	• Average storage days longer than average • By achieving the target, potential to reduce greenhouse gas emissions by 2% and to increase profitability by €1,039

The overall benefit of achieving all greenhouse gas targets would be to reduce emissions by approximately 2.6% and increase profitability by €3,577.

9.7 Case Study 6: Suckler to Weanling

Eamon Holohan, Rathdowney, Co. Laois

The Holohan family run an organic suckler enterprise in Co. Laois. They farm a total of 85 hectares (mixture of dry and heavy ground). The farm has 100 suckler cows with progeny sold as weanlings.

There is a mix of suckler cows breeds (Limousin, Hereford and Simmental) which are bred to Saler stock bulls. Calving is split between autumn and spring. A calving interval of 376 days was achieved in 2011, with heifers calving into the herd at 2 years. The weaning rate was 0.9 calves per cow. Bulls and heifers are sold to an organic finisher weighing an average of 400 kgs at 9-12 months (depending on requirements).

The farm converted from conventional production to organic to production in 2008. As a result there is now a lower stocking rate and output compared to conventional systems of production but a low carbon footprint is still achieved due to the low level of inputs used. There was apprehension about changing to organic production due to the necessity to reduce numbers and stocking rate but now the Holohan's have increased their numbers again and have gained confidence in farming without fertiliser and concentrates. As a result, the grassland management, breeding and usage of organic fertilisers have all improved. It is estimated that as a result of converting to organic production, the concentrate and fertiliser bill has fallen by an average of over €20,000 per year.

Major improvements were required in grassland management and changes made included: new paddocks for rotational grazing; introduction of clover; regular topping; and effective utilisation of organic manures to get maximum response. Manure is utilised in 2 ways: more liquid slurry from slatted tanks is utilised during the grazing season; while farmyard manure from straw bedded sheds is mainly used on silage ground.

The breeding policy on the farm has also been adapted to suit the requirements of the organic system. They have introduced Salers sires which provide replacements with a lower mature weight and an ability to achieve a good weight gain at grass, reducing the need for concentrates. The Salers are easy calving and the cross breeding has improved fertility.

The message from this farm is that low outputs can generate good returns once inputs are maintained at a low level. Improved grassland management can reduce the fertiliser and concentrate requirement while increasing animal performance. Breeding management can also provide significant improvements in performance.

Table 12: Outcomes from the Carbon Navigator for the Murphy Farm

Aspect	Achievement	Score (1-10)	Target	Comparison
Length of Grazing Season	226 days for cows and weanlings	5.2 (cows) 8.7 (weanlings)	254 days for cows and weanlings	• Lower than average • Reduces profitability by €4,911 compared to average • By achieving the target, potential to reduce greenhouse gas emissions by 2.5% for cows and 1.9% for weanlings and to increase profitability by €8,595
Calving Rate	0.9	9.7	On target	• Higher than average • Increases profitability by €5,160 compared to average
Age at First Calving	28.6 months	7.5	25 months	• Lower than average • Increases profitability by €4,216 compared to average • By achieving the target, potential to reduce greenhouse gas emissions by 1.1% and to increase profitability by €3,614
Liveweight gain per day of age (g)	900	8.4	On target	• Lower than average • Decreases profitability by €15,215 compared to average
Nitrogen Usage (kg N/kg live weight beef)	0	10	On target	• Lower than average • Top 10% of farmers – 0.18 kg N per kg beef produced
Slurry Application and Method	• 100% spring by splash plate • Average storage of 60 days • 1.337 kg CO_2e/ kg live weight (greenhouse gas)	9.3	On target	• Average storage days lower than average

The carbon footprint for the farm is around a third below the national average for this production system. The overall benefit of achieving all greenhouse gas targets would be to reduce emissions by approximately 5.5% and increase profitability by €12,208.

10. Research Conclusions

Climate change is impacting and will impact further on Irish farmers and farming systems over the coming decades. The impact will be due to climatic conditions but also due to policies implemented to reduce the overall level of greenhouse gas emissions from agriculture (and society in general). While Irish beef and dairy production are very efficient in terms of their carbon footprint, agriculture accounts for 32% of national total emissions and therefore need to be addressed. The focus of this report is on the micro farm level actions and the conclusions also focus at that level. This is not ignoring the macro level but is considering the elements which are within the control of farmers.

The NESC report on Climate Change (2012a) suggested that it was necessary to balance the emphasis on *'how much'* emissions reduction to target with more focus on 'how to' achieve the reductions. The findings from this research endorse those conclusions and highlight the importance of working with farmers to achieve improvements rather than simply setting out targets which they must achieve.

There is considerable confusion among farmers and others about climate change and the terms used to describe it (emissions; greenhouse gases; carbon sinks; carbon sequestration; carbon footprint; carbon leakage); the range of gases (CO_2; CH_4; N_2O); and the different quantification approaches (IPCC; LCA). There is also limited understanding of the origins (at farm level) of the specific gases. A greater understanding may lead to a greater adoption of changes at farm level.

One of the major challenges is the lack of knowledge and understanding of the impact that farm practices have on greenhouse gases or on how practices can be changed in order to reduce the negative impacts. In addition, when farmers think of climate change impacting on them, they generally think of the varying weather practices. Farmers are not in general considering how policy measures or regulations which may be introduced to address climate change might impact on their farming operations (positively and/or negatively), impose restrictions on their production systems or lead to additional costs.

The discussion on climate change as it relates to Ireland also highlights the conflicts of interest regarding the issue. Agriculture is currently one of the better performing sectors in the Irish economy and viewed as contributing to the future prosperity and recovery of the national economy. The Food Harvest 2020 report has set ambitious targets for increased output and value of output from the main agricultural sectors. Therein lies the conflict between economic (increased output) and environmental objectives (reduced emissions). The achievement of the targets is recognised as having the potential to increase emissions.

Due to the small carbon footprint relative to other countries, there are opportunities for Irish agriculture to prosper from the focus on climate change and greenhouse gas emissions. The increasing demands for low carbon food products offers potential to promote and market Irish food as such.

The confusion with regard to the meaning of climate change and greenhouse gas emissions and the lack of understanding of how to address the issue at farm level is now being addressed with the development of the Carbon Navigator by Teagasc and Bord Bia and the initiation of carbon audits at farm level. The Carbon Navigator provides a worthwhile measure and indicator of the carbon footprint on individual farms and provides guidance on addressing issues which further reduce the environmental impact of farming.

Evidence from the carbon audits undertaken by Bord Bia show that despite the relatively good position of Irish farm practices in terms of their carbon footprint, there is considerable potential to further improve the carbon efficiency of farms which will also potentially lead to improvements in management efficiency and productive profitability.

Extensive research has been undertaken nationally and internationally on farm level actions to address climate change. Teagasc, UCD and others are undertaking ongoing research at national level. Many of the outcomes highlight practical measures relating to management practices and efficiency which could be adopted at farm level. The big gap appears to be in the communication and explanation to farmers of what they can do on their own farms to reduce their own emissions and contribute to reducing emissions from Irish agriculture. Communication would also overcome the fears and lead to a better understanding of the issue. Therefore, the challenge remains to effectively communicate the research messages to farm families and encourage the adoption of practices which will lead to reduced emissions.

While agriculture is a source of greenhouse gas emissions, it is evident that it has the potential to reduce emissions by: sequestering CO_2 in biomass and soil; increasing efficiency in the utilisation of inputs such as fuel, fertiliser and pesticides; producing biofuels to replace fossil fuel energy; improving the efficiency of usage of nitrogen; and reducing emissions from manure.

Evidence from research shows potential for reducing emissions in: improvement of genetic merit of livestock; reducing age at first calving and length in the herd; extending the grazing season; reducing beef finishing times; improved nitrogen efficiency; increased use of clover; use of nitrogen inhibitors; minimum tillage; anaerobic digestion; production of renewal fuels; and changes in management practices. The benefits of adopting these practices extend beyond environmental improvements as they are generally worthwhile in terms of production efficiency and as result have the potential to enhance profitability. Forestry also has significant potential to sequester carbon dioxide and offset emissions from other sectors.

Farmers have the potential and the capacity to work to address the impact of climate change and reduce emissions at their own farm level and ultimately national level. However, they need advice and guidance on the most appropriate actions to take. Advisory services, discussion groups and other mechanisms need to be explored for ways of getting the messages on climate change through to farmers. In addition, farmers will need reassurance that the actions they have taken are worthwhile both environmentally and financially.

11. Recommendations

The focus of this report is on *'farm level actions to reduce climate change impacts'* and therefore the recommendations specifically address aspects at farm level. It is evident from the research that there is considerable uncertainty among farmers regarding climate change, the impacts, the causes and how to reduce the impact. Therefore the most important recommendations relate to information and communication with farmers.

The process of information and communication should involve a multi-agency/stakeholder approach which is structured, based on presentation of clear facts, grounded in science and without implication of blame or criticism of farmers for past performance. With this regard, lessons can be learned from the past experience with regard to environmental measures. Farmers react negatively when measures appear to be imposed without due consultation and explanation whereas balanced and incentivised measures generate a more positive response. Similarly measures within cross compliance are broadly adhered to once explained properly and grounded in practical measures. Therefore the targets for emissions need to be clearly presented to farmers and explained in terms of what they mean at farm level.

The first stage of the information campaign needs to explain in simple terms: what the impact of climate change is; how it is developing; the extent to which farmers contribute to climate change both positively and negatively; and how farmers can play a role in adapting practices for their own benefit and the overall environmental benefit. The aim is to assist farmers in gaining an understanding of the concept and an acceptance that farming contributes to greenhouse gases and climate change and encouraging a willingness to take action to address it on each and every farm in the country. Critically important is the presentation in a balanced way of the consequences of not voluntarily taking action at farm level *'do nothing approach'* and ultimately being forced to do so by policy measures/legislation.

There is a need to produce a simple guide for farmers on climate change and greenhouse gas emissions: clear facts; causes; impacts; and the actions that can be taken to address emissions.

As a mechanism to reduce emissions from agriculture, all farms should undertake a carbon audit and the carbon navigator used to both measure and produce practical recommendations for each farm. While it would not be possible to visit each individual farmer to follow up on the carbon audit results, a series of information meetings should be organised across the country which seek to explain the results of the audits, interpret the findings and discuss the actions that can be taken at farm level. In particular these meetings should seek to clarify issues surrounding climate change and emissions but most importantly highlight that many of the actions which could benefit the environment could also financially benefit farmers. The potential of developing the carbon navigator further should be encouraged in order to explore further beneficial productivity factors which could then be addressed by farmers.

Case studies (similar to those included in this report) are a useful and interesting approach to communicating the message to farm families. In particular, the case studies could also explain the concept of carbon audits, the aspects that contribute to emissions, and the actions that can be taken to reduce emissions.

The agricultural media have a role to play in information provision and knowledge enhancement. This role could be undertaken by general information articles focused on local (national and farm level) actions and could utilise real farm scenarios (case studies) to illustrate this.

National greenhouse gas emission reduction targets need to be combined with associated measures/incentives which would encourage farmers to adopt management practices which would lead to reduced emissions. Similar to specific environmental and farm waste control measures in the past which encouraged farmers to take action to address critical issues. Measures should be considered in tandem with an information/communication campaign.

Demonstration/monitor farms focused on addressing greenhouse gas emissions should be developed similar to those for other goals (e.g. development/expansion, management etc). These farms could clearly demonstrate the costs and benefits in a real farm situation. In fact, it should be possible to include a greenhouse gas/climate change focus onto existing monitor farms (dairy, beef and sheep etc.) and to specifically observe these farms with this intention in addition to their original focus. This approach would provide farmers with an opportunity to see in practice what other farmers are doing to address emissions and both the achievements and challenges in doing so.

In order to achieve progress on reducing greenhouse gas emissions, there is a need to focus on appropriate mitigation measures which provide tangible benefits for farm families as well as for the environment. This also includes encouraging farmers to adopt practices which improve water and energy efficiency.

It is evident that scientific research is significantly informing the actions which can be taken at farm level. It is important to continue to provide resources for research in this area to further reduce emissions and improve the environment. Monitor farms provide an opportunity to: demonstrate the research findings at farm level; assess the impact in *'real farm scenarios'*; and further the research knowledge.

The discussion group programme (dairy, beef, sheep and tillage) should be utilised to disseminate information and provide advice to farmers on management practices to reduce greenhouse gas emissions. There is an opportunity within these programmes to demonstrate actions and to focus on achieving best practice.

Advisors and consultants providing advice to farmers may need upskilling in the area of greenhouse gases and climate change mitigation. General farm management advice needs to take account of the carbon/greenhouse gas implications of taking particular actions on the farm (and an opportunity to explore alternative scenarios). Where farmers are expanding production/increasing output, they need to be advised on the approach which minimises any increase in emissions or leads to a reduction in emissions.

Farmers should be consulted on the development of policy measures addressing climate change and greenhouse gas emissions so that there is understanding about the need for the measures, the approach undertaken and the design of the measures.

The low carbon nature of Irish agriculture and food can be potentially exploited as a marketing tool for Irish food. This can only be adequately exploited when accurate measurement is available at farm level, which can be verified and audited, products labelled and marketed accordingly.

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Appendix

Membership of NRN Climate Change Working Group

The Climate Change Working Group was facilitated by Dr Pat Bogue and involved the following members:

Dr Tommy Boland, UCD;
Mr Padraig Brennan, Bord Bia;
Ms Mary Buckley, ICMSA;
Mr Sean Campbell, Campbell Environmental Consultants;
Dr Bernard Hyde, EPA;
Dr Gary Lanigan, Teagasc;
Mr Thomas Ryan, IFA; and
Ms Grace Maher, IOFGA .

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