Nuffield Farming Scholarships Trust

Sponsored by Royal Welsh Agricultural Society and Innovis Ltd

Maximising returns through reducing methane emissions – an opportunity for the UK Sheep Sector

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October 2012

Contents

Disclaimer

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1. Executive Summary

The message is clear – climate change is happening and agriculture is viewed as part of the problem – it's also part of the solution. UK agriculture contributes approximately 9% of UK greenhouse gas emissions and as an industry we need to rise to the challenge of finding sustainable reductions of these gases. Vitally, this also needs to take into account rising global demand for food, wider environmental goals such as water quality and most importantly, from a producer's perspective, a profitable and vibrant industry.

So what is it that we are meant to be reducing? When thinking about climate change carbon dioxide is normally considered as the greenhouse gas (GHG) responsible for the rise in global temperatures. However, agriculture only produces a relatively small amount of carbon dioxide and it is two other gases, nitrous oxide and methane, which are responsible for the majority of our emissions. Unfortunately, on a like for like basis, both these gases have higher 'global warming potential' than carbon dioxide. Methane is approximately 25 times more damaging to the atmosphere compared with carbon dioxide whilst nitrous oxide is about 298 times more potent. Nitrous Oxide is largely released from soils and the use of nitrogen fertilisers. Methane is naturally produced from ruminant livestock and is the basis of many of the headlines in the press calling for a reduction in red meat consumption due to the 'burping and belching' of cattle and sheep.

There is, however, undoubtedly a challenge for the red meat sector. Various figures are quoted for global emissions from livestock with estimates normally in the region of 80 million tonnes of methane produced per year or about 18% of all greenhouse gas emissions. Sheep are purported to be responsible for about 10% of the methane emissions, the majority of which are derived from sheep production in the African, Asian and Pacific regions. From an EU perspective, figures presented in 2004 by the Institute of Environment and Sustainability, suggested that sheep and goat meat production were responsible for 4% of total livestock greenhouse gas emissions (carbon dioxide, nitrous oxide and methane) from the 27 member states. In comparison poultry meat was responsible for 8% of emissions and eggs 3%. Emissions derived from pork production were 25%. Overall emission levels can however be misleading, and due to differences in biological efficiency and yields, lamb meat has one of the highest carbon footprints of all the meats and therefore highlights the need for the sheep industry to tackle the problem.

Whilst this seems like an unwelcome challenge, we can also see this as an opportunity to develop the viability of our sector. The emergence of new technologies and increased awareness of the value of reducing GHGs may produce significant opportunities provided we can work towards capitalising on our improvements. As an industry we need to be seen to be taking steps to reduce emissions and to be able to offer robust solutions including increased carbon capture through our management of soils. This is a new and developing area of science which could provide many economically viable solutions provided there is continuing support for scientific research. This is essential if agriculture is to meet new challenges associated with climate change.

Fortunately there are already some practical solutions the sheep industry can apply using technology and knowledge which are available. Reassuringly many of these practices are also considered 'best practice' and can improve margins from sheep production. Improving efficiency of production is currently one of the over-arching principles behind reducing GHG emissions and includes management practices such as;

- Maximising utilisation of feed
- Improved manure management
- Using best practice in the management of soils
- Applying fertiliser to maximise efficiency of uptake
- Genetic improvement in production traits such as lamb growth rate, ewe fertility and ewe longevity.

As an example of what can be achieved compared to 1990, the New Zealand national flock produces slightly more meat from 43% fewer ewes due to increases in the number of lambs reared and average carcass weight. Researchers estimate that this productivity improvement has led to a reduction in the carbon footprint of lamb of about 17%. There is no reason why similar gains can't be achieved from UK sheep production through continuing improvements in management, nutrition, health and breeding.

There is also a great deal of promising research looking at the role of nutrition in reducing methane emissions. High sugar grasses have been shown to not only reduce methane but also nitrous oxide emissions, whilst work being carried out internationally is looking at the use of novel forages, supplements and vaccination. Research has also shown natural differences between animals in both their feed efficiency and the amount of methane produced even on the same diet. Many of these approaches are however in their infancy and may well have both practical and cost barriers to widespread application.

UK sheep farming has the added advantage of being able to offer food production against a background of the many environmental benefits livestock production brings. Most of the land farmed for sheep is unsuitable for other forms of food production and alternative sources of protein which are considered to produce lower amounts of GHGs often compete with cereals which are suitable for human consumption. The capability for carbon storage within our soils can also be highlighted particularly for the large areas of 'unimproved' land which are unsuitable for regular cultivation.

There are still however many areas that require clarification including the development of a common method for calculating emissions, the mechanisms through which farmers will be able to benefit from reducing emissions on an individual 'farm level' and how government (and retailers) will implement and balance rewards and regulations.

In the meantime development of arguments in support of sheep production is vitally important to help combat those who use climate change as a means to turn consumers against the consumption of red meat. Demonstrating that improved efficiency of food production can be part of the solution to climate change is a key strategy to ensure that the sheep industry is set to meet the coming challenges.

2. Introduction

I farm a 350 acre upland sheep farm in partnership with my parents, running 950 crossbred ewes. The area in which we farm is in the heart of Carmarthenshire in West Wales. From the top of our farm we are able to see both the fertile Towy valley renowned for its dairy farming and the start of the Brecon Beacons National Park where sheep predominate.

I have always been committed to agriculture and began my journey with a degree in Animal Science followed by a PhD at Aberystwyth University. My thesis topic was 'Breeding Sheep for Resistance to Roundworms' and this led my interest in both sheep breeding and disease control. Following a five year period with a sheep breeding company I returned to the family farm where I now also run my own sheep consultancy business, KN Consulting. My consultancy business fits in well with my involvement in the family farm and I find that the experience I have gained through managing my own sheep farming business informs my attitude to the consultancy work. My aim is to work with producers to get the most out of their sheep farming business. Ultimately we all have to face the realities of running a business so return on investment, cost-benefit analysis and making a profit from sheep production underpins the advice and support I provide.

Shortly before setting up my own business I realised that my involvement in agriculture over the last 10 years of working in academia and then for a commercial company meant that I might be able to add some of my own experiences to organisations that were representing the industry. Having been members of the Farming Union of Wales (FUW) for many years the logical next step was to start attending local county meetings. At the same time I was also accepted to sit on the Welsh National Committee for the National Sheep Association (NSA) where industry issues were under constant discussion including reform of the Common Agricultural Policy, electronic identification in sheep and a new agri-environmental scheme. Nearly four years later I have gained so much support and encouragement from both organisations that I would wholeheartedly recommend any young person looking to make a difference to get involved. I am now heavily involved in both the FUW and the NSA and sit on a number of committees as well as chairing the newly formed FUW Animal Health and Welfare committee, chairing our County Branch and being the Welsh representative on the NSA UK Technical and Policy Committee. I am now also a Welsh representative on-behalf of the Moredun Foundation. Fortunately I don't ever seem to get bored with talking about sheep and farming!

View of the farm

3. Background to study topic

Although I didn't know it at the time my voyage towards a Nuffield scholarship began in 2008 with the reading of the Welsh Assembly Governments consultation document on the new agri-environmental scheme 'Glastir'. This scheme is largely unwelcomed by the Welsh agricultural sector with the industry concerned about the implementation of the scheme and its effect on the Welsh countryside and inherent relationship with agriculture. However, of concern to myself was the language surrounding greenhouse gas production by agriculture and requirements on the sector to reduce the carbon footprint of its farming practices. At the same time there were many headlines in the press about the damaging effect of livestock on the environment and how cutting livestock numbers was required to prevent 'global warming'.

> *"As environmental science has advanced, it has become apparent that the human appetite for animal flesh is a driving force behind virtually every major category of environmental damage now threatening the human future - deforestation, erosion, fresh water scarcity, air and water pollution, climate change, biodiversity loss, social injustice, the destabilization of communities, and the spread of disease"*
>
> Worldwatch Institute, 2004

Many of the headlines at the time and subsequent drive to reduce meat consumption are driven by those who fundamentally oppose livestock farming and see issues surrounding climate change as a useful addition to their argument. A quick Google search gives the following headlines "Go veggie to save the planet", "Livestock's carbon footprint: catastrophic" and "Killer cow emissions". The 'Meat free Monday' campaign is still going strong with over 32,000 'likes' for their Facebook group and there are many websites offering to sign up consumers for regular reminders on the environmental benefits of not eating meat. Whilst wholeheartedly disagreeing with these views we do have to recognise that there is a challenge that as producers of lamb, beef (and milk) that we need to address. Globally livestock are responsible for a significant proportion of GHG (greenhouse gas) emissions.

In some areas of the world there has been deforestation in a bid to increase land availability and to increase production of grain crops to use as animal feed. Evidence has also been put forward which suggests that the livestock sector is the largest source of water pollutants through animal waste, fertiliser and pesticides and soil erosion.

Many of these environmental concerns are however associated with developing countries and different challenges face countries such as the UK whose agricultural production systems have evolved over significant periods of time. The Common Agricultural Policy and associated codes of 'Good Agricultural Practice' means that UK agriculture is able to offer food production with much less impact on the environment. In the case of extensive lamb and beef production it can be argued that such production systems actually underpin the good management of the countryside. Furthermore the sector is constantly working towards reducing the environmental footprint of farming systems through national, regional and voluntary initiatives. Issues surrounding GHGs are however more difficult to tackle and there will be increasing pressure on all systems of food production to reduce their contribution to global warming. **So why focus on methane?**

When it comes to this particular GHG almost half of the world's emissions come from natural sources. These include wetlands, rivers and streams, gas hydrates on the ocean floor, and permafrost, with the methane resulting from bacterial decomposition of organic material in an anaerobic environment. Termites are the second largest source of natural methane producing the gas as part of their digestive processes. Livestock emissions are classed as man-made (or anthropogenic) emissions but are not the only source. Rice cultivation is a significant emitter of methane along with sewage treatment, landfill, coal, oil and gas mining and biomass burning. It was however a report titled 'Livestock's Long Shadow' released by the United Nations in 2006 which put livestock at the forefront of the debate and supported those who called for limiting or even avoiding consumption of meat and milk. For livestock production, and the sheep sector in particular, reducing methane which is a natural by-product of ruminant diets is therefore a particular challenge. The production of methane is in fact associated with one of the sheep sector's most important attributes: the ability to turn poor quality forage, via the rumen, into a high quality protein suitable for human consumption.

I have however always considered that sustainable livestock farming can deliver both financial and environmental benefits. A Nuffield Scholarship was therefore the ideal opportunity to see how other countries were addressing these challenges and how the UK sheep sector could be shaped by future challenges.

Some examples of anti-meat propaganda

www.meatfreemondays.com/resources_mfm/downloads/MFMPoster1.pdf

www.vegansociety.com/uploadedImages/User_Hubpages/Education/Education_Resources/Environment.jpg

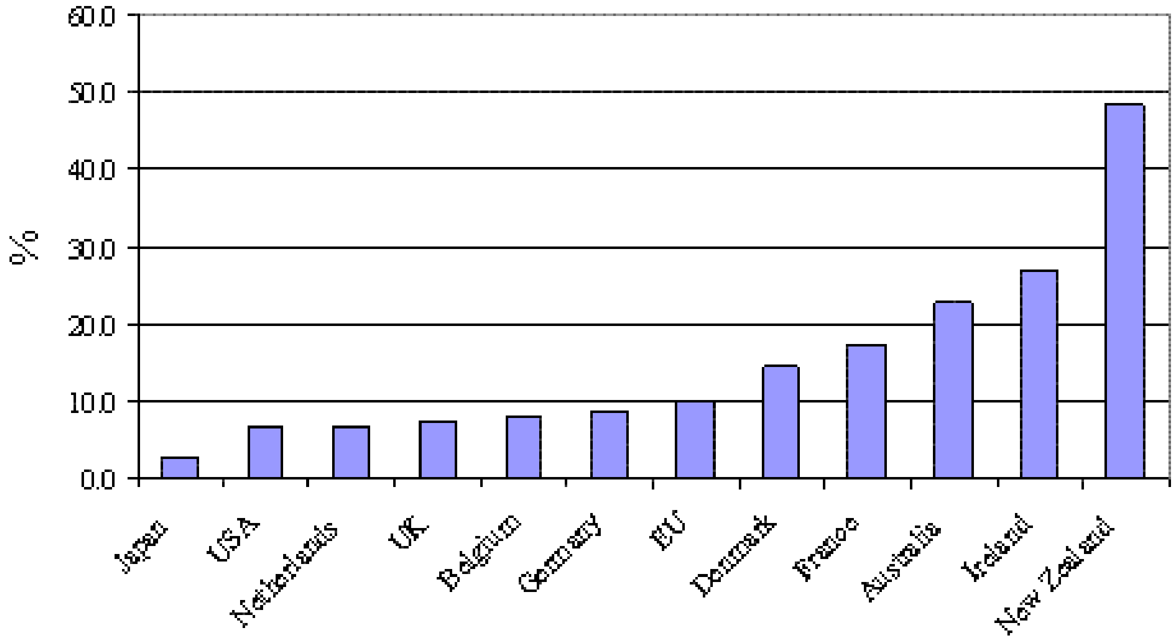
4. Countries visited and meetings held

My travels took me to three countries that I felt would be facing similar challenges within their farming sectors: Ireland, New Zealand and Australia. All three are developed countries with a strong research base and modern approaches to food production.

Country	***Contribution of agriculture to national GHG emissions***	***Contribution to world GHG emissions***
UK	*9%*	*2%*
Australia	*17%*	*1.4%*
Ireland	*29%*	*0.16%*
New Zealand	*48%*	*0.2%*

To set these figures into a more international context (below) it can be seen that Australia, Ireland and New Zealand have particular challenges facing their agricultural sectors when it comes to reducing GHG emissions and reaching legislative targets.

Emissions from agriculture in various countries *(United Nations Framework Convention on Climate Change)*



During my time in each of the three countries I visited a range of different organisations representing both the sheep and dairy sectors as well as looking at the most up-to-date research being carried out. This led me to farming unions, research organisations, conferences, breeding companies and of course I managed to fit in a few visits to farms to see how some of the technology to improve efficiency of production is being used in practice.

4a. September 2011: Southern Ireland

Sheep production is a significant contributor to the national economy with an output valued at €180 million in 2011 (*Teagasc, 2011*). The national flock consists of 2.5 million ewes, down from a peak of more than 4 million ewes, and consists of approximately 32,000 flocks with an average flock size in 2010 of 93 ewes. Exports make up a large proportion of sales with over 70% of lamb sold outside the country. The majority of lamb is produced from the lowland sheep flock and sheep farms are characterised by relatively small flocks with only 9% of flocks having 150 ewes or more and 22% of flocks having between 20 and 40 ewes.

In total two weeks was spent in Southern Ireland with the following visits;

- Teagasc
- Sheep Ireland
- University College Dublin
- Irish Farmers Association
- Irish Farmers Journal
- Sheep breeders and commercial producers

The trip also included attendance at a three day international conference titled the "4th International Symposium on Animal Functional Genomics" which took place in Dublin.

See photos on next page.

4b. November/December 2011: New Zealand

Sheep production is an important contributor to the NZ economy and as of June 2011 the national flock stood at 20.6 million breeding ewes and 10.6 million ewe hoggets, dry ewes, wethers and rams in approximately 29,000 flocks (*Beef + Lamb, 2012*). The Romney breed still predominates consisting of 46% of the national flock with Merino, Perendale, Coopworth and Corriedale making up a further 27.2% (*Beef + Lamb, 2011*). Wool still makes up a significant proportion of global supply comprising of approximately 12% of world production. The vast majority of NZ lamb is exported with the European Union still being the main destination although North Asia, North America and South Asia also considerable markets.

Despite a rise in dairy production over the last five years sheep and beef farming continues to be the dominant agricultural land use in New Zealand, occupying more than four times the area used by the second largest, dairying. *(continued 2 pages further on)*

Visit to University College of Dublin research farm

Belclare ram, which is a maternal composite developed by researchers at Teagasc, with ewes at mating

Amongst many individual visits during my time in NZ I was able to meet with the following;

- AgResearch Invermay
- AgResearch Grasslands
- Abacus Bio
- Dairy NZ
- AgFirst
- New Zealand Agricultural Greenhouse Gas Research Centre
- Pastoral greenhouse gas research consortium
- Sheep Improvement Ltd
- Beef + Lamb New Zealand
- Pfizer
- Federated Farmers
- Ministry of Agriculture and Forestry (now known as Ministry for Primary Industries)
- Lincoln University
- NIWA
- Sheep breeders and commercial producers
- Fellow Nuffield Scholars

Rapid expansion of the New Zealand dairy industry has led to concerns over increasing over environmental. In some cases winter housing of dairy cattle was being discussed to reduce poaching

Pollution concerns at Lake Taupo in the North Island of NZ means that Nitrogen 'capping' has been introduced for farmers in the catchment area. This limits stocking rates and fertiliser applications for predominantly sheep and beef producers

4c. February 2012: New Zealand

Whilst at the end of my stay in NZ a conference was announced which fitted directly with my Nuffield topic. Furthermore I had previously been involved with a project funded by the Welsh red meat levy board (Hybu Cig Cymru) and this was an ideal opportunity to present the findings of the work. My two week visit to Australia was therefore preceded with another week spent in the North Island of NZ.

Presenting the results of a project I was involved with on behalf of the Welsh Lamb and Beef Levy Board which looked at the role of genetic improvement in reducing methane emissions from the Welsh National Flock. Palmerston North, New Zealand,January 2012, at the NZAGRC annual conference.
hccmpw.org.uk/medialibrary/publications/Reducing%20Methane.pdf

4d. February 2012: Australia

Meat and Livestock Australia provide a good introduction into the Australian sheep industry. The country is the second largest exporter of lamb producing 8% of the world's lamb and mutton supply, exporting 48% of its lamb and 90% of all mutton produced. The sheep industry contributes around 5% of the value of total Australian farm exports with the Middle East being the main export market. The national flock stands at just over 42 million sheep aged one-year or older with nearly 29,000 properties farming sheep. Similarly to Ireland and New Zealand, Australia has seen a decline in the size of the national flock following reductions in global wool prices and in recent years there has been an increasing emphasis placed on meat production compared with wool production.

During my time in Australia I travelled extensively throughout the New South Wales region and during my two weeks travelling was able to meet with the following organisations and individuals;

- Cooperative Research Centre for Sheep Industry Innovation (Sheep CRC)
- Meat & Livestock Australia (MLA)
- NSW Department of Primary Industries
- National Farmers Federation
- Australian Farm Institute
- Sheep breeders and commercial producers
- Fellow Nuffield scholars

Improving soil carbon levels is an increasingly important part of Australian agriculture

Significant periods of drought means that the consequences of climate change are of real concern

5. The Challenge

"Responsible for about 100 million tonnes of methane a year and one of the largest sources of man-made methane".

No this isn't livestock but it is a source of food: rice. Frustratingly this gets little coverage in comparison with either red meat or milk production. So what is the actual challenge facing livestock production and the sheep sector in particular?

> *"By joining together in having one meat-free day each week we'll be making great steps towards reducing the environmental problems associated with the meat industry."* Meat Free Monday campaign.

5a. The challenge for global livestock production

Since the 1970s scientists have become increasingly concerned that concentrations of greenhouse gases (GHG) in the atmosphere resulting from human activities are raising temperatures and destabilising the Earth's climate. These activities include burning fossil fuels, deforestation and modern agriculture practices. Atmospheric concentrations of GHGs have increased from pre-industrial levels and strong evidence has been submitted that this has already caused an increase of 0.7°C in the average global temperature. Climate models suggest that temperatures are likely to rise a further 1.1 to 2.9°C for lowest emission scenarios and between 2.4 and 6.4°C for highest emission scenarios *(International Panel on Climate Change, 2007)*

Whether or not you agree with climate change or the causes of the rise in global temperatures the majority of politicians, non-governmental organisations, lobby groups, researchers and consumers do, so if we want to promote a vibrant industry meeting the needs of the 21st century we cannot ignore the problem. Instead we must look for solutions which support our sector rather than simply reducing livestock numbers and significantly reducing meat consumption as is being called for.

5b. Livestock's long shadow

The first major public engagement with issues surrounding livestock production and emissions came with the publishing of the report titled "Livestock's Long Shadow" by the Food and Agriculture organisation (FAO) of the United Nations in 2006. The report discussed the role that livestock plays globally highlighting that this agricultural sector is responsible for the following;

- 40% of global agricultural gross domestic product
- Employing 1.3 billion people
- Providing one-third of peoples protein intake

The report also introduced the impact of a growing population on demand for livestock products with a projection for a doubling of demand for meat by 2050. Most notably the report also highlighted the environmental impact livestock production had on the wider environment including;

- Land degradation
- Water pollution
- Reduced biodiversity
- Greenhouse gas emissions

It was the statement that the livestock sector is a ‘major player’ and responsible for 18% of all global emissions that resulted in many negative headlines at the time. Given particular attention by pressure groups was the statement that agricultural emissions were responsible for a higher share of global emissions than transport. Since the daily consumption of food is vital for human survival I have no ethical concerns with agriculture producing more emissions than transport much of which, in developed countries, is based around choice rather than necessity.

> *“The environmental impact per unit of livestock production must be cut in half, just to avoid increasing the level of damage beyond its present level”.* FAO, 2006

Interestingly, in the same paragraph within the report, the role of intensification and increasing productivity in combatting these emissions was also discussed highlighting the following as potential solutions for reducing the environmental impact of livestock production:

- Improving diets
- Improving manure management and the use of biogas for renewable energy
- Use of conservation tillage and cover crops
- Increased use of agroforestry

At the time such opportunities were not well covered in the wider press and following the publication of Livestock’s Long Shadow the challenge for those involved in agriculture was focused around combatting calls for reducing red meat and milk consumption. This report was therefore a major tipping point for livestock production and put the sector at the top of the list when it came to greenhouse gas emissions. Since then the debate has become more balanced with a much greater understanding of the positive role animals can play but this is based on the responsible and sustainable farming methods which are practised in the UK. We mustn’t forget this and instead we should strive to make our production systems as environmentally friendly as possible within the bounds of profitable production systems.

5c. The challenge for UK agriculture: reducing its environmental footprint

Discussing the challenge of reducing the environmental (particularly carbon) footprint of UK agriculture it was suggested on more than one occasion that given its relatively small (~7%) contribution to national emissions there should be minimal focus on the sector compared with other ‘low hanging fruit’ such as energy production from non-renewable sources.

Personally I agree, but all the evidence I have seen from government (both at national and EU level) and consumer/media driven output suggests that such a view is not widely held.

> *"Changing the way land is used, recycling waste, and dedicating enough space to growing bioenergy crops it is possible to bring down atmospheric carbon dioxide to safe levels. Not doing this means losing natural ecosystems and facing increasingly dangerous levels of atmospheric carbon dioxide."* University of Exeter, 2012

5d. The Foresight Report: The Future of Food and Farming: challenges and choices for global sustainability

> *"The food system will be strongly affected by the direct effects of climate change, and also by the policies adopted to mitigate its effects. The latter include measures outside the food system that will affect the economies of food production and distribution, and actions taken within the food system to reduce its substantial greenhouse gas emissions"* The Future of Food and Farming: Challenges and choices for global sustainability, 2011

In March 2011 just as I began my Nuffield Scholarship I was introduced to the **Foresight Report: "The Future of Food and Farming: challenges and choices for global sustainability 2011"** at the Contemporary Scholars Conference. This UK Government-commissioned report provided a more balanced approach into the challenges and opportunities facing agricultural production. Interestingly the report highlighted the following:

- Policy makers need to recognise food as a unique class of commodity and adopt a broad view of food that goes beyond narrow perspectives of nutrition, economics and food security
- General priorities should include the development of new 'varieties' of livestock, capitalising on recent advances in biosciences whilst still preserving rare breeds and closely related wild relatives of domesticated species to maintain a genetic bank of variation that can be used in the selection of novel traits
- Advances in nutrition and related sciences could offer substantial prospects for improving efficiency and sustainability of animal production
- The revitalisation of extension services to increase the skills and knowledge base of food producers is critical to achieving sustainable increases in productivity in both low-income and high-income countries
- Scientific and technological advances in soil science and related fields could offer a better understanding of constraints to crop production and better management of

soils to preserve ecosystem functions, reduce pollutant run-off and cut greenhouse gas emissions
- Food security is best served by fair and fully functioning markets and not by policies to promote self-sufficiency. However, this does not mean relinquishing a country's responsibility to provide food for its population

Furthermore the report introduced the term 'sustainable intensification' into the debate which has since been widely used in the political debate on the future of UK food production.

> *Sustainable Intensification: "Producing more food from the same amount of land. Whereas in the past, simply increasing yield in terms of crops or the amount of meat produced in terms of livestock has been the be-all and end-all, we are now talking about the sustainable intensification agenda trying to optimise a far more complex set of objective functions, in particular, a marked increase in resource efficiency, so that means using less water, less nitrogen, less other inputs so that one is eating into natural capital to a lesser degree. Secondly, it means producing more but reducing the footprint of food production on the environment."* The Future of Food and Farming: Challenges and choices for global sustainability, 2011

Further recommendations applicable to UK agriculture were developed in the UK Regional Case Study "Options for sustainable increases in agricultural production" produced by Professor Chris Pollock from Aberystwyth University. These included:

- There is a need to maintain or improve the delivery of ecosystem services from land including the need to mitigate greenhouse gas emissions
- The continued application of technology will increase the potential productivity of UK farming and allow the UK to meet a large proportion of its domestic food requirements
- Producers must be able to operate in an economically viable industry where good practice is widespread and where there are rewards for producing food in a sustainable way
- Emphasis must be placed on closing the gap between the best and worst performing farms
- Food production should not be compromised at the expense of non-food and energy crops
- Increasing production should not ignore or undervalue environmental services
- Better availability of effective training and advice networks is required
- Public awareness should be sought for the 'basket of benefits' delivered by sustainable farming systems

Following on from the publication of the Foresight Report the UK Minister for Agriculture revealed that he had established the 'Green Food Project' bringing together industry, environmental and consumer organisations to drive forward the findings of the report. The aim of this project is to put 'theory into practice' by:

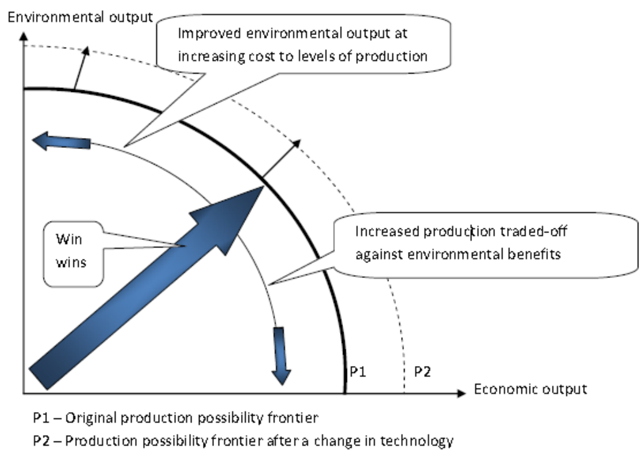
- Improving growth and competitiveness of UK food production
- Increasing domestic food production and addressing issues surrounding global food security
- Improving farming's environmental performance

In July of 2012 the project published its initial findings for UK agricultural production as well as more detailed recommendations for a number of specific sectors (excluding sheep production). The report considered the value of various actions in terms of both their productivity and environmental benefits. Ideally solutions would consist of 'win-win' scenarios which would generate both general improvements in production and the environment. It was however noted that in some cases a 'trade-off' approach would be required.

Other points raised by the report included;

- Short term versus long term approaches can be taken to production and environmental gains
- Opportunities could exist for adding value to produce through marketing based on 'environmental good'
- There is a need to recognise other service provisions such as animal welfare
- It is important to find means of calculating the trade-off between improvements in production and the environment and to identify appropriate means to measure progress
- Whilst there has been investment in 'blue-sky' agri-food research this has not been balanced with applied or near-market research

The diagram below is a representation of the trade-off between production and the environment highlighting the role that improved technology could play in affecting this relationship (Green Food Project Conclusions. DEFRA 2012)



5e. The challenge for UK sheep production: embracing change

I am reliably informed by many that there is a challenge in encouraging UK sheep producers to embrace change be that electronic identification, genetic improvement or using flock health plans and preventative medicine. Given my close involvement with the industry I find that whilst the statement is somewhat a generalisation there are still too many producers who seem unwilling to address inherent inefficiencies (both technical and business) in lamb production. I touch upon some of my views on how to encourage change within the conclusions section but unfortunately have yet to come up with a fool proof approach to approaching this very significant challenge!

Poor production methods can be seen in all production systems

Optimising performance from forage requires attention to detail and good levels of management

Increasing production levels will only improve profitability if wastage is avoided

5e. The challenge for UK sheep production: addressing the fragmented supply chain

I had hoped to identify only one key challenge for the UK sheep industry but felt I had to address supply chain issues.

One of the key challenges recognised when discussing increasing food production in-conjunction with reducing environmental footprint is the need to reduce wastage in the system. This generally applies to the wastage of inputs but in order to deliver the outcomes required from livestock production it is necessary to prevent wastage of inputs, financial losses and the 'wastage' of information. A fragmented supply chain as is currently in place for the UK Sheep Sector is responsible for a range of issues associated with wastage. For example:

- There is (in general) very little discussion between breeders and commercial producers. Are the correct animals being bred for efficient lamb production? Are breeding policies increasing lambing difficulty and therefore 'wasting' flock potential?

- Are the wrong types of movements of livestock increasing costs to the industry? Should more lambs be moved from hill/upland units for efficient finishing on lowland units as part of an arable rotation? Are animals moved long distances for slaughter? Do we need better access to smaller, local abattoirs? Could electronic auctions be reintroduced?
- What are the financial and production costs associated with the lack of feedback on lambs at slaughter? Are we breeding the right type of lambs for the consumer? Are we wasting inputs through producing over-fat lambs?
- Is the feedback that is received from lambs at slaughter fit for purpose? Can we replace the EUROP classification grid with an alternative that gives a better measure of lean meat yield? Can technology be used to provide more consistent feedback on health and disease issues?

Issues surrounding the supply chain deserve much more time than is available in this report but ultimately they must be considered alongside the challenge of reducing the carbon or environmental footprint of lamb production to ensure a truly sustainable system of lamb production.

> *Over the last 20 years New Zealand agriculture has benefited from greater co-operation, better use of resources, and a competitive industry structure that allows for a better response to market signals. This has led to productivity growth in the sector, improving from an average of 1.5% per annum in the pre-1984 period, to an average of 2.5% per annum in the post-1984* "Meat in Focus"

6. Setting the scene

In order to fully understand the opportunities afforded by a changing emphasis on land management and food production it is useful to consider how different countries are reacting to the challenge.

6a. The EU

In March 2007 the EU identified a series of targets for the reduction of GHG emissions and increased use of renewable energy by 2020. These are known as the "20-20-20" targets and comprise of:

- A reduction in GHG emissions of at least 20% below 1990 levels
- 20% of EU energy consumption to come from renewable sources
- A 20% reduction in primary energy use compared with projected levels achieved through improving energy efficiency

Furthermore, emissions reductions may be increased to 30% should other major emitting countries commit to further reductions in their emissions.

> *"There is now a widespread consensus that the development of resource efficient and green technologies will be a major driver of growth" Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage,* EU 2010

Agriculture, which is responsible for 9% of total EU GHG emissions, has already seen a 20% reduction between 1990 and 2006 as a result of:

- Declining livestock numbers
- More efficient application of fertilisers
- Better manure management

This is well above the average 11% reduction in emissions in all EU sectors.

Further measures to reduce emissions through EU policy are likely to be implemented through reform of the Common Agricultural Policy and agri-environmental schemes. National authorities are therefore encouraged to include measures to tackle GHG emissions when designing and implementing rural development programmes – climate change is a key priority in the EU's rural development policies.

6b. The Common Agricultural Policy

Significant reforms have been made to the Common Agricultural Policy (CAP), notably in 2003 and 2008. Further reform is on-going with an initial deadline of 2014 already moving back to a 2015 start date. This current reform 'The CAP towards 2020' is in response to emerging economic, social, environmental and climate related challenges facing society. CAP reform also aims to create a more equitable distribution of payments between the 27 EU member countries.

The EU CAP therefore aims to address;

- Food security
- Provision of public goods
- Management of natural resources
- High quality food production

6b(i). Objectives of CAP reform

Viable food production

- To contribute to farm income and limit its variability
- To improve sector competitiveness and share in food chain value-added
- To compensate areas with natural constraints

Sustainable management of natural resources and climate action

- To guarantee provision of public goods
- To foster growth through innovation
- To pursue climate change mitigation and adaptation

Balanced territorial development

- To support rural viability and employment
- To promote diversification
- To allow social and structural diversity in rural areas

In addition to the Basic Payment, each holding will receive a payment per hectare for respecting certain agricultural practices beneficial for the climate and the environment. Member States will use 30% of the national envelope in order to pay for this. It is suggested that this will a compulsory element of the scheme but with many amendments having been put forward by member states continuing discussions means that the final requirements have not been published. The original conditions, put forward in a consultation document consisted of three additional requirements that producers would have to meet along with the 'cross-compliance' measures already in place.

Ecological focus areas

According to the current proposals farmers have to assign 7% of their land as ecological focus areas. Such areas must then act as fallow land, landscape features, buffer strips or afforested areas.

Crop diversification

This would oblige farmers to grow at least three different crops with the largest covering no more than 70% of the farm area and the smallest no less than 5%.

Preservation of permanent grassland

This relates to grassland which has not been reseeded for at least five years and requires producers to convert no more than 5% of this area each year.

NB: Organic producers have no additional requirements as they are already considered to show clear ecological benefit

Cross compliance

All payments currently made through CAP are linked to a number of baseline requirements relating to animal welfare, animal health and the environment. These are known as Statutory Management Requirements and this requires producers to keep their land in 'Good Agricultural and Environmental Condition'. Specific areas covered include soil erosion, overgrazing, protection of hedgerows and watercourses, preservation of trees and prevention of pollution and run-off. The award of all payments from the Direct Payment national envelope will continue to be linked an updated list baseline requirements.

The CAP also relates to wider 'Rural Development' and the next round of funding will contain the following priorities;

- Fostering knowledge transfer and innovation
- Enhancing competitiveness
- Promoting food chain organisation & risk management
- Restoring, preserving & enhancing ecosystems
- Promoting resource efficiency & transition to low carbon economy
- Promoting social inclusion, poverty reduction and economic development in rural areas

Of particular interest to the requirement to address GHG emissions and climate change are some of the details provided in regards to the Rural Development projects with member states still required to maintain 25% of their Rural Development funding on issues related to land management and the fight against climate change.

Some key points from the simplified menu for Rural Development projects:

Innovation: This key theme will be served by different Rural Development measures such as knowledge transfer and cooperation. It is aimed at promoting resource efficiency, productivity, low emission, climate-friendly and resilient development of agriculture, forestry and rural areas. The aim is to achieve this through greater cooperation between agriculture and research in order to accelerate technological transfer to agricultural practice.

Knowledge: The aim is to strengthen measures for Farm Advisory Services linked to climate change mitigation and adaptation, to environmental challenges and to economic development and training.

6c. The UK

The UK Government response to climate change was set out in the Climate Change Act of 2009. The act includes a legally binding target for the UK to reduce its GHG emissions by at least 80% below 1990 levels by the year 2050. Specific reduction targets have been set and for agriculture this has been summarised in the Defra document 'Defra's Climate Change Plan 2010'. Between 2010 and 2020 UK agriculture currently has a target reduction of 11%. In planning to achieve the Government's target of an 11% reduction on current GHG emission levels, CO_2 equivalent emissions per kilogram of meat are taken as the key parameter in measuring real gains in the efficiency of livestock production rather than merely reductions in stock numbers. The latter would simply transfer production, and therefore emissions, elsewhere in the world. **Sector emissions are however regularly updated and the industry has already seen a reduction in emissions from 1990 levels with a 23% reduction in nitrous oxide emissions and 18% reduction in methane emissions.**

> *"Agriculture and the land use sector is already responsible for roughly a third of the world's emissions, and global emissions must be reduced by at least half by 2050 if we are able to have even a 50% chance of keeping temperature rise to 2^{o}C"* Defra Climate Change Plan 2010

As well as the setting of targets Defra has also taken the following actions:

- The investment of £12.6m in improving the science and measurement of on-farm emissions (Agriculture GHG Inventory)
- The launching a pilot scheme to offer integrated advice to farmers on land management and reducing emissions
- The introduction of 15 new or revised options under Environmental Stewardship that can help farmers adapt to climate change
- Lobbying for the protection of the rural environment to have a central role in the future Common Agricultural Policy due to be introduced in 2015

Furthermore Defra has stated that it is supporting "win-win" actions including better fertiliser management and improved efficiency of livestock production including improved animal health. It is suggested that these changes will be achieved through the 'Industry Greenhouse Gas Action Plan' and improved advice on low-carbon farming.

6d. Ireland

Greenhouse gas emissions from agriculture are responsible for 29.1% of total national emissions *(Teagasc, 2011*). A Climate Change Response Bill has set a 20% target for reduction in emissions from all sectors.

Overview of Irish emission targets compared with EU *targets (Irish Farmers Association, 2011*)

Year	Ireland (Climate Change Bill)	EU
2020	28%	20%
2030	40%	No target set
2050	80%	No target set

The Irish Farmers Association, which is an industry organisation representing the interests of Irish producer,s is opposed to the targets set out for the following reasons:

- Measures proposed will decimate the national herd, with Teagasc research showing that a 30% reduction in carbon output will reduce the cattle population by almost 40%. It is estimated that each 1% cut in emissions from the beef herd will cost €30million
- Measures proposed will increase international greenhouse gas emissions as sustainable milk and beef production in Ireland will be replaced by less carbon efficient food produced on deforested Amazonian land in South America

There are currently no formal plans for reducing emissions from agriculture apart from the uptake by primary producers of knowledge generated through research. With this in mind Teagasc, the National government funded provider of agricultural research, is tasked with generating research focused on reducing greenhouse gas emissions from agriculture.

As part of a collaborative programme Teagasc is therefore conducting research on a range of mitigation options aimed at reducing the carbon footprint of Irish produce including:

- Improving the genetic merit of cows
- Extending the grazing season
- Reducing beef finishing times
- Restructuring of the national herd
- Improvement of Nitrogen efficiency
- Increased use of clover
- Dietary modification
- Use of nitrification inhibitors
- Minimum tillage techniques

"Achieving the apparently contradictory and intertwined objectives of combating climate change and achieving food security is

> *accepted to be one of the most important policy challenges for the world at the start of the 21st century"* Teagasc, Ireland

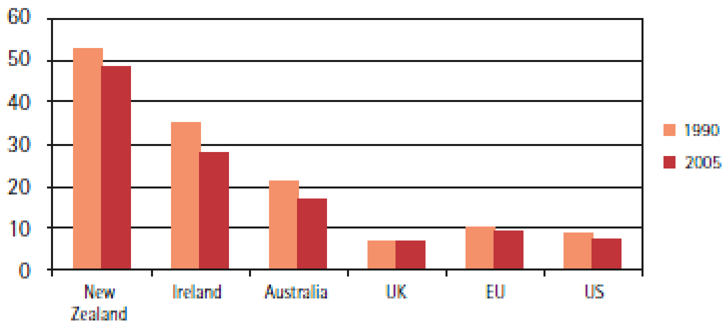
Ireland has also seen a reduction in agricultural GHG emissions. Data generated by Teagasc has shown the following reductions in emissions between 1990 and 2006:

- 12.4% reduction in methane emissions per kg of milk produced
- 4.1% reduction in nitrogen fertiliser use
- 6.8% reduction in overall emissions
- 3.1% reduction in cattle numbers
- 4.7% reduction in sheep numbers

6d(i) Food Harvest 2020

Food Harvest 2020 - 'A vision for Irish agri-food and fisheries' - is a Department of Agriculture, Food and Marine-commissioned report. Published in 2010 the report has proposed ambitious targets for increases in milk and red meat production. A 50% increase in milk production by 2020 has been established for milk production and a 20% increase in the value of both beef and lamb meat has been set. This will lead to challenges for the reduction of emissions with a predicted increase in GHG emissions of 3% compared with 2009 levels. Capitalising on opportunities such as the 'green' image of Irish produce is one of the three pillars set out for agriculture in the Food Harvest 2020 report. Teagasc is also working on indicators of the sustainability of Irish products which will include GHG emissions.

Diagram below: Irish agricultural GHG emissions as a proportion of total national emissions (Teagasc, 2008*)*



6e. New Zealand

Before visiting NZ I had assumed that, given the importance of agriculture to the economy, there would be little pressure on the industry to reduce its greenhouse gas emissions. However, agriculture is responsible for 48% of the country's emissions and it was evident tha, in order to meet obligations under the Kyoto Protocol, NZ was having to tackle the issue. NZ is therefore facing a challenge when it comes to agricultural emissions with a far larger than normal proportion of NZ emissions derived from methane and nitrous oxide from agriculture. Legislation directly affecting agriculture was therefore being introduced in the form of the Emissions Trading Scheme (ETS).

6e(i). The Emissions Trading Scheme

The Government's main policy tool to reduce emissions is an Emissions Trading Scheme that puts a price on GHG emissions. The ETS came into effect in NZ in July 2010. New Zealanders, including farmers, are now paying the ETS on fuel and energy and work carried out by Beef + Lamb NZ has estimated that on an average sheep and beef farm with 4,000 stock units the ETS has added an additional cost of $1,475 a year to their operating costs. Currently the legislation is due to directly include agriculture from 2015. This is on a transitional basis with sheep and beef producers facing a charge for all on-farm emissions from 2016.

Initially there will be a 90% free allocation of credits which means that farmers will be liable for 10% of their livestock emissions (energy and fertiliser will be paid separately). The free allocation of credits will reduce by 1.3% year on year from 2016 onwards. At the moment carbon liabilities will be dealt with at the processor level. Changes in the carbon price will have a direct impact on final costs of any scheme. Since the market price for carbon is very uncertain the final cost will continuously vary like other commodity prices.

The ETS is a highly controversial policy amongst NZ farmers. Under the current ETS proposals farmers are not rewarded for reducing on-farm emissions. The point of obligation is at the point of slaughter and emissions are assessed purely on a per-head or on a per kg carcass weight basis. This approach does not take into account on-farm animal performance or any other mitigation measures that could reduce emissions from livestock production. Furthermore should technology be introduced which leads to reductions in overall emissions production this cannot be rewarded under the current legislation. Industry organisations therefore argue that biological agricultural emissions should not be added to the legislation until affordable mitigation technologies exist which can be financially rewarded through the ETS.

During meetings with the NZ Ministry of Agriculture (now known as the Ministry for Primary Industries) these concerns were however recognised and considerable effort and funding was being put in place to recognise on-farm efficiency improvements. It was suggested that farm-specific carbon measurements could be put in place with a much more sensitive estimation of emissions. This would however introduce considerable levels of bureaucracy and data management and from an EU perspective I was reminded of the challenges facing both farmers and government in implementing and policing current legislation. Furthermore any methodology for the estimation of GHG liabilities would need to be internationally recognised in order to qualify for the reductions required through the Kyoto Protocol.

The results of a Farm Confidence Survey which was carried out by Federated Farmers in July 2011 showed that the Emissions Trading Scheme and concern over climate change policy was the single biggest concern for NZ farmers. Furthermore farmers highlighted the same issue as the second most important issue for Government to address.

See chart on next page

Federated Farmers annual survey of NZ producer concerns (July 2011)

Single biggest concern			Highest priority for Government		
Rank	Issue	%	Rank	Issue	%
1	Climate change policy & ETS	14.5	1	Reduce government spending	16.5
2	Input costs	12.8	2	Climate change policy & ETS	12.1
3	Compliance costs & regulation	12.0	3	Reduce government debt	9.
4	Exchange rate	11.5	4	Support agriculture & exporters	9.2
5	Debt, interest rates & banks	8.2	5	Reduce compliance & regulation	8.8
6	Farmgate & commodity prices	7.8	6	Economy & business (general)	8.7
7	Weather	6.6	7	Monetary policy	6.2
8	Public perceptions of farming	4.7	8	Earthquake recovery	5.4
9	Local government & rates	4.4	9	Industry-specific issues	3.4
10	Industry-specific issues	4.0	10	Trade liberalisation	3.3

Summaries of the response from Beef + Lamb, Dairy NZ and Federated Farmers are quoted below and after listening to the arguments put forward I agree that the policy will put unfair pressure on NZ producers.

Beef + Lamb response

"A more sophisticated design is required to drive abatement of agricultural emissions. Any alternatives must include assessment of individual farmer behaviours and could include targeted incentives for the development or trialling of new abatement technologies. In order to incentivise abatement of emissions in agriculture, as opposed to simply abating agriculture, an ETS must:

- Assess individual farm business's emissions performance
- Recognise the mitigation effect of all scientifically proven mitigation technologies"

Dairy NZ response

"In a situation where the dairy sector is liable for its emissions, DairyNZ strongly supports an on-farm point of obligation for those emissions. An on-farm point of obligation will ensure that all farmers have an incentive to put in place the appropriate proven mitigation measures, as they will see the benefits from that measure. Dairy NZ consider that a processor-level point of obligation for farm-level emissions has the effect of converting the ETS to a uniform tax on farmers, who will not see any individual rewards for adoption of mitigation tools and thus will not be exposed to a key driver for behaviour change"

Federated Farmers response

"Given the imbalance in applying a carbon price on NZ food producers while competitors avoid any similar cost and cost-effective mitigation options remain largely non-existent, there must be conditions on the entry of biological agricultural emissions into the ETS. Federated Farmers would consider it reasonable for future reviews to consider whether;

- Competitors in other countries face similar emissions costs
- Economically sustainable mitigation technologies are available for widespread uptake
- International rules allow NZ to recognise the uptake of such technologies

Furthermore, climate change policies should be based on good science, be practical and cost-effective, and allow NZ farming to remain economically viable and internationally competitive"

Despite issues surrounding the impact of the introduction of the ETS on NZ agricultural production the government has taken a very supportive stance when it comes to research into reducing GHG emissions.

6e(ii) The Pastoral Greenhouse Gas Research Consortium

Established in 2002 the goal of the Pastoral Greenhouse Gas Research Consortium (PGGRC) is to decrease New Zealand's total agricultural emissions of GHGs by 10% per unit of output in 2013 relative to 2004. The priorities of the consortium include:

- Establish New Zealand as a global leader in agricultural GHG mitigation
- Identify and develop economic on-farm technologies to improve production efficiency and reduce GHG emissions
- Encourage, by 2013, 33% of NZ farmers to implement at least one greenhouse gas mitigation technology
- Increase the agricultural sectors (farmers and support industries) knowledge of climate change and target reductions in emissions
- Ensure national coordination of all GHG-related investments and develop further international collaboration and involvement to increase global capability
- Exploit commercial opportunities arising from the science and technologies in a global market
- Contribute to preparing NZ Agriculture to be competitive in a carbon constrained global economy beyond 2012 and adapting to the effects of climate change

The PGGRC has therefore developed a research programme with six objectives consisting of:

- Rumen microbial ecology and rumen microbial strategies to reduce methane emission
- Methanogen genomics

- Methanogen vaccines
- Exploiting animal to animal variation
- Low GHG emitting farm systems
- Nitrous oxide mitigation

Since 2002, $37 million of funding has been invested into the Pastoral Greenhouse Gas Research Consortium from a range of organisations including B+L NZ.

6e(iii). The New Zealand Agricultural Greenhouse Gas Research Centre

The New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) was founded by the NZ Government and opened on the 3rd March 2010. The NZAGRC is a partnership between research providers working in the area of agricultural greenhouse gas reduction and the Pastoral Greenhouse Gas Research Consortium. It is a "virtual" centre and the research that it funds is carried out by researchers working in their own organisations. The Research Centre is 100% government funded and it is expected that about $48.5 million will be invested in the Centre by the over a ten year period. The aim of the centre is to help NZ meet its international obligations to reduce GHG emissions without reducing agricultural output. As well as the research being carried out through the centre it is worth highlighting that emergence of the Global Research Alliance on Agricultural Greenhouse Gases (GRA) as a collaborative global research initiative. The GRA is an international initiative to increase collaboration and develop solutions for reducing GHG emissions without compromising food production. It has 32 member countries (including the UK) and the NZ government has set aside an additional $45 million to support the alliance.

> *"Our role is to find ways for New Zealand to meet its international greenhouse gas emission obligations without reducing agricultural output*" NZAGRC, New Zealand

6f. Australia

Australia is well versed in the impact of climate variability having recently emerged from a long period of drought. This provides an additional perspective on the debate to reduce national greenhouse gas emissions and was the focus of much media discussion during my time there. Through its commitments under the Kyoto Protocol Australia has set a target to reduce emissions by between 5 and 25% by 2020. If no action is taken it is expected that GHG emissions will be 20% higher compared with 2000 levels. The reductions required are equivalent to a reduction of nearly half of every Australian's carbon footprint.

> *"Tackling greenhouse gas emissions is considered to be one of the most serious national and international challenges of our time"* CSIRO, Australia

With agriculture contributing nearly 20% of national GHG emissions the planned 80% reduction in total emissions by 2050 will affect the sector. The government does however recognise the value of agriculture to the economy with the livestock sector alone worth about

$18 billion per year with $15 billion generated from exports. Considerable funding is therefore being made available including the following:

- Research into emerging technologies and innovative management practices: $201 million
- On-farm projects with application of research: $99 million
- Extension and knowledge transfer: $64 million
- Development of methodologies for offsetting emissions: $20 million

Other funding elements include;

- Carbon Farming Initiative non-Kyoto Carbon fund: $250 million
- Biodiversity Fund: $946 million
- Indigenous Carbon Farming Fund: $22 million
- Regional Resource Management Planning for Climate Change: $44 million
- Carbon Farming Skills Programme: $4.2 million
- Land Sector Carbon and Biodiversity Advisory Board: $4.4 million

6f(i) The Carbon Farming Initiative

The Carbon Farming Initiative (CFI) is a voluntary government carbon offset scheme and has been proposed as a mechanism that will enable farmers to generate revenue from the sale of GHG mitigation and sequestration activity. In order to qualify farmers will need to adopt accredited methodologies and will be subject to audits and verification including the submission of regular returns. If these returns confirm that scheme requirements have been met then CFI credits will be awarded based on the equivalent amount of carbon dioxide emission reduction achieved. Ownership of these rights will be recognised and credits tradable. Participation is voluntary and demand for CFI credits will initially consist of companies or individuals who wish to take voluntary action.

In order to be recognised under the scheme the following criteria must be met:

- Additional: an action must be taken which would not take place in the absence of the scheme
- Permanence: an action must be able to demonstrate a benefit over a 100 year period
- Leakage: no additional emissions must be produced elsewhere
- Measurable and verifiable: systems must be in place to accurately measure or estimate changes and must be verified by an independent third party
- Internationally consistent: estimation systems must be consistent with international estimation standards
- Peer-reviewed science: supporting evidence must be peer-reviewed science and subsequently published in a relevant journal

The CFI officially commenced on the 8th of December 2011 and since April 2012 land managers have been able to apply to undertake projects. At the present time there are only four options available consisting of:

- Capture and combustion of landfill gas

- Destruction of methane generated from manure in piggeries
- Environmental plantings (establishment and management of permanent native forests)
- Savanna burning

Additional options are in the process of being approved and these include:

- Native forage from managed regrowth
- Reduction of emissions of methane through the application of a feed supplement to dairy cows
- Destruction of methane generated from dairy manure in covered anaerobic ponds
- Reforestation and afforestation
- Management of large feral herbivores (camels) in the Australian rangelands

7. Some examples

During my travels to Ireland, New Zealand and Australia I was interested in looking at examples of both initiatives to improve agricultural production and how knowledge transfer was put into action.

7a. Examples from Ireland

Sheep Ireland

Following a review carried out by a range of industry experts in 2008, Sheep Ireland was set up in 2009 with the aim of facilitating and promoting genetic improvement in the national flock. Funding has been provided by the Irish Department of Agriculture (DAF) consisting of €2.64 million over 4 years.

Following a plan based on twenty strategic priorities Sheep Ireland has:

- Established breeding objectives and selection criteria for the Irish National Flock
- Established the LambPlus® performance recording scheme for ram breeders
- Formed a maternal lamb producers (MALP) program
- Formed a central progeny test
- Created a Sheep Ireland database

> *"The aim of Sheep Ireland is to achieve the greatest possible improvement, from genetic and other factors, in the profitability of the national sheep flock for the benefit of Irish farmers and the sheep industry"* Sheep Ireland

LambPlus®

2011 saw over 200 breeders participating in the scheme with approximately 8,000 pedigree recorded ram lambs born in LambPlus. Educating ram purchasers is seen as an important part of increasing uptake of genetic improvement. Indexes are presented in the form of the €uro-Star breeding index and reflects how much profit a farmer can expect to realise from purchasing the ram. In order to accommodate varying producer requirements the following four indexes have been developed;

- Production Index – measure of genetic merit for terminal traits
- Maternal Index – measure of genetic merit for maternal traits
- Lambing Index – measure of genetic merit for lambing traits
- Overall Sheep Value – the overall sheep value of an animal combining sub-indices together

Overview of Sheep Ireland breeding indexes and traits recorded

	Production Index	Maternal Index	Lambing Index
Contributing traits	Birth weight	Ease of lambing	Ease of lambing
	40 day weight	Weaning weight	Lamb survival
	Weaning weight	Lamb survival	
	Days to slaughter		
	Ultrasound Muscle and backfat scanning	Ultrasound muscle and backfat scanning	

Central Progeny Test

The Central Progeny Test (CPT) was developed as a ram and trait comparison rather than a breed comparison and is focused upon identifying the best genetics regardless of breed. The intention is to evaluate as many rams as possible whilst maintaining linkages through breed pedigree. The CPT is carried out in four flocks throughout Ireland and in 2011/2012 involved 32 rams from six different breeds and 2,745 progeny born and recorded through the programme.

Maternal Lamb Producers (MALP)

MALP flocks were originally designed to demonstrate that genetic improvement through ram improved ram selection can increase flock profitability. In 2010 6,939 ewes were recorded in 24 flocks with 9,400 lambs EID tagged, DNA sampled and weighed on two occasions. Discussions are now however on-going with a future emphasis likely to be on further improving genetic linkages and acting as test flocks for commercial services.

Teagasc Demonstration flock at Athenry

The Teagasc demonstration flock at Athenry on the West Coast of Ireland was set up in 2011 to develop ‘Profitable and sustainable pasture-based systems of sheep production’. Key areas being looked at are stocking rate, prolificacy, grass supply and demand and lamb performance at pasture. Six self-sufficient farmlets have been set up with three different stocking rates and two levels of prolificacy with the following parameters:

Stocking rate

- Low (10 ewes/Ha)
- Medium (12 ewes/Ha)
- High (14 ewes/Ha)

Prolificacy

- Medium (1.5 lambs weaned/ewe)
- High (1.8 lambs weaned/ewe)

Each of the six groups contains 60 ewes to give a total of 360 ewes. A full range of measurements is being taken including dry matter utilisation, daily herbage allowance, daily intake and pasture quality. Lamb growth rates are recorded, health issues recorded and records kept of lamb sales. This three year study began in the autumn of 2011 and the aim is to transfer knowledge gained through this work to commercial producers throughout Ireland.

7b. Examples from New Zealand

I was impressed with both the Research and Development and Knowledge Transfer capabilities Beef + Lamb NZ (Red meat levy board). Working with other service providers such as private consultancy companies, research institutes and universities meant that producers where able to access a range of services, resources advice and events all delivered using a cohesive approach afforded by a single levy board.

Farmer-initiated technology and transfer programme (FITT)

The aim of this farmer initiated programme delivered through Beef + Lamb NZ is to help farmers help themselves. Financial assistance is made available to investigate issues and opportunities applicable to the local farming system. Grants up to $10,000 are made available for one year and allow farming groups to access technical help and cover some of the costs associated with analysis and learning. Completed reports are made available and topics covered have included:

- Grazing management to reduce bearings (prolapse)
- Accurate on-farm assessments of mortality
- Closed flock breeding with the Inverdale Gene
- Optimum ewe mating weight and condition score
- Establishing fodder crops on steep hill country

Any sheep or beef farmer is eligible to apply and simply requires at least three farmers in the group.

Farm^{IQ}

Farm^{IQ} is an ambitious initiative consisting of four partners: Silver Fern Farms, Landcorp, Tru-Test and MAF (plus others in the future). Established in 2010 it is a 7 year programme with six distinct areas: farm productivity, genetics, database, processing, marketing and governance. Electronic identification is an important component of Farm^{IQ} and linked to processing technology aims to provide direct feedback through the supply chain and back to the producer.

Funded by the Primary Growth Partnership R&D programme the project has a total budget of $151 million with 61% derived from industry investment and 39% from MAF.

> *The Vision: "To create a demand driven integrated value chain for red meat that delivers sustainable benefits to all producers"* Farm[IQ]

Farm[IQ] is unique in its development of a database which forms the basis of the project. Data collected on-farm which can accommodate individual records will allow traceability through the supply chain with the management of an individual animal being directly compared against carcass traits including both overall yield and also meat quality traits such as tenderness.

> *"Farm[IQ]'s aspirational goal is to grow the red meat sector's contribution to NZ GDP by $8.8 billion by 2025. This will be achieved by the concurrent development of six separate projects, which work together to more closely connect the farmer and the customer – ultimately adding value across the chain" FarmIQ, 2011*

Ultimately the implementation of Farm[IQ] aims to drive improvements to both producers and consumers. From the perspective of the consumer it's all about improving the experience of eating lamb and also providing assurance as to the safety and sustainability of the product. For producers, benefits could be seen through individual animal records allowing identification of the best (and worst) performing animals. Being able to compare performance of different groups of animals on the same farm would also be expected to help evaluate varying management practices whilst feedback on carcass quality could ultimately facilitate increased returns for animals meeting consumer requirements.

7c. Examples from Australia

Precision Pays

The Sheep CRC has identified the benefits of moving towards greater 'precision and optimisation' of the breeding, management and marketing of sheep. At the heart of this is moving from flock management to managing individual animals or selected groups of animals. The first step in this process is intensive measurement followed by making the most of the data collected. Given that many farms operate very low stocking rates over large areas of land some unique approaches to the collection of individual records is being taken. Walk-over weighing sets weigh scales and EID readers in remote locations often at water points. As animals pass through the weighing system a weight record is automatically recorded and transferred back to the farmstead. If animals are losing weight action can be taken immediately. Such technology also has other applications. With repeated records of which lambs pass through the EID reader with each ewe it is possible to assign lambs to dam therefore allow pedigree recording on large numbers of ewes which lamb with little supervision.

Other examples of how precision sheep management can increase profits included:

- Auto-drafting of ewe pre-shearing meant that based on historical records wool can be baled according to specific target markets
- Variation in carcass yields of 41-50% can be linked back to breeding rams and form the basis of management decisions
- When feed becomes a limiting factor the poorest performing animals can be selected for culling therefore keeping the capital value of the flock in the form of high producing ewes

The Information Nucleus

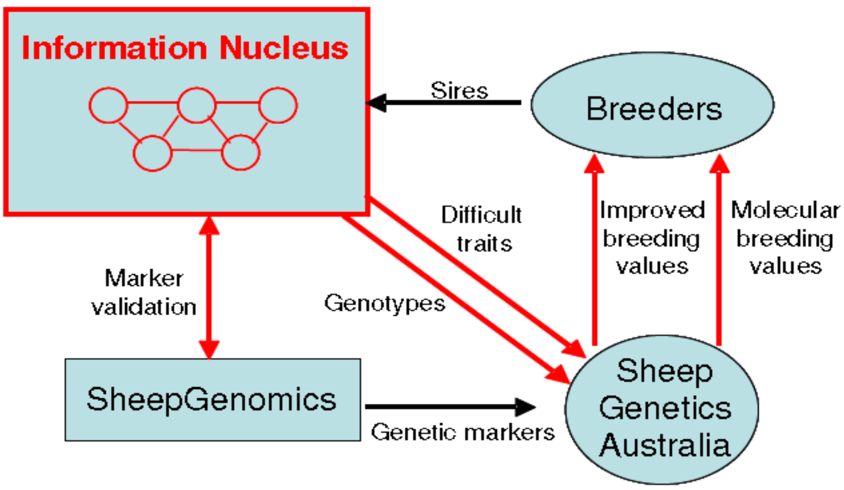
The Information Nucleus is a unique genetic resource set in place with industry funding. The aim of the programme which began in 2007 and set to last until 2014 is to allow pedigree and commercial producers throughout Australia to exploit breeding values for new traits and to underpin the development of genomic technology in the sheep sector. The Information Nucleus also acts as a base for research activities particularly for novel traits which are difficult to measure on-farm.

> *"Investment in the program will help us achieve industry's focus on developing genetic tools that maintain current rates of genetic gain and merit for eating quality, while increasing lean meat yield by 2% by 2015,"* Meat and Livestock Australia

The initiative has involved five flocks located throughout Australia. Each flock contains 1,000 ewes which are mated using artificial insemination to selected industry rams that have been performance recorded. All animals are intensively recorded to provide a comprehensive set of measurements which can be traced back to genetic information. This allows:

- Accurate estimation of genetic parameters for a range of economically important traits including meat quality traits
- Provision of a phenotypic resource suitable for whole genome association studies

*See below: diagrammatic representation of the flow of information in the Information Nucleus (*Meat and Livestock Australia*)*



8. The science

8a. Greenhouse gas emissions

'Greenhouse gas' is a generic term used to describe six different gasses: carbon dioxide, nitrous oxide, methane, perflurocarbons, hydroflurocarbons and sulphur hexafluoride. The three GHGs most relevant to agriculture are carbon dioxide, nitrous oxide and methane.

Each gas has a different impact on global warming, termed global warming potential. These differences are in part due to the gases persisting in the atmosphere for different periods of time. In order to produce a common method for comparing the overall contribution of different gases to global warming they are compared over a 100 year period. The global warming potential of different gases are currently being reviewed as is the 100 year period however this is currently still the most widely adopted terminology.

Greenhouse gas	Chemical formula	Global warming potential	Lifetime in the atmosphere (years)
Carbon dioxide	CO_2	1	50 - 200
Nitrous Oxide	N_2O	298	114
Methane	CH_4	25	12

Some greenhouse gas emissions occur naturally whereas others are generated by human activities and these are known as anthropogenic sources of GHG emissions.

Carbon dioxide

Natural sources: volcanoes, forest fires and respiration from plants and animals

Anthropogenic sources: burning fossil fuels, wood fuels, forest clearance and several industrial processes

Nitrous oxide

Natural sources: microbial action in soils

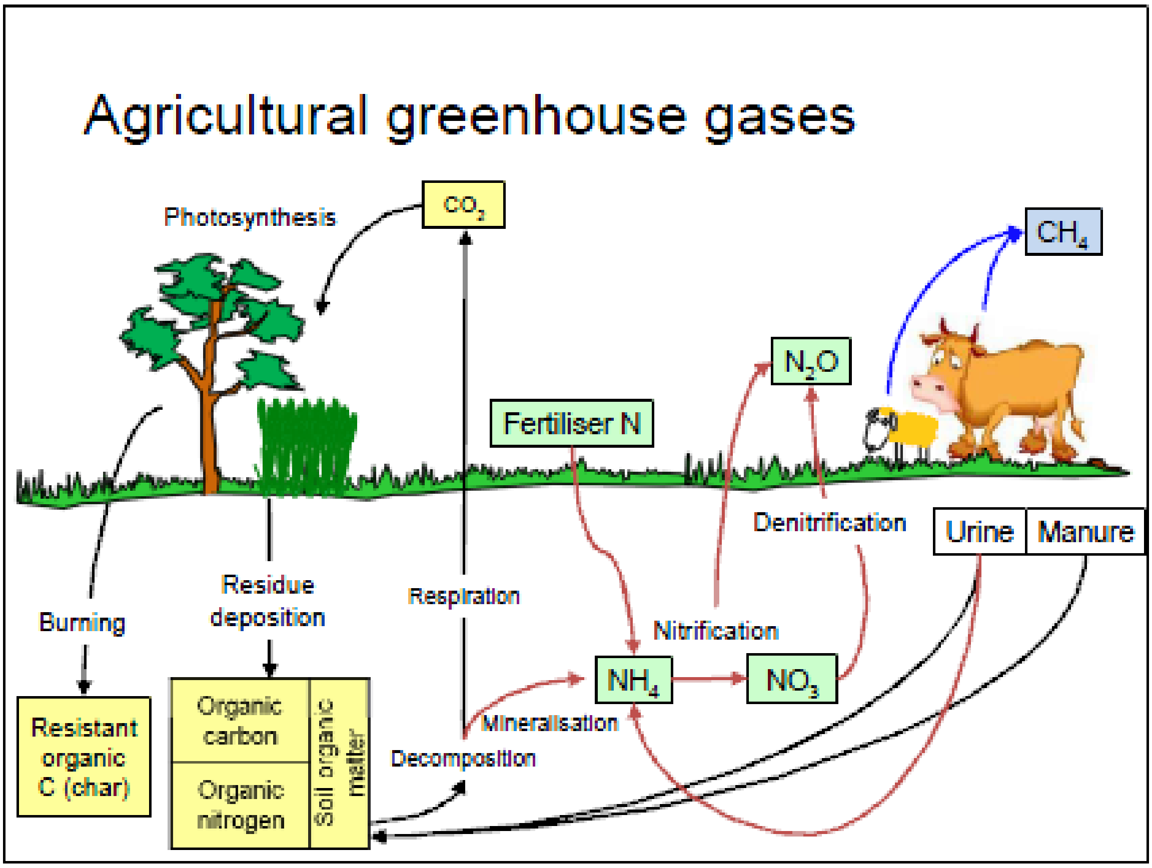
Anthropogenic sources: application of nitrogenous fertilisers and the Haber-Bosch process, soil disturbance, manure management

Methane

Natural sources: wetlands, termites, wild fires

Anthropogenic sources: farmed ruminants, decaying organic matter in landfill, rice production in paddy fields, coal mining

Below : illustration of greenhouse gas emissions from agricultural practices (Jeff Baldock, CSIRO. The Carbon Debate: Climate Adaptation*)*



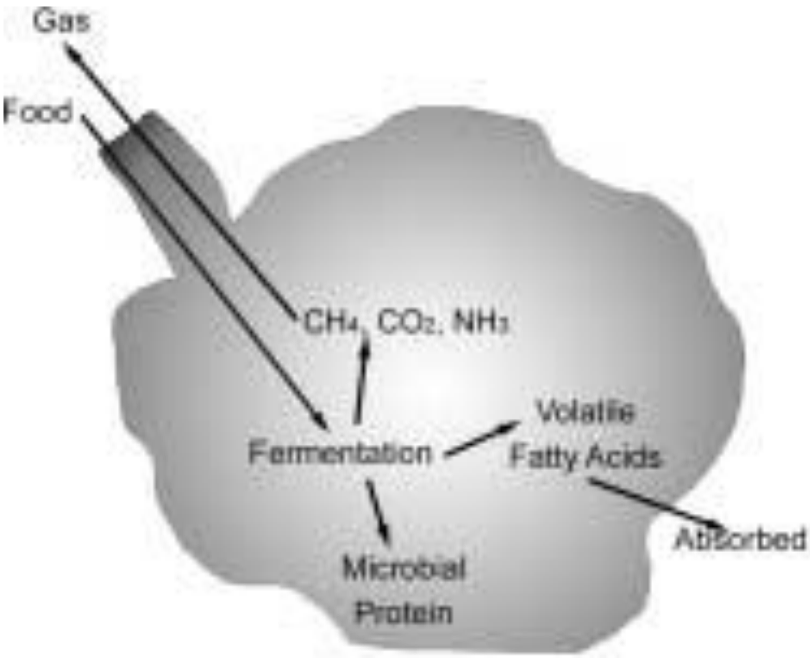
8b. Methane: - the problem gas for lamb production

Throughout the report so far I have discussed the need to reduce overall GHG emissions from livestock and the wider issues surrounding the need to reduce the overall environmental footprint of red meat production. For ruminants however the challenge is to reduce levels of nitrous oxide and methane emissions. For sheep production, reducing methane emissions is the main challenge since the majority of its production (about 90%) is driven by the process of turning relatively poor quality forage, unsuitable for human consumption, into meat. A small proportion of methane is also produced through manure management; however the small scale of its production under predominantly outdoor-based systems means that this source is of minimal concern in the challenge to reduce overall emissions.

The majority of methane results from the natural fermentation processes that take place mostly in the rumen. This is known as enteric fermentation and the methane produced is known as enteric methane emissions.

Ruminants cannot digest the cellulose in plants; instead they rely on a diverse and symbiotic microbial community contained within the rumen. Up to 75% of a ruminant's energy supply comes from the products of microbial metabolism of dietary carbohydrate. Following rumen digestion a small proportion of dietary energy and protein is passed directly into the abomasum. Short-chain volatile fatty acids (VFAs) are also produced as part of the digestive process and are absorbed through the rumen wall into the animal's bloodstream.

*Diagram to show Rumen fermentation (*Jardine, Boardman, Osman, Vowles and Palmer. University of Oxford*)*



The rumen microbial community is therefore a complex ecosystem and over a long period of evolution has led to a mechanism for the disposal of excess hydrogen through the conversion of carbon dioxide into methane. This is exhaled by the animal. In fact the majority of methane produced by ruminants is 'burped' from the mouth and nostrils. The majority of methane emissions therefore result from rumen processes although the large intestine is also responsible for a small proportion of overall emissions.

Methane emitted from livestock can also be viewed as a waste product, representing a loss of 2-12% of dietary energy available to the animal. As such, the production of methane both directly from enteric fermentation and from the decomposition of organic animal waste, is a reflection of the inefficiency of the digestive process.

On the next page see diagrams to give a global overview of methane emissions plus atmospheric concentrations of methane over the last 1,000 years.

Diagram to show overview of global sources of methane emissions (National Aeronautics and Space Administration, 1997)

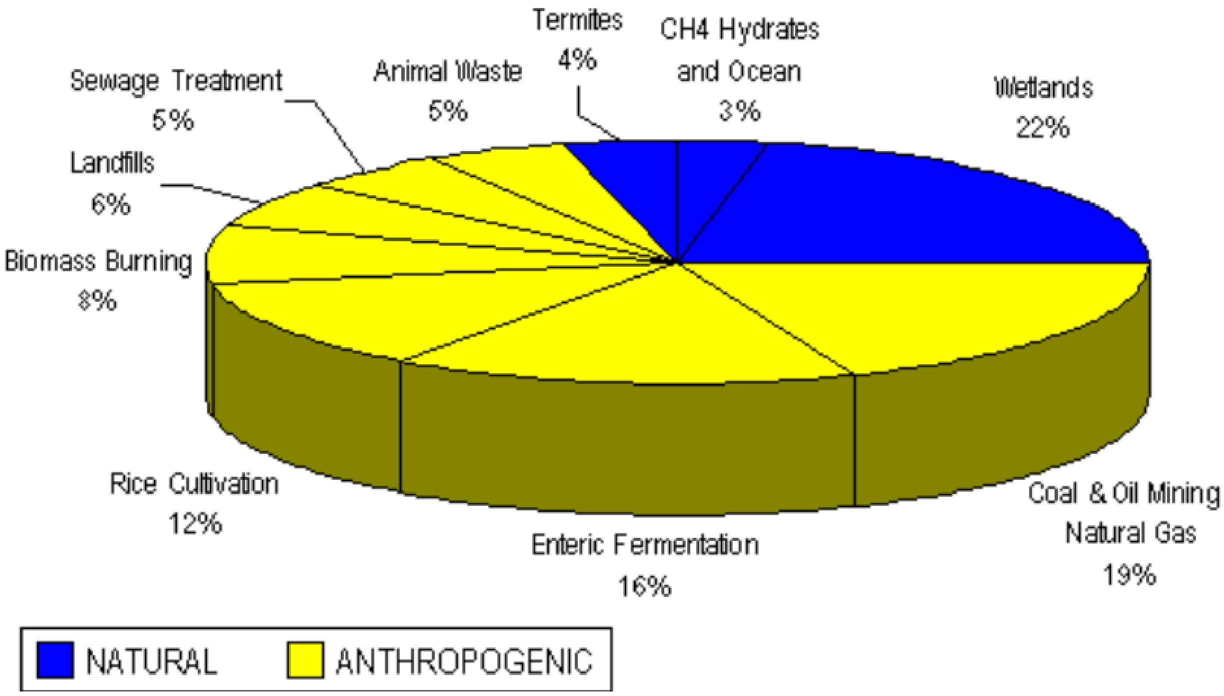
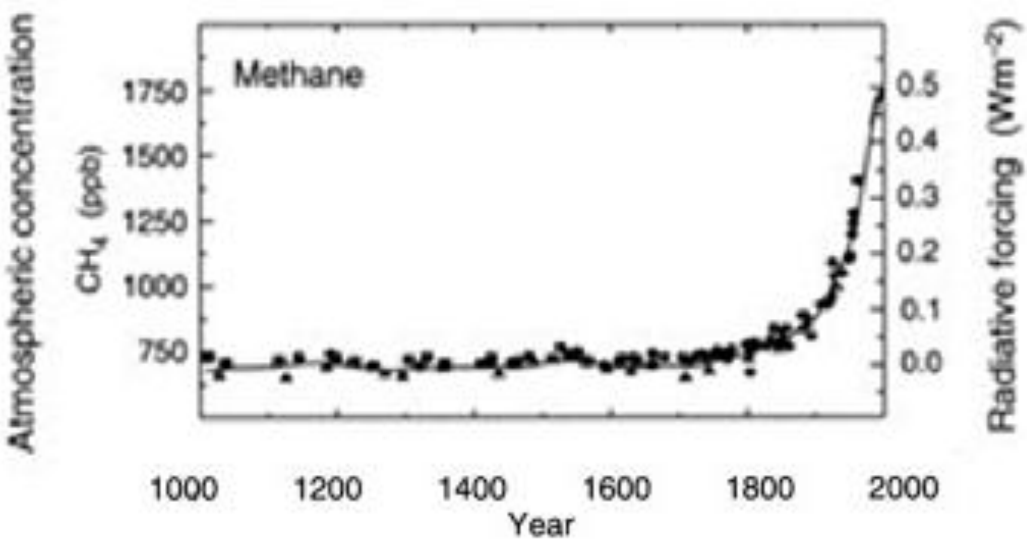


*Diagram to show atmospheric concentrations of methane over the last 1,000 years (*IPCC, 2007*)*



8b(i) Some facts about methane

- Methane was first identified in the late-18th century by an Italian physicist as being the flammable gas rising from waterlogged marshes

- Livestock account for up to 35-40% of world methane production

- Termites are the second largest source of global natural methane emissions; they produce the gas as part of their normal digestive process

- Rice production is responsible for similar levels of methane emissions as livestock production

- Reductions in methane emissions can lead to relatively rapid changes in atmospheric concentrations; a half-life of seven years means that if no further methane was produced the amount of methane in the atmosphere would halve over this period

- Approximately **$^2/_3$** of total GHG emissions from sheep farming result from methane production

- It is not the individual animal which is responsible for the production of the gas. Rather, it is the natural present rumen micro-organisms which produce the gas as a by-product of the breakdown of feed

- Around 80% of methane emitted from livestock comes from fermentation of feed in the digestive tract and around 20% from anaerobic digestion in liquid manure. From sheep systems the majority of methane is derived from fermentation

- The UK national flock is responsible for 17% of all UK methane emissions

- Methane represents a loss of energy from the animal's diet and reducing the amount of the gas emitted can result in productivity improvements

- Methane production in the rumen decreases when the proportion of concentrate in the ration increases

- Considerable variation exists between methane emissions from an adult sheep but typical values are in the region of 20-30g/day. In comparison a dairy cow averages methane emissions of 250g/day

- National GHG estimates, including methane, are subject to constant revision in the annual reporting cycles to take into account new guidance based on the outcome of national research and revised information on energy use and improved data from other sources

- **However, given the current methodology for estimating GHG emissions (see later section) UK emissions figures are determined by the number of livestock**

in the national inventory rather than changes in efficiency and uptake of mitigation measures

Estimates of global methane emissions from various animal sources (Food and Agriculture Organization*)*

Animal type	World population (million)	Annual methane production (kg/head/year)
Cattle (developed countries)	573	55
Cattle (developing countries)	653	35
Buffaloes	142	50
Sheep (developed countries)	400	8
Sheep (developing countries & Australia)	738	5
Goats	476	5
Pigs (developed countries)	329	1.5
Pigs (Developing countries)	445	1.0
Wild ruminants & herbivores	100-500	1-50
Humans!	4670	0.05

Despite being non-ruminants, it can be noted from the above table that people are also responsible for the production of methane - but not *all* people. Research has shown that about half the population are 'emitters'. Fortunately further discussion of this topic is outside the scope of this report!

8b(ii). Measuring enteric methane emissions

Enteric methane emissions are difficult to measure and require specialist equipment - varying in sensitivity and practicality - for in-field measurements. There are two main methods for the estimation of methane from individual animals which vary in their sensitivity, cost and practical application.

1. Methane chambers

Methane chambers are regarded as the standard method for measuring methane emissions. This technique uses self-contained chambers in which the animal is confined for a varying period of time. Controlled air-flow enters the chamber with measurements taken pre and post exit providing a value for the level of methane emitted by an animal. Controlled feeding also allows methane output to be compared against dry matter intake.

Advantages

- Is a direct measure of emissions
- Accurate and precise
- Measure all forms of animal waste
- Operates in a well-controlled environment

Disadvantages

- Expensive
- Labour intensive
- Can only measure a small number of animals at the same time
- Acts as an artificial environment
- May not be applicable to grazing conditions

It is however possible to create 'scaled down' versions of these chambers suitable for short term measurement of methane emission which may in turn have practical on-farm applications particularly as part of a larger breeding programme. Alternatively, for the measurement of groups of animals it is possible to create a large-scale version on the same principle which consists of a 'tent' housing the animals. This has been used at Aberystwyth University measure emissions at grazing.

Methane tent at Aberystwyth University

See photos of measurement chambers at AgResearch Grasslands in New Zealand overleaf

Lambs being acclimatised before entering the methane measurement chambers at AgResearch Grasslands in Palmerston North, New Zealand

Methane measurement chambers at AgResearch Grasslands, Palmerston North, New Zealand

AgResearch Palmerston North, New Zealand

In April 2011 a purpose-built facility for individual measurement of methane from sheep was opened. An attached pre-conditioning room holds stock for diet acclimatisation and rumen stabilisation. After 7-10 days, animals are transferred to the respirators where temperature and humidity are controlled during their two-day trial, and methane emissions are continuously measured. With $1.2 million funding it is now possible to measure 24 animals at a time. An attached pre-conditioning room holds stock for diet acclimatisation and rumen stabilisation. After 7-10 days, animals are transferred to the respirators where temperature and humidity are controlled during their two-day trial, and methane emissions are continuously measured.

Alongside these sophisticated measurement chambers work is also going on at AgResearch Invermay to create an 'on-farm' version with a 30 minute period in a simple chamber being used to measure relatively large numbers of individuals for genetic selection.

2. SF_6 tracer technique

This technique for measuring methane emissions uses a bolus type permeation tube which contains a known amount of SF_6 gas. The bolus is placed in the rumen with the SF_6 gas acting as a tracer. Associated with the tracer is a device which sits just above the nostrils and acts to collect samples of breath which in turn contain the methane gas. Attached to this is a canister located under the neck of the animal which contains the samples of breath. The canister is replaced following a set period of time and a sample of the respirated air is evaluated for estimation.

Advantages

- Is relatively cheap
- Can estimate methane from grazing animals
- Can measure relatively large numbers of individual animals at the same time

Disadvantages

- Is an indirect measure of emissions
- Lower levels of accuracy
- High variability
- Some animals are more consistent than others

See photo of SF6 tracer equipment overleaf.

SF6 tracer equipment

3. Future developments

Given the importance of measuring methane emissions research is also taking place into identifying additional techniques. Of particular interest is the GreenFeed system. This system consists of a portable 'fume hood' which is suitable for on-farm application. The following sequence takes place:

- Animal identifier (e.g. EID tag) is read
- Animal places head inside to consume a portion of feed
- A fan pulls air over the head and nostrils
- Continuous measures of methane, carbon dioxide and airflow are made
- The data is processed with daily methane production extrapolated for the animal

The system can be integrated into milking parlours and indoor feeding systems as well as on remote pasture based systems. *See a demonstration unit below.*

8c. Calculating greenhouse gas emissions

There are many different approaches to calculating greenhouse gases for agriculture. These include national inventory techniques (used to monitor national emissions) and carbon footprinting and lifecycle analysis.

Although following similar principles, each approach will differ in the way it calculates emissions. The precise approach depends on their purpose, whether it be to provide a simple tool for farmers to make a broad assessment of their carbon footprint or to allow for more detailed and sensitive analysis.

8c(i). National inventory

Reporting the current emissions position is a problem because the measurement systems in place for the national inventory are crude. Currently Defra reports GHG emission levels using the International Panel for Climate Change (IPCC) Tier 1 methodology. This is a relatively simplistic methodology and includes applications which may not be relevant to some UK conditions. In order to reduce the large uncertainties in the estimation of emissions DEFRA is funding the 'GHG inventory platform project'. Expected to be completed at the end of 2016 it is envisaged that this will allow the use of the more sophisticated Tier 2 methodology which also uses nationally derived estimates for emissions. However the current Tier 1 methodology will be used until then. For the agricultural sector the problem with the Tier 1 methodology is that it does not reflect reductions in emissions through improvements in efficiency.

8c(ii). Carbon footprinting and Life Cycle Analysis (LCA)

A **'Carbon Footprint'** is used to define the GHG emissions associated with a product or process. A carbon footprint therefore takes into account more than just carbon dioxide; it also considers all other GHGs.

> *"72% of UK supermarket shoppers are in favour of carbon labels on food. The survey also found that 42% had changed their shopping habits in the last 10 years in response to environmental concerns"*
>
> The use and usefulness of carbon labelling food: A policy perspective from a survey of UK supermarket shoppers

Although guidelines exist (www.ghgprotocol.org) there currently is no European or global standard procedure to calculate an agricultural carbon footprint. In the absence of a standard procedure comparing the carbon footprints from using different methodologies is problematic. Further issues also arise from the use of carbon footprints including:

- Defining the methodology – is this consistent and transparent?
- Defining the boundary – which emissions are included and how are shared emissions accounted for?

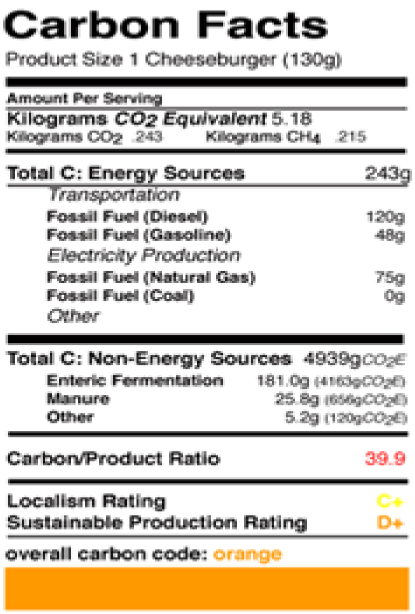
- Estimation of emissions data – what is the level of uncertainty associated with the estimates and what assumptions are being made?

There are also further uncertainties in estimating GHG emissions from the agricultural sector. This is due to complexities in the natural systems that are the source of emissions. These uncertainties are particularly large for nitrous oxide. For example, estimating the quantity of nitrous oxide released following fertiliser application is affected by a range of factors including weather, soil type and management practices.

In the meantime, a number of consultancy companies have developed their own carbon calculators which allow enterprise, or business, carbon calculations to be carried out. In the livestock sector, dairy processing companies are leading the way. Some UK retailers have started working with producer groups to identify and begin the process of benchmarking the carbon footprint of different farms. The use of physical studies to evaluate the effectiveness of GHG emission mitigation options at the system scale are prohibitively expensive and time consuming. Mathematical modelling of nutrient flows and losses in whole systems is now considered an invaluable tool with which to perform such examination and quantify whole farming system impacts. Appropriate models can in principle be used to evaluate effects of potential mitigations which are not yet technically feasible, to assess where resources for research and development should targeted. Modelling is very effective at bringing to light potential ‘pollution swapping’ and ‘win-win’ options for mitigation, and mitigation measures that need further experimental evaluation.

Some examples of carbon labelling on food products:

North America : red meat



www.openthefuture.com/cheeseburger

UK : milk

www.thegrocer.co.uk

Life Cycle Analysis is the process from 'cradle to grave' or more commonly in agriculture from 'cradle to farm gate'. There are however many additional complexities when carrying out this analysis in agriculture compared with other industries. The principal feature is that agriculture utilises land and soil. Estimating long term balances requires the use of simulation modelling, which must be adapted to the local context, to take into account variations in soil texture, rainfall and altitude. Many agricultural systems are interlinked and therefore changes to one system, for example arable crops used for animal feed, will have knock-on effects to other systems, i.e. the animal systems. In addition, the animals may be reared in geographically diverse areas incorporating lowlands as well as highlands.

For the carbon footprinting of individual farms the UK sheep sector creates a number of challenges not least the relative complexity of some of the systems operated! For example how could the carbon footprint of lamb from the following enterprise be estimated on a routine basis?

- 750 ewe flock. Approximately half the annual replacements are homebred and the remainder are purchased as ewe lambs. Depending on prices some purchased yearlings are also introduced.
- Lambing takes place in 3 batches with 50 to 80 aged ewes lambed at the beginning of February. The main batch of ewes lamb from the 1st of March and ewe lambs lamb from mid-April for 3 weeks. Early born lambs are creep fed but the remaining lambs are grass based. Any remaining lambs on the 1st of November are either housed and finished on ad-lib creep or sold as stores. In some years when cull ewe values are high the ewes normally used for early lambing ewes have been sold and only two batches of lambing take place
- A suckler beef herd is also retained on the farm.
- Silage is produced for both the beef and sheep enterprises. Early lambing ewes are housed for 8 weeks pre-lambing and then remain housed for a further 10-14 days depending on weather. March lambing ewes are housed depending on weather and grass availability but will typically spend 2 to 4 weeks indoors. As well as silage these ewes are over-wintered on the forage crop Kale which is also used for youngstock from the beef herd
- A small contracting business also operates from the farm with farm machinery used for both enterprises.

Apart from the difficulty in the allocation of inputs between the different enterprises, an 'accurate' carbon footprint would require a great deal of time and sophistication! Obviously a farming system should not be changed simply to enable carbon footprinting but this does serve to illustrate the relative complexities involved in many livestock farms. Not only does this cause difficulties for carbon footprinting but it also acts as a barrier to tools for business improvement such as benchmarking and calculating production costs.

An additional challenge of **Carbon Footprinting** is the current inability to modify emission factors. Productivity will be taken into account to some extent through kg of lamb sold (impacted through scanning and rearing percentage) but does not well reflect days on farm and in particular ewe live-weight and efficiency. Current approaches for both carbon footprinting and the national inventory assume that each mature sheep is responsible for 8kg of methane per year regardless of whether she is a 90kg continental ewe or a 40kg hill ewe. Without this level of sophistication some of the approaches to improving efficiency will not be recognised.

This challenge is however being addressed through a carbon footprinting tool being developed in NZ by agricultural consultants Abacus Bio. 'Hoofprint' takes a sophisticated approach to dealing with animal emissions and provides a much more sophisticated representation of on-farm emissions. The relative simplicity of NZ farming systems with little conserved forage, a single date of lambing and a much better understanding of flock performance is of great help.

On a parallel issue to carbon footprinting, of local importance to the UK livestock industry is the significant role sheep have in delivering environmental goods and services like biodiversity, habitat management and landscape character, as well as enhancing the value of pastures as carbon sinks. An environmental accounting model that values these issues alongside the GHG cost of production is needed to make sure livestock managers have a fully balanced report of their farming system. We therefore need to account for the benefits as well as costs.

8d. The Carbon Footprint of lamb

Throughout the report I've referred to the need for lamb producers to address GHG emissions. This is well demonstrated through the comparison of the carbon footprint of lamb compared with other food products. Whilst a range of figures have been presented through a number of UK projects the results tend to vary from 10 to 20kg of CO2 equivalents per kg liveweight of lamb. The following table illustrates the challenge facing the ruminant sector (*Plassman and Edward-Jones*)

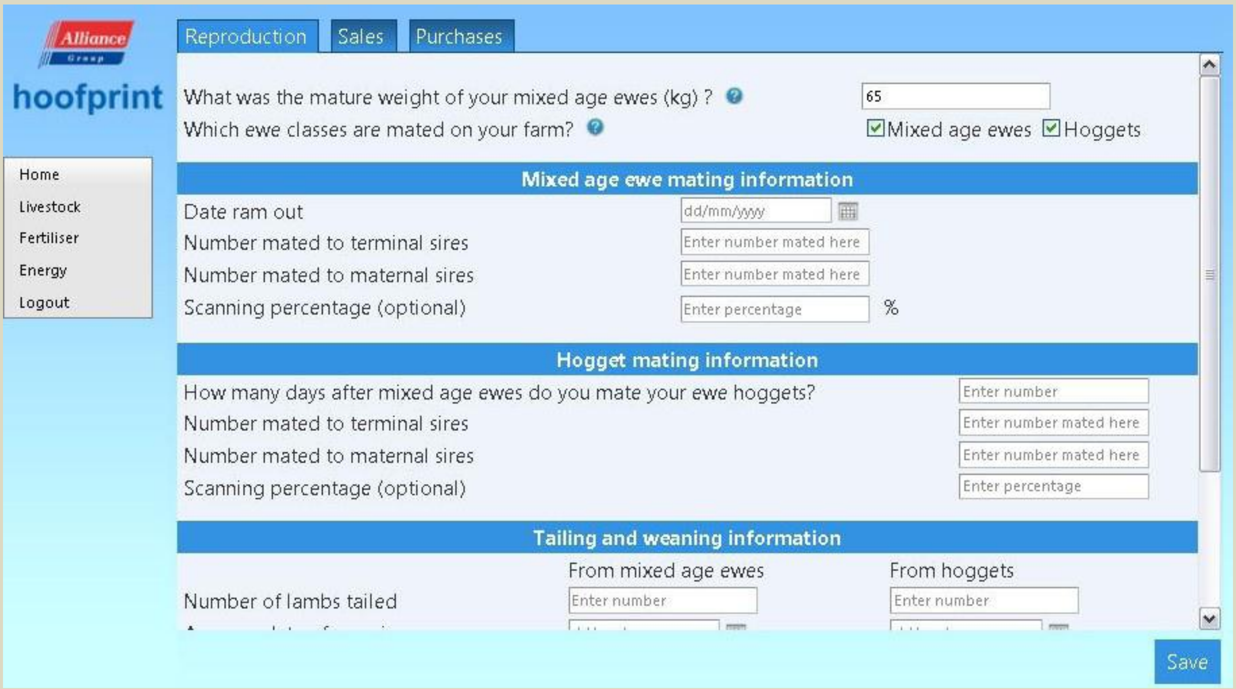
Item		**kg CO_2e / kg**
Apples	low	0.5
Potatoes	low	0.6
Strawberries	low	0.8-1
Milk (per litre)	low	1
Green beans (UK)	low	1.4
Frozen chips	med	5-6
Pork	med	3-6
Chicken	med	4-6
Tomatoes	med	2-9
Cheese	med-high	7-13
Lamb	high	14
Beef	high	12-23

There is however considerable variation in the carbon footprint on individual farms with values ranging from 8.1kg to 31.7kg (*Edward-Jones et al, 2009*). Similar variation is found in all studies looking at the carbon footprint of lamb.

NZ has also carried out a great deal of work looking at the carbon footprint of lamb with similar results achieved. When the issue of GHG emissions from livestock first reached prominence in the press there was some 'competitiveness' over the environmental credentials of lamb from NZ versus from the UK. However, all recent evidence is highlighting the need for both countries to simply actively promote the benefits of lamb consumption and not look to compete on the carbon footprint element. Should this take place the only winners would be the poultry and pork sectors (which have substantially lower footprints).

Hoofprint® carbon footprinting tool

When it comes to carbon footprinting the most practical and robust tool I have seen is the Hoofprint® package developed by the consultancy company Abacus Bio Ltd in New Zealand. Developed on behalf of the processor the Alliance Group Hoofprint® uses internationally recognised methodology and despite the very complex mathematical assumptions behind the model the tool has minimal data entry requirements.



www.abacusbio.com/pdf/AB_Breeder_Summer2010.pdf

8d(i) Reducing overall emissions levels

Reducing the overall amount of methane produced by an animal is best achieved through either manipulating the diet or direct modification of the rumen microflora.

Given the complex nature of the rumen and associated microbes a great deal of research work is currently taking place to provide a greater understanding of the interactions and modes of action. Increased knowledge in this area is a precursor to further opportunities to reduce overall levels of methane production per animal.

Methane emissions from an individual animal depend on genetics, daily feed intake, feed quality and the efficiency with which feed energy is converted into product (meat or milk).

8d(ii) Nutritional strategies

Changing feed type

Methane emissions depend in part upon the efficiency of rumen fermentation and the quality of the feed. Improvements to the quality of animal feedstuff, particularly in terms of digestibility and energy value, or improvements to rumen efficiency provide a route to methane reductions. This means that increasing the proportion of concentrates in a ruminants diet will actually reduce the amount of methane produced. More of the feed consumed can be converted into production and the reduction in the forage proportion of the diet means fewer of the methanogenic micro-organisms are present in the rumen. However, this takes a narrow approach to the GHG debate and full analysis of the carbon footprint of the system often leads to higher overall emission levels when all the 'costs' associated with the growing of a crop for animal consumption are considered. Similar analysis of the feeding of cattle maize versus grass silage has shown comparable results with cattle producing less methane when fed maize silage but when accounting for additional emissions from the growing of the crop the grass silage fed animals led to a lower carbon footprint.

Advantages	Disadvantages
Allows high levels of production using relatively small areas of land	Using cereals and soya in animal feed will generally increase the carbon footprint
Allows for year round supply of meat products	Increasing global demand and recent droughts has led to economically unviable cereal costs for ruminant diets
	Ethically it is becoming difficult to justify the use of food products which could otherwise be consumed by people

Changing forage type or forage attributes

Methane is produced by the action of bacteria on the cellulose contained within forage consumed by the animal. Changing either the type of forage consumed or nutritional properties of individual forages are both areas being researched.

Improving the digestibility of forage can reduce emissions both through improvements in animal productivity as well as a reduction in the proportion of energy lost as methane due to a reduction in dietary fibre. Since methane is released from the fermentation of feed the shorter the amount of time the feed spends in the rumen the less methane is produced. Increasing forage digestibility will lead to increased rate of passage and therefore also lead to reduced methane production.

Altering the composition of forage to increase the rate of breakdown in the rumen could also reduce methane output. There is some evidence to suggest that increasing the proportion of sugars contained within ryegrass could lead to better nitrogen utilisation and therefore lead to a reduction in both nitrous oxide and methane production. Research at Aberystwyth University has shown that lambs fed a diet of 'High Sugar Grasses' can reduce methane output by up to 20%. Many farmers across the UK are now using these varieties and the UK retailer Asda has teamed up with British Seed Houses to introduce Aber High Sugar Grass and Aber clovers to its 13,500 farmers across the UK.

> *"By introducing Aber HSG to our extensive British farming network we will increase profitability by over £10m in the first year alone, which is money in the pockets of farmers. This programme will also contribute to Walmart's global goal of removing 20 million tons of greenhouse gases from the supply chain."* Asda

Advantages	Disadvantages
Productivity gains can be used to drive uptake	Actual reductions in methane will vary considerably between different farming systems

Diet supplementation

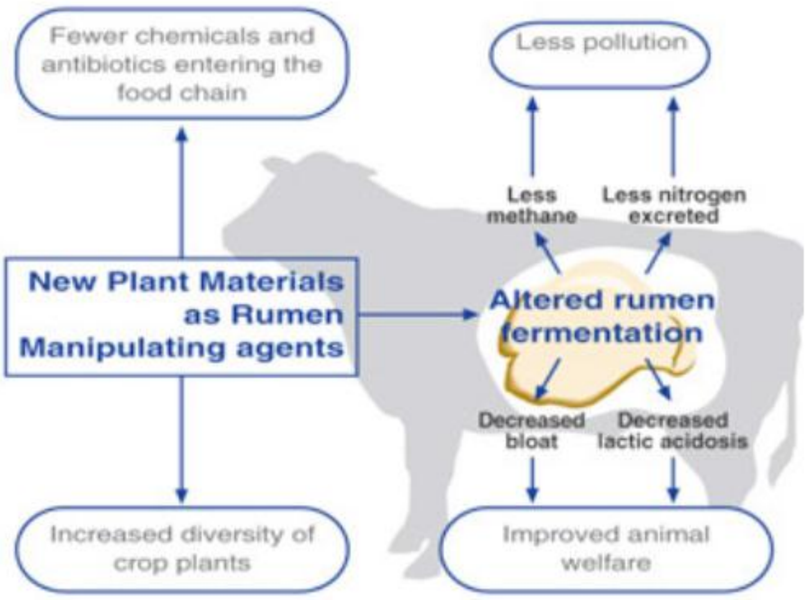
Adding a supplement to the diet has been shown to affect total methane output through changes in the rumen microflora. Candidate products have included the following;

- Garlic
- Tannins
- Yeast
- Curry spices
- Essential oils
- Organic acids
- Lipids

This technique works through either acting as an alternative source for the Hydrogen resulting from fermentation processes or by inhibiting methane producing organisms.

An EU wide research project ‘Rumen-up’ has identified more than 20 plants that may have a role improving rumen digestion including inhibition of methane production.

The Rumen-up concept (Knowledge Scotland)



Advantages	Disadvantages
Could lead to increased productivity if higher levels of energy consumed could be captured by an animal	Will lead to additional costs
	Requires routine feed supplementation which is not practical or cost-effective in extensive forage based systems

8d(iii) Breeding for low methane animals

Considerable variability exists between animals in their enteric methane emissions and it is likely to be possible to breed animals which naturally produce lower levels of methane on the same diet. The mechanisms through which differences exist are not fully understood but suggested causes include intrinsic differences in the microbial ecosystem or physical characteristics of the rumen itself. Considerable research in this area is being carried out in both NZ and Australia and there is now therefore evidence that there is sufficient genetic variation between individual animals to select individuals which are naturally low methane emitters. In this case the challenge for on-farm application is the ability to measure large numbers of animals in industry flocks to allow evaluation alongside traits such as growth rate and maternal attributes. Furthermore, genetic selection is likely to take a considerable period of time to provide significant reductions in emissions however the benefit of such an approach is that it leads to cumulative and permanent changes in total methane emissions and can be applied to populations which are not subject to routine nutritional supplementation. The application of genomic technologies in which considerable research investment is being made in New Zealand and Australia does is however likely to lead to significant advances in this area of sheep breeding.

Advantages	Disadvantages
Genetic changes are permanent and cumulative	Selection for low methane emitters will reduce genetic gain in other production based traits
Can be integrated into current breeding schemes	Requires relatively low cost, high throughput and comparable techniques for measuring methane from individual animals
	Would require both breeder participation and uptake by commercial producers

8d(iv) Vaccination

Although rumen micro-organisms have evolved a commensal relationship with ruminants research has shown that reduction or removal of certain groups within the population can lead to a reduction in the amount of methane produced. Furthermore this could also act to improve the efficiency of digestion since methane production represents a loss of between 2 and 15% of gross energy consumed that would otherwise be available for animal production.

There is therefore international work looking at the role of immunising ruminants against their own methane producing rumen bacteria.

The diverse nature of the rumen microflora in-conjunction with complex interactions means that such avenues represent a considerable challenge not least in any potential interactions with rumen fermentation and the permanence of any effects observed.

See overleaf for Advantages/Disadvantages

Advantages	Disadvantages
Could lead directly to reduced emissions without the need to change farm management practices or genetics	Would lead to additional costs and may need repeating at regular intervals.
Relatively simple validation systems would be required for participation in any carbon or emission trading schemes	Changes to the rumen microflora may lead to other physiological changes which reduce production levels or ability to cope with changes in nutrition
Routine vaccination is practiced on many farms against a range of diseases	

The majority of the options presented for reducing absolute emissions require significant investment in research and consideration of how maximum uptake could be achieved within the commercial environment. Each approach therefore needs to consider the value proposition that could be presented to producers. Where increase in productivity or reductions in costs are achieved then a clear cost-benefit can be demonstrated. With present knowledge such benefits are only likely to be seen with technologies that improve forage digestibility and/or improve partitioning of nutrients: for example the rapidly increasing use of High Sugar Grasses based on subsequent improvements in animal performance.

8d(v) Timescales for proposed approaches to reducing methane emissions from ruminants

Short term	Medium term	Long term
Reduce animal numbers	Forage species which lead to lower methane emissions	Manipulation of the rumen ecosystem
Increase productivity per animal	Modification of rumen function	Breeding animals for low methane production
Manipulation of diet		

8d(v) Reducing methane emissions from sheep production

Since methane emissions are not easily captured or quantified mitigation strategies need to focus on reducing production at source based on scientific principles of rumen function and interactions with levels of feed intake and feed quality

Total emissions = number of animals x *days 'on-farm'* x *emissions per head per day*

Overall levels of methane emissions may be reduced by altering any of the above parameters.

There are two approaches: reducing the 'intensity' of emissions through improvements in efficiency and reducing overall emissions by modulating the amount of emissions produced from digestive processes. The first approach has a range of management and technological options available whilst the second is the basis of a great deal of international research to develop on-farm applications.

8d(vii) Reducing the intensity of emissions

This approach relies on reducing the amount of emissions per unit of measurement. Generally, for the beef and lamb sectors the unit of measure under discussion is the amount of methane (or GHG) produced per kg of product e.g. per kg of carcass weight. Other units are however often presented including emissions per hectare of land. Alternatively when equating different products the unit of comparison can be per megajoule of energy or grams of protein.

Addressing emission levels using an intensity-based approach has significant advantages including;

- Recognising existing efficiencies
- Incentivising behaviour change
- Reducing the risk of carbon leakage and impinging on international competitiveness
- Setting clear commercial drivers for investment in mitigation strategies

8d(viii) Why increasing production per animal reduces methane emissions

As a by-product of digestion, methane output is generally linked to energy requirements and feed intake. Therefore, increasing production increases the total energy requirement and therefore the amount of methane produced. However, when taking into account the animal's maintenance requirements in-conjunction with their levels of production the overall methane emissions per unit of output e.g. kg of lamb or wool is lower for more productive animals. This is because a significant amount of energy requirements are used simply to maintain a healthy state. For non-productive animals this accounts for all of their energy requirements. Once the basic requirements for maintenance are met, energy is also needed for production: for growing, for pregnancy, for lactation and for wool. The total amount of energy required therefore increases with increasing production, but the energy required for maintenance generally remains constant. This means that with increasing production the proportion of energy required for maintenance is reduced therefore leading to lower methane output per unit of output.

In 2011 I was involved in a project which modelled the role of genetic improvement in reducing enteric methane emission from the Welsh National Flock. The results demonstrated that current genetic improvement programmes would lead to small but significant reductions in emissions. Some examples from the study illustrate the role of increasing production on reducing enteric methane emissions.

www.hccmpw.org.uk/farming/projects/effect_of_genetic_improvement_on_greenhouse_gas_emmissions

Example 1

Increasing lambs reared by 20%

	Scenario 1	**Scenario 2**
Rearing percentage	120%	140%
Reduction in enteric methane emissions per kg of lamb produced		-9%[1]

Example 2

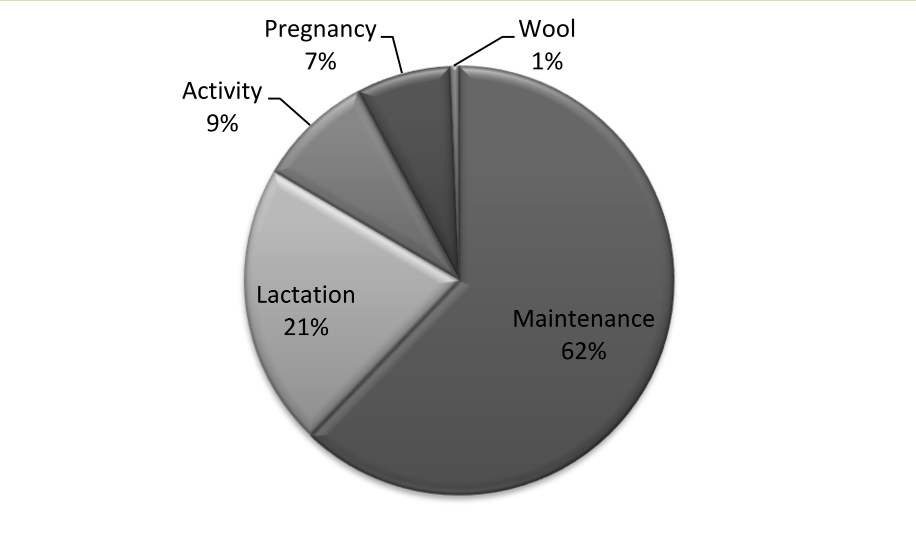
Increasing growth rate of single lambs by 10%

	Scenario 1	**Scenario 2**
Average growth rate to sale (g/day)	225	248
Reduction in enteric methane emissions per kg of lamb produced		-1.5%[1]

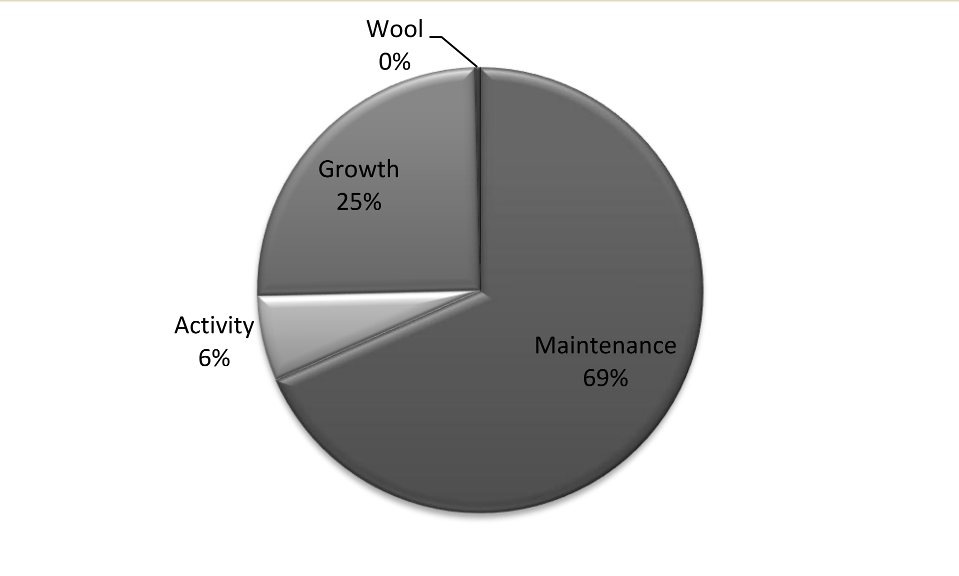
[1] The results are based on modelling changes within a single year and exclude longer term implications on female replacement rates, ewe live-weight and cull ewe and ram carcass

Furthermore, graphical representations of enteric methane emissions per animal demonstrate the impact maintenance requirements have on overall output.

Distribution of annual energy requirements for a mature lowland ewe



Distribution of annual energy requirements for a lowland lamb



Since energy requirements are directly linked to dry matter intake and methane production the results illustrate the importance of diluting the maintenance 'cost' against as much production as possible.

8d(ix) Defining efficiency

Whilst increased levels of production can lead to lower methane emissions, in order to prevent an increase in other GHG gases for example through the increased feeding of concentrates it is important to increase efficiency of production rather than simply increasing output. Reducing emissions intensity therefore relies on increasing biological efficiency of production. However, "efficiency" is poorly defined and generally overused term in livestock production. The definition of efficiency quoted in the Collins Dictionary does however proving a starting point and can be interpreted as 'making more from less'.

> *Efficiency: "The ratio of the useful work done by a machine, engine, device, etc, to the energy supplied to it."* Collins dictionary

Upon researching the term efficiency I also came across an equation based on work done by Dr Gordon Dickerson in the 1970s describing bio-economic efficiency for animal production;

Per breeding female — And her offspring

$$\frac{\text{Expense}}{\text{Product}} = \frac{(R_d + I_d + B_d \cdot F_{md} + F_{pd}) + N_o[D_o(I_o + B_o \cdot F_{mo} + F_{po}) + S_o]}{P_d \cdot V_d + N_o \cdot P_o \cdot V_o}$$

Where,

R_d = annualized replacement cost per breeding female.

I_d = annual non-feed cost per breeding female (i.e., dam).

B_d = average metabolic body size of breeding female.

F_{md} = annual maintenance feed cost per B_d.

F_{pd} = annual above-maintenance feed cost per breeding female.

N_o = annual number of offspring marketed per breeding female.

D_o = days from weaning to market age for offspring.

I_o = daily non-feed cost for offspring during the postweaning period.

B_o = average metabolic body size of offspring during the postweaning period.

F_{mo} = daily maintenance feed cost per B_o.

F_{po} = daily above-maintenance feed cost.

S_o = annual non-feed cost per offspring marketed.

P_d = annual product marketed per breeding female.

V_d = value per unit of breeding female product.

P_o = annual product marketed per offspring.

V_o = value per unit of offspring product.

What I took from this is that there are many key drivers for both biological and economic efficiency and that addressing the challenge of reducing emissions needs to be based on a systems approach rather than purely focusing upon one single driver of improving productivity.

8d(x) Efficiency improvement opportunities

Within the sheep industry there are a number of opportunities for improving efficiency of production:

1. **Increasing the longevity of breeding stock** – so the costs of their non-productive rearing phase are spread over a greater weight of meat produced.
2. **Increasing the fertility efficiency of breeding stock** – so they produce more slaughter stock and a greater weight of meat in their productive lives.
3. **Increasing the feed efficiency of slaughter stock** – so they produce more meat per unit of input.
4. **Increasing animal survival rate** – so inputs are not lost through the death of an animal.
5. **Optimising the mature weight of breeding ewes** – so additional maintenance costs are not introduced through unnecessarily high live-weights.

To add some more detail:

Optimising ewe live-weight

Efficiency improvements can be made through optimising ewe live-weight. A 60kg ewe rearing two lambs to 32kg each is 15% more 'efficient' than a 75kg ewe rearing two lambs to 34kg each. It is however possible to take this too far with ewes genetically and physiologically unable to produce lambs meeting mainstream market specifications. Optimising ewe weight rather than simply minimising is therefore the opportunity for this approach to reducing methane emissions.

Reducing disease incidence

Disease probably represents one of the biggest losses of efficiency and increasing methane emissions from sheep production. Even sub-clinical reductions in growth rates of 20g/day can increase lamb finishing times by 28 days. Lameness is a significant contributor to lowering productivity in UK flocks leading to reduced fertility, lamb losses and lowered growth rates as well as the welfare implications.

8d(x) Increasing efficiency through genetics, nutrition and management practices

Genetic improvement

Each of the counties visited recognised the role that genetic improvement can play in both increasing flock profitability and reducing GHG emissions. Both NZ and Australia had very well structured national breed improvement programmes with the NZ approach to breeding sheep 'fit for purpose' being world renowned for reducing costs and labour requirements associated with lamb production. Compared with the UK, commercial producers were much more committed to accessing genetic improvement in their own flocks. Uptake in Australia did seem more limited particularly for the Merino breed but this was being addressed through the use of knowledge transfer programmes.

Both NZ and Australia have a comprehensive range of traits which are part of the evaluation programmes including;

- Birth weight
- Growth rate
- Maternal weaning weight
- Fat depth
- Eye muscle depth
- Wool traits
- Numbers of lambs born
- Numbers of lambs weaned
- Scrotal circumference (Australia)
- Worm resistance

Both New Zealand and Australian sheep production has entered the age of genomics. Breakthroughs have included the development of the '50K panel for sheep'. This DNA-marker panel from Pfizer Genetics and developed in conjunction with AgResearch delivers molecular breeding values (mBVs). Funding for this work came from Beef + Lamb NZ and support from levy bodies is the most appropriate means of introducing such technologies into the National Flock.

The 50K panel for sheep will allow for the inclusion of new hard to measure but economically important traits into a breeding programme as well as improving the accuracy of other traits. Research is therefore now able to focus on introducing new traits into traditional breeding programmes include meat quality traits, efficiency of feed production and low methane emitting individuals.

Genomic technology is already been utilised by the dairy sector and could provide a hugely valuable tool for the UK sheep industry if we can address the need for well recorded populations of sheep in which to research, validate and 'train' the relationship between genes which drives genomic evaluations.

Nutrition

Improving overall levels of nutrition can lead to improvements in productivity. However, in order to prevent unintentional increases in overall GHG levels nutritional changes which improve productivity are best targeted at utilisation. For example, research has shown that improved lamb growth rate can be achieved through rotational grazing post-weaning. Utilising non-productive animals within the flock at the same time can allow for preferential grazing by lambs followed by dry ewes which can be used to 'mop-up' the remaining poorer quality pasture therefore ensuring high digestibility regrowth for the next round of grazing.

Management

Flock (and individual management practices) can lead to considerable variation in animal performance even utilising the same genetic base and operating similar nutritional strategies. Timing can be particularly significant when it comes to maximising productivity. In a UK summer with warm, wet conditions a week late treatment for internal parasites can lead to considerable production losses and in some cases even the death of individual animals. Footrot is a common disease on the majority of UK flocks and due to its high levels of infectivity waiting to treat lame animals when housed can increase flock incidence from 1-2% to 10%+ in a very short period of time.

8d(xii) Efficiency in action

In all countries visited technological advances were seen as the route to reducing the intensity of emissions and figures are often quoted which demonstrate the reductions in emissions that have already been achieved through advances in animal performance and farm management practices.

Results presented by Beef + Lamb NZ highlight the role that increasing biological efficiency can play. Since 1990 the NZ Sheep Industry has seen an 18% increase in lambing percentage, a 25% increase in lamb carcass weight lead to a 64% increase in kg of lamb sold per ewe. This equates to a 44% reduction in ewe numbers only resulting in a 5% drop in lamb output. NZ researchers estimated that this productivity improvement has reduced the carbon footprint of lamb by more than 20% over the same period. Between 1990 and 2006 Irish milk production has seen a 12.4% reduction in the amount of methane produced per kg of milk due to improvements in biological efficiency.

9. The opportunities

Everybody I spoke to during my travels recognised the challenge facing agriculture. Identifying the opportunities afforded by these challenges was not quite so obvious! I am however optimistic about the future of farming as a whole and sheep production in particular. There is strong global demand for lamb and mutton and although consumption per person may decline a growing population size will likely mean global market requirements will increase. Our challenge therefore is to both meet international demand for red meat with an affordable product whilst also producing an environmentally sustainable product for more 'local' markets in the developed countries i.e. UK, Europe, the US and Canada.

Agriculture has always faced challenges and has always responded to any changes required. In the post Second World War era farmers increased production to address food shortages. Land was reclaimed and a scientific approach was taken to animal breeding. Modern techniques for conserving forage were taken up by livestock producers and stock were housed in modern buildings to increase farm productivity. In the 1960s the use of modern wormers began and the advent of routine vaccination placed more emphasis on disease prevention. All this was done to address the challenge of the time which was to maximise food production. In the 1980s and 1990s the emphasis changed to increasing biodiversity. Again farmers responded.

Now we have to combine both production and the environment and to become even more sophisticated in how we do this. We now need to increase food production and maintain biodiversity as well as meeting new challenges such as reducing GHG emissions.

After careful consideration I would therefore like to present the following opportunities to the UK sheep industry.

9a. Investment in research

The greatest opportunity I have come across is the increased productivity and profitability that could be gained from government and industry investment into research. Furthermore the global challenge now means that there is an emphasis on global collaboration further increasing our access as farmers to advice and new technology. There are some obvious targets for increased research investment. Genetic improvement offers permanent and cumulative genetic gain and the limited advancements in the UK sheep sector over the last 30 years mean that there are still huge opportunities for improvement. In all biological systems disease has the ability to act as a limiting factor to productivity. Investment into disease prevention and control using a range of approaches from genetics through to vaccination, nutrition and pharmaceuticals is likely to be one of the most significant opportunities for reducing emissions bought about through 'wastage' in the farming system. As an example BBSRC (*Biotechnology and Biological Sciences Research Consortium*) have announced £9.5million of research funding into animal health directly relating to reducing GHG emissions.

9b. Delivery of knowledge transfer

Investment in research is of limited value without translating this knowledge into practical on-farm applications and then having a clear route for the dissemination of this knowledge. There is no single blueprint for knowledge transfer but I do feel that the challenges of 21st century require a new approach to the dissemination of information. Traditional knowledge transfer is often based around evening meetings with a main speaker giving a PowerPoint presentation. This is quite often combined with a farm visit but generally this approach is based around a group of farmers passively listening to a limited number of contributors. I was interested to see how other countries were approaching the challenge and whilst there wasn't an 'eureka' moment some interesting concepts were being introduced.

One of the problems associated with an evening meeting format is that it can often limit access to producers with young families. Work being carried out in NZ was looking at the benefit of holding afternoon meetings whilst in Australia, partly to address large distances, 'webinars' were being trialled where producers accessed an on-line discussion from their own home. Another concept I came across in NZ is the use of 'phone-in' sessions with producers able to dial in to a conversation between industry representatives on a topical issue. With advance notice, questions could be sent in by producers and while it was not possible to speak during the session producers were able to listen in on the discussion. Whilst perhaps not as interactive as a traditional meeting there would be considerable cost savings in both time and fuel as well increasing the access of producers across the UK to valuable advice. In the UK an informal network of a range of people involved in agriculture has been developed through the 'British Farming Forum' (*www.farmingforum.co.uk*) with over 10,000 members registered for the site.

On my return to the UK, and following discussion with a range of bodies, these issues are being recognised and addressed by those actively co-ordinating knowledge transfer - this is to be welcomed. There is still however a need for 'sustainable intensification' of food production to be considered in-conjunction with the 'sustainable intensification' of knowledge transfer.

9c. Adding value to land

If we are to increase food production we need to ensure that the most appropriate land is used for each agricultural sector. Lamb and beef production is best focused on areas of land that are unsuitable for arable cropping, or used as part of a break crop in an arable rotation. Regardless of land type there is however often an area of a farm which cannot offer optimum production. With the need to offer further environmental benefits farmers and land owners can use these opportunities to add value to their business. Alternative energy is a viable option for many agri-businesses: wind, solar or hydro-electric. Research into looking at the use of grass as a biofuel is on-going in the UK. Tree planting might be economically viable on some areas of land without significantly reducing food production. Ultimately we need to consider the land we farm as an asset and only one of the options for it is food production. In the future alternative energy, the accruing of carbon credits or provision of ecosystem services could all serve to increase farm revenue.

10. Conclusions

A: Conclusions for UK agricultural production

1. Governments, non-governmental organisations and lobby bodies are sufficiently invested that they are unlikely to reduce pressure on agriculture to lower greenhouse gas emissions

2. Economic difficulties and the need to increase export income from agricultural products may however lessen the pressure in the short term with priorities given to increasing national revenue

3. We cannot expand the current 'business as usual' model without putting food security, ecosystem services and profitability at risk

4. Increasing efficiency of food production and 'making more from less' is an avenue that the sector can promote in regards to reducing emissions and is a concept that we can use to engage consumers

5. There is no single approach that will reduce GHG emissions. Instead a suite of tools is required

6. Investment in science is the most cost-effective means of reducing emissions. Increasing knowledge of biological interactions, genotype by environmental interactions, nutrition and reducing disease incidence can reduce emission intensity

7. Research into reducing absolute levels of emissions through changes in nutrition, genetic selection for reduced methane production and tools such as vaccination can also play an important role in reducing emissions

8. An international collaborative approach is vital to maximise the development of knowledge and expertise in this area of research

9. In order to encourage uptake clear value propositions need to be put in place which favour their uptake by commercial producers. Options based on improvements in resource utilisation are expected to provide cost-benefits to primary producers whereas other options may be associated with increased costs.

10. The majority of carbon footprinting tools have a high level of uncertainty attached. Care should therefore be taken as to how they are used to compare individual businesses

11. Due to improved feed quality and shorter finishing times GHG emissions are generally lower for more 'intensive' lowland production systems compared with extensive hill flocks. The challenge for more extensive producers is to promote additional system benefits such as carbon sequestration, biodiversity and landscape features and utilisation of land unsuitable for arable crops

12. Further research is needed into how best to characterise emissions from individual farming businesses. It is important that any tools used adequately describe the effect of key parameters such as animal efficiency and use the most appropriate soil carbon estimates

13. An industry wide consultation should take place into the use of carbon footprinting and associated carbon labelling

14. We need to avoid 'carbon leakage' which replaces sustainable agricultural production with importation of less carbon efficient food

15. Improving the sensitivity of the national inventory is vital to allow efficiency improvements to be detected and accounted for when presenting emission levels against international obligations

16. Current proposals within the reform of the CAP, particularly the 'greening' measures proposed will not address the need to reduce methane emissions from livestock production. The proposed increased emphasis on research and knowledge transfer may however lead to real reductions in the intensity of methane emissions from red meat production

17. Technological advances will provide solutions for reducing emission intensity in the long term and all sectors of agriculture should embrace scientific developments wherever possible

18. Top producers require a targeted approach to knowledge transfer. Information technology seems to be the most appropriate way of targeting these highly competent agribusinesses and should be made a priority within the development of any future knowledge transfer programmes

19. 'Food, fibre and energy producer'. This is the job title used by a fellow Australian Nuffield Scholar on his business card. This phrase has stayed with me and I've come to recognise that as farmers we need to consider how best to utilise our most valuable asset – the land we own. Whilst food production is our foremost concern why not look to produce further goods including fibre, energy and even wider environmental goods such as flood prevention and carbon storage? If it pays we should consider it!

20. The challenges facing agriculture combined with the opportunities afforded by science means that the sector can be seen to be entering a new 'green revolution' 200-300 years after the 'agricultural revolution'.

See next page for Conclusions for UK sheep production

B. Conclusions for UK sheep production

For the UK sheep sector the challenge is to be part of the solution to reducing GHG. emissions whilst producing a high quality product from land unsuitable for arable production. In particular we need to make changes in our approach to technological advances and information technology.

1. We need to recognise that lamb will always be a 'high value' product but need to prevent consumers switching to other sources of protein through the effective control of costs whilst still returning a profit to producers

2. The supply chain is challenged to remove unnecessary costs throughout the industry and to provide communication back to primary producers

3. We need to consider whether sufficient rewards are available for farmers producing a product that meets consumers' requirements for a lean meat cut and also providing good value for money

4. Implementation of substantial genetic improvement in the sheep industry is vital. We need to recognise the need for genetic improvement to both improve product quality and also reduce production costs with the introduction of selection on functional traits such as lamb vigour, longevity and disease resistance

5. Addressing the need for rationalisation and consolidation of genetic resources in order to target genetic improvement and the use of genomic technology is required whilst still providing a mechanism to maintain the 'gene bank' of some of the minority breeds

6. Improving the health status of the national flock to improve welfare and reduce unnecessary costs and reducing productivity is vital

7. Support is needed for producers to enter the era of information technology including whole flock electronic identification, mobile technology such as farming apps and use of software to collect, track and analyse performance data both within flocks and through the supply chain

8. Promotion strategies are required which engage producers in scientific advances and which provide clear routes to market

9. Reducing the carbon footprint of lamb is required for a long-term sustainable future for this red meat product

10. It is important to prevent fragmentation of the supply chain through the introduction of carbon labelling.

11. Recommendations

A. General recommendations for reducing emissions from UK sheep production

> ***"Farming is going through a period of change. We cannot look back to previous eras or fail to consider whether our current production systems are fit for purpose. We need to refine our approach to business, to focus on meeting market requirements and to make the best use of the resources we have: the soil, the land, the animal and even the rumen microbes!"***

1. UK sheep producers can achieve efficient lamb production at sustainable market prices. However; it is only a minority of producers who are currently achieving this. Why is this? Some of the cause will be inherent challenges within the business such as scale, historic management, breeding decisions and debt but tackling these problems can be seen as an opportunity for improvement rather than an insurmountable problem.

2. This does not mean that we all have to move to a single production system and there is likely always to be a role for more 'niche' production systems such as early lambing but ultimately we need to recognise that our systems of sheep production need to be based around forage or sustainable sources of feed such as by-products inedible directly by people.

3. In order to adapt to the changing economic and environmental climate flocks the average UK flock size will most likely need to increase and I hope that the next round of CAP allows for this. Whilst not suggesting 'mega sheep farms' and even recognising that small farms can by financially and environmentally sustainable some increase in flock size would provide opportunities for improving efficiency and reducing production costs.

4. With increasing use of technology comes the challenge of its impact on overheads. Flock sizes of 1,000 plus ewes would help to drive investment in technological advances and focus producers on the application of genetic improvement and selection of breeding stock 'fit for purpose'. Currently it would cost approximately £5,000 per farm to introduce electronic identification and equipment for collection of weight data equating to £5/ewe.

5. The number of producers also has a direct bearing on knowledge transfer and the uptake of new technology: the more individual farming units there are the harder and more expensive it is to target advice and resources. Furthermore, the range of producers means that it is difficult using traditional knowledge transfer delivery in the UK to fulfil both the requirements of the ‘top 25%’ of producers who wish to refine their business practices with the ‘bottom 25%’ who need more substantial changes to their farming system and business management.

B. Recommendations for farmers

1. Focus on making the best use of the resources available

2. Know your flock: Are ewes weaning their own bodyweight? How fast are lambs growing? Are unrecognised diseases reducing growth rate? Is nutrition limiting genetic potential or is genetic potential failing to respond to nutrition supplied?

3. Know your business: How do your production costs compare with similar enterprises? Are labour costs too high? What is the return on capital? Is the business at risk from market fluctuations?

4. Embrace genetic improvement: no single source of genetics is the answer but using objectives measures bought about through genetic improvement programmes are

5. Embrace information technology (including EID!)

6. Look to utilise social media and local networks for up-to-date information and technical advice

7. Don’t dismiss the concept of payments for providing ‘ecosystems’ services such as improving biodiversity, reducing flood risks and storing carbon but lobby for payments based upon value delivered rather than income forgone

8. Protect home and export markets – legislation is necessary to provide consumer confidence in the product

9. Support organisations that can lobby on your behalf – we need a strong voice to combat single-issue campaigns

10. Don’t think of Irish, NZ or Australian lamb as competition – our real competitors are on the supermarket shelf in the form of chicken and pork

11. Respond to the need to reduce emissions through addressing certain management practices but focus upon increasing efficiency which represents the future of lamb production

12. Recognise that the livestock sector can offer win-win scenarios with sustainable solutions for reducing the environmental footprint of lamb production - increasing efficiency of production also drives economic performance

Finally, I was asked the question in NZ if I could make one recommendation for UK sheep production what would it be. I had no prepared answer to hand but the first thought that came to mind was increased cooperation. I still stand by this statement!

C. Recommendations for UK government and policy makers

It could be argued that, with food production and security being such an important issue, agriculture should not be included in international climate change frameworks. However, since it is already a target for reductions I would recommend the following:

1. Set the challenge and ask primary producers for solutions

2. Invest in research and knowledge transfer

3. Review current mechanisms for knowledge transfer. It is important to consider the needs of those who will be driving agriculture forward in the next 5-10 years rather than the perceived requirements of the current age profile of the industry

4. Use market forces wherever possible rather than legislation

5. Support an intensity based approach to reducing emissions (e.g. per kg of product) which provides direct recognition of the need for food production to increase and removes penalties for efficient production

6. Carefully consider policies and incentives to prevent carbon leakage

7. Don't expect 'income foregone' to drive changes in management practices. Land is an asset and since producers are always being told to take a business approach to farming we then cannot be expected to devalue what we do and what we can offer in the form of food production and wider environmental services

8. Where legislation is required this should be based on risk analysis rather than the precautionary principle

9. Consider whether agricultural emissions should be distinguished from emissions derived from sectors such as travel and manufacturing. Should biological emissions really be treated with the same level of concern as those derived from a flight for a foreign holiday? Is the carbon dioxide produced from the manufacturing of household goods comparable to that released from cultivating land for a wheat crop? Should emissions from agriculture not be at the bottom of the list for targeted cuts when a reduction in food production is at risk?

D. Recommendations for researchers

1. Focus on developing 'fit for purpose' systems of lamb production based on objective measures of flock efficiency including dry matter requirements, feed utilisation, disease resistance and meeting consumer requirements for environmentally friendly, healthy lamb

2. Whilst manipulating animal diet is a principal mitigation strategy, industry uptake will require either a clear cost-benefit through improvements in animal performance and/or mechanisms for increased returns either through the market place or additional funding sources

3. Consider how best to utilise the 5^{th} quarter to improve producer returns and increasing the overall efficiency of products derived from sheep farming

4. Develop an industry wide initiative for research into, and protection of, unique genetics provided by some UK minority breeds

5. Develop robust carbon accountancy methodologies with sufficient sensitivity to pick up efficiency improvements

6. Identify on-farm measures for the provision of environmental goods. These include a better understanding of the economic value of different ecosystem services

7. Continue to collaborate. In an era of limited funds and global challenges both national and international collaboration is vital

8. Don't underestimate farmers!

12. Post-Nuffield

The time since receiving my Nuffield award in January 2011 has flown by. Nearly two years later I am just as committed to sheep farming and equally passionate about sheep! My travels have reinforced my view that lamb production has a viable future in meeting the global demand for protein but we can't forget the price pressures that will face us and we must continually strive to reduce the cost of production whilst still accepting that lamb will always be a high value product for consumers.

I believe that there are challenges for UK sheep production with the need to address inefficiencies in the supply chain, embrace technological advances, improve the health and genetics of the national flock and of course reduce the carbon footprint of lamb production whilst still providing wider environmental and societal goods.

From the perspective of my own sheep consultancy work I have taken my Nuffield Scholarship as a challenge to keep up-to-date with the research work being carried out globally and to make sure the businesses I work with are able to make use of this information. I believe that lamb is best suited to forage based production systems but, provided the system in place meets consumer requirements, is profitable and has good welfare standards I am not prescriptive in my approach to production systems. I have therefore developed a range of products and services specifically aimed at improving the efficiency and profitability of lamb production. My focus is on working out the best approach for each individual business based around cost-benefit and scenario analysis. Among the tools I have developed are computer models that can be used to look at issues surrounding flock variables. This includes – amongst many others - mature ewe size, prolificacy, growth rate and days on farm. I am also developing an 'Efficiency Audit' which brings all these factors together for both pedigree and commercial producers as well as creating whole flock models which look in detail at factors affecting cost of production and profitability. Furthermore I seem to have developed a passion for the use of key performance indicators - or 'KPIs' - in sheep flocks and am now on a mission to develop practical and informative tools for monitoring and improving business performance. Time will tell whether I succeed in their widespread use!

Before Nuffield I was not a fan of social media but as well as being a great way of keeping in touch with many of the people I have met through my Nuffield travels I have also recognised the role it can play in knowledge transfer and even adjusting to market changes and environmental conditions. I now use both Facebook and Twitter to keep up-to-date with all the headlines and tease out snippets of information which can be applied to both my own farming business and to those I work with. One of the many organisations I follow with interest is the NZ farming union 'Federated Farmers'. I am particularly interested to see how the Emissions Trading Scheme is finally implemented and the impact on livestock farmers in the country. Recognising the value of social media as a source of both information and networking opportunities means that my consultancy business KN Consulting now has its own Facebook and Twitter account!

As to my specific Nuffield topic I am now able to introduce issues surrounding methane emissions into more or less any conversation about sheep! On a serious note the relationship between efficiency and GHG emissions will continue to inform both my consultancy work and also my involvement with industry organisations. Furthermore the experience of a Nuffield Scholarship has taught me the value of learning from and sharing experiences with others who are passionate about their area of agriculture. I therefore applied for, and was fortunate to be awarded, one of sixteen places for the first ever 'Rural Leadership Programme' which has been jointly developed by Farming Connect and the Royal Welsh Agricultural Society with the aim of inspiring a new generation of leaders in rural Wales.

On the farm I am continuing on my journey of improving the productivity and profitability of the farming business. I did however have a 'Nuffield moment' when visiting a fellow Nuffield Scholar's sheep farm in NZ, realising that the running of my own 950 ewe flock should only be a part-time occupation enabling me to expand my consultancy work. I have therefore made changes to the breeding structure of the flock moving back to breeding my own replacements and focusing upon efficiency of production and not just overall production levels.

The first question I now ask when making a decision on my own farm or working with clients is 'what is the business case' – I still invest in the flock and the business but only once I've worked out the cost-benefit implications of the decision to be made. I put this down to my visit to fellow producers in New Zealand and Australia!

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My own farm in Carmarthenshire. Typical of many upland farms we have a mix of improved and unimproved grazing. I have instigated a great deal of grassland improvement over the last 4 years and here the ewes have just been turned out onto rested field for lambing (Spring 2011). Making the best use of forage will continue to be my main priority, alongside improving overall efficiency.

13. Acknowledgements

I would like to thank the Nuffield Farming Scholarships Trust for the opportunity to travel to different countries and most importantly to open doors to meet with knowledgeable, passionate and inspiring people. Particular thanks also go to my sponsors the Royal Welsh Agricultural Society and Innovis Ltd.

I would also like to thank all those in the industry who have encouraged me over the last four years. I would like to thank members and staff of the Farmers Union of Wales and specifically fellow members of the Carmarthenshire County Executive. I would like to extend my appreciation to Meinir Bartlett, Brian Walters, Lorraine Howells and Hazel Wright for all the support they have given me.

My biggest thanks however go to my parents who coped with a miserable wet winter whilst I was enjoying particularly good weather on my travels. Thank you also to my youngest sister Elisabeth for her words of support before embarking on my travels and for recognising that being a fan of sheep and sheep farming can actually open the door to all sorts of opportunities and challenges!

Sponsors

Royal Welsh Agricultural Society
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Referees

Dewi Jones, Innovis Ltd
Dr Janet Roden, Aberystwyth University

Ireland

Richard Dewhurst and Padraig O'Keliy (Teagasc Grange)
Michael Mullin, Tim KEady, Ciaran Lynch & Philip Creighton (Teagsc Athenry)
Noirin McHugh (Teagasc Moorepark)
Michale McHugh (Teagsc advisor)
Alan Fahey (UCD, Dublin)
Kevin Kinsella (Irish Farmers Association)
William Hutchinson (Pedigree breeder)
Amii Cahill (Nuffield Scholar)
Nathan Tuffy & Padraig Foley (Irish Farmers Journal)

New Zealand

Guy Trafford, Chris Logan, John Hickford & Tony Bywater (Lincoln University)
Ike Williams (Ram breeder)
Ian Little (Facilitator)

Kristy Demmers, Sara Edwards, Benoit Avery, John Rendel, John McEwan, Grant Shackell, Michael Lee, Sue Peoples, Jason Archer & Cecile de Klein (AgResearch Invermay)
Jude Sise, Peter Amer, Cameron Luderman, Tim Byrne, Jo Kerslake & Anna Campbell (Abacus Bio)
Robbie Hughes and Family (Texel breeder)
Murray Rohlof (Ram breeder and consultant)
Sharl Liebergreen (Pfizer)
Richard Fitzgerald (Nuffield Scholar)
Andy Fox (Nuffield Scholar)
Keith Lassey & Andrew MacMillan (NIWA)
Erica van Reenen, Richard Wakelin & Ben O'Brian (Beef + Lamb NZ)
Collier Issacs ($Farm^{IQ}$)
Simon Tucker (Dairy NZ)
Jeanette Maxwell, Dave Burth & Jacob Haronga (Federated Farmers)
Andrea Pickering & Gerald Rhys (MAF)
Mark Aspin (Pggrc)
Harry Clarke (NZAGRC)
Lycinda Berry (AgFirst)
Mark Shepherd (AgResearch Ruakuro)
Caesars Pinares Patino, Peter Janssen, Margaret Brown & Brent Barrett (Agresearch, Palmerston North)
Sally Lee and Family (AgFirst consultant and farmer)
Nicola Waugh (Nuffield Scholar)
Jane Mitchell (Nuffield Scholar)
James Parsons (Nuffield Scholar)
Richard Fitzgerald (Nuffield Scholar)
Chris Adams and Family (Farmer and entrepreneur)

Australia

Julie Brien (Nuffield Scholar)
Ashley White, Gordon Refshauge & Dave Hopkins (Cowra Agricultural Research and Advisory Station, NSW)
Douglas Alcock (Cooma Agricultural Research and Advisory Station, NSW)
Hutton Oddy, Julius van der Werf, Kennet Geenty, Lucinda Hogan (CRC, NSW)
Michelle Anderson (Orange Agricultural Research and Advisory Station, NSW)
Pip Brook (Port Stephens Research Centre, NSW)
Tom Davison (Meat and Livestock Australia)
Renelle Jeffrey (Australian Farm Institute)
Rodney Watt (Ram breeder)
Jennifer Hawkins (Nuffield Scholar)
Michael Inwood (Nuffield Scholar)
David Cattanach (Nuffield Scholar)

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