Hybu Cig Cymru
Meat Promotion Wales

The Welsh Way:

Towards Global Leadership in Sustainable Lamb and Beef Production

meatpromotion.wales

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Foreword

From the HCC Chair – Kevin Roberts

The climate crisis we face is urgent, and global in scale.

Humanity is facing the challenge of producing enough high-quality food and distributing it equitably among our growing population. In doing so, we must avoid short-term solutions that further degrade the atmosphere and soil of our planet and jeopardise the food security of future generations.

This is a huge challenge. It is one that begins on our own doorstep.

As a red meat body, we believe that the 'Welsh Way' of farming has a great deal to offer. Our ambition is nothing less than to make sheep and cattle farming in Wales a global exemplar of how to produce quality food, sustainably and efficiently.

There are many things we already do well. Welsh farmers can be proud that we produce high-quality protein on marginal land, which is largely unsuited for arable crops. We do so overwhelmingly in non-intensive systems, using grass and rainwater to rear animals, thereby avoiding contributing to deforestation and unsustainable use of water resources elsewhere in the world.

But we can do even better.

This document outlines a series of measures which can reduce greenhouse gas emissions and cut waste, in ways which will promote the economic and cultural sustainability of the vibrant Welsh communities which are sustained by livestock agriculture and food production.

It also goes further. Livestock agriculture is unique; alongside working to lower its impact, it can also contribute positively to carbon sequestration, soil regeneration and increased biodiversity. Here we present new research giving a snapshot on how Welsh farms are already helping to store carbon in grasslands and hedgerows and propose how we can do even more in future.

Our aim is to ensure that consumers, when choosing Welsh Lamb or Welsh Beef, can be confident that their meat is produced to the highest possible standards of sustainability, and to play our part to combat our shared global challenges of climate change and food security.

1 Introduction

Hybu Cig Cymru – Meat Promotion Wales (HCC) recognises the urgency and gravity of the challenge of sustainability. It is a challenge that is global in scale and encompasses climate change, food security, social justice, land use and soil degradation.

All sectors of human activity – including agriculture and food production – have a role to play in responding to the emergency. HCC recognises that difficult choices have to be made, and creative solutions found, to feed a growing world population equitably without further degrading the environment and adding to climate change.

We believe passionately that food and farming in Wales are already making a positive contribution, and can do more over the coming years.

In 2012, HCC's *Red Meat Roadmap* laid out clear steps that farmers and processors could follow to help make Wales' red meat sector a global exemplar in terms of sustainability.

These measures have formed the blueprint for HCC's work with the industry. Ongoing work with farmers and processors has delivered improvements in shelf-life and reductions in waste. The current strategic EU and Welsh Government-funded Red Meat Development Programme focuses on several areas which have an impact on efficiency and sustainability; from sheep and beef animal health planning to breeding improvements in the national sheep flock.

Much has changed since 2012 in terms of our understanding and the debate on climate change. New research has highlighted the different climate impacts of short-lived greenhouse emissions such as methane as opposed to carbon dioxide. Our understanding of carbon capture in soils has also improved.

Here we examine how Wales stands in the global context of sustainability and food security and put forward a case of where our meat sector can make a real positive difference.

We also analyse where sheep and beef farming in Wales stands at present – particularly its emissions and its carbon sequestration potential. We present new research that suggests that hill and upland farming in Wales can constitute a sustainable, low-emissions system of food production.

This document also quantifies future gains; what actions can be taken on farm, and throughout the supply chain, to make the Welsh red meat sector a global leader in sustainable food production

1.1 Livestock Agriculture and Emissions

In establishing the impact and potential mitigation effects of livestock farming, it is essential to consider the latest research in the field of climate science.

Three main gases which impact on global warming are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). In the atmosphere, these absorb energy and slow the rate at which energy escapes to space, thereby acting as a blanket on the earth.

They do so at different rates. Nitrous oxide is regarded as the most potent greenhouse gas as it absorbs more energy than methane, which in turn absorbs more than carbon dioxide. To arrive at a standardised measurement of the three gases, the system of 'GWP100' has come into common usage. This system converts these gases into a common metric of Carbon Dioxide Equivalent (CO_2e), which estimates how much energy gases will absorb over 100 years.

As *Table 1* shows, methane is regarded as being 25 times as potent as carbon dioxide, while nitrous oxide is over ten times as potent as methane.

Table 1: Carbon Dioxide Equivalent of Greenhouse Gases

Gas Name	Symbol	1 kg in CO_2 equivalence
Carbon Dioxide	CO_2	1 kg CO_2
Methane	CH_4	25 kg CO_2
Nitrous Oxide	N_2O	298 kg CO_2

Source: Eurostat. Glossary: Carbon dioxide equivalent.

https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Carbon_dioxide_equivalent#:~:text=A%20carbon%20dioxide%20equivalent%20or,with%20the%20same%20global%20warming

New research, however, has argued that this measurement does not pay sufficient attention to how long the gases exist within the atmosphere.[1] Carbon dioxide, for instance, will remain in the atmosphere for a millennium, whereas methane breaks down in around 10-12 years.

As leading climate scientist Michelle Cain explains, "long-lived pollutants, like carbon dioxide, persist in the atmosphere, building up over centuries. Short-lived pollutants, like methane, disappear within a few years. Their effect on the climate is important, but very different from that of carbon dioxide: yet current policies treat them all as 'equivalent'.[2]

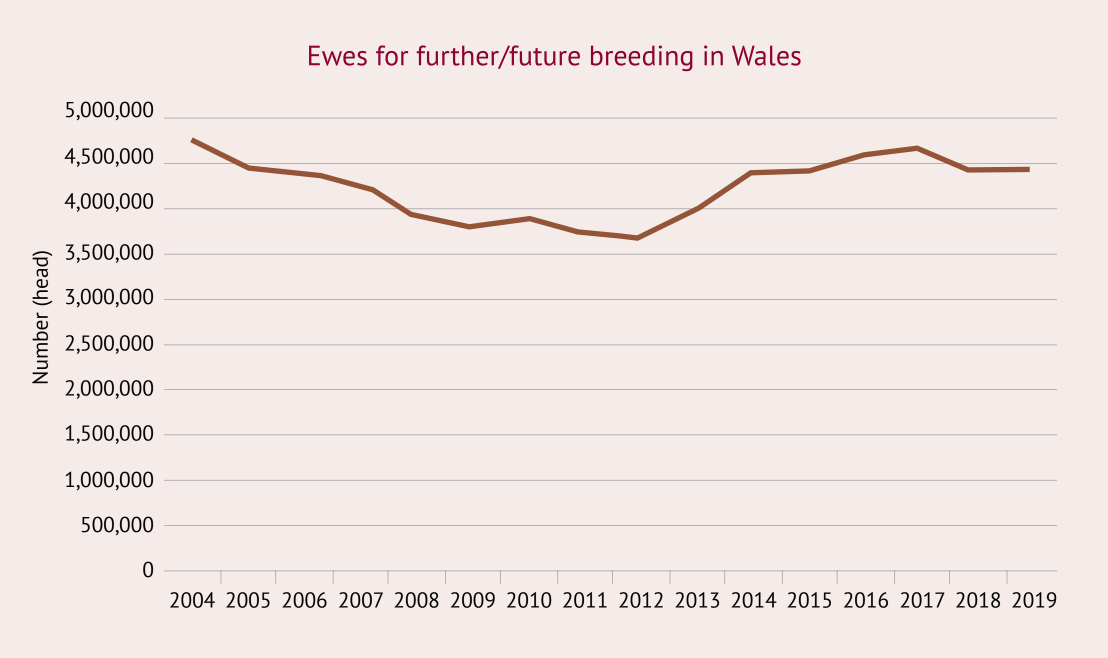
As approximately 90 per cent of the greenhouse gas emissions associated with lamb and beef production are composed of methane and nitrous oxide, this work has profound implications for how we should regard the climate impact of agriculture as opposed to other industries which mainly emit long-lived carbon dioxide.

Considering the issue from a global perspective, livestock agriculture which is increasing in terms of the number of breeding animals, and therefore increasing its methane emissions, is a pressing problem in terms of climate change.

However, if numbers of ruminant animals are static, the methane within the atmosphere is in balance – part of a natural cycle whereby emissions are broken down, photosynthesised by grassland, and consumed again by animals.[3] Carbon dioxide is, therefore, a stock gas where any new emissions add to the concentrations already present in the atmosphere. Whereas methane can be considered a flow gas, which will remain constant if it is destroyed at the same rate of emissions from well-managed grass-based systems.

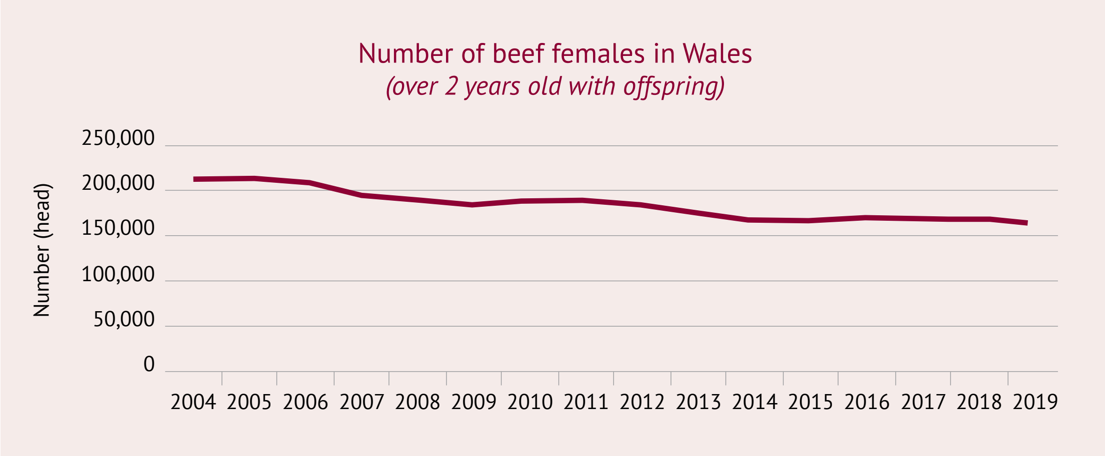
In Wales, numbers of breeding animals in both the sheep and beef sectors have been stable for many years, suggesting that no new methane is currently being added to the atmosphere by lamb or beef production.

Figure 1: Numbers of Breeding Ewes in Wales



Source: Welsh Government. June Survey of Agriculture and Horticulture, Wales. June 2019.

Figure 2: Numbers of Breeding Beef Cattle in Wales



Source: Welsh Government. June Survey of Agriculture and Horticulture, Wales. June 2019.

This stability in livestock numbers has significant land-use implications as the level of greenhouse gases needed to be offset by red meat production is much lower than anticipated under GWP100. It also means that any emissions reduction, carbon sequestration and offsetting measures implemented on Welsh farms could be used to offset the global warming impact of other sectors in the economy.

As will be argued later in this document, reducing methane emissions, even while maintaining current levels of output and economic activity, is possible, and offers an exciting opportunity for the Welsh lamb and beef sector to become a global exemplar in sustainability.

Achieving this will also help Wales to deliver international commitments on climate change and the environment, as laid out in the United Nations Framework Convention on Climate Change. Also, the Kyoto Protocol and the 2016 Paris Agreement set out a global framework to limit global warming to well below 2°C and pursuing efforts to limit it to 1.5°C.[4] It will represent an exciting contribution from livestock agriculture to the Welsh Government's ambition to achieve net-zero emissions by 2050 and to do so in accordance with the principles of the *'Well-being of Future Generations Act'* of 2015 in terms of improving the economic, social, environmental and cultural well-being of Wales.[5]

1.2 The Global Context and the 'Welsh Way'

In terms of meeting Wales' global responsibility of responding to the climate crisis, it is important to consider the landmark 2019 report of the Intergovernmental Panel on Climate Change (IPCC), *Climate Change and Land*. This report addressed a range of related issues on a global scale: greenhouse gas emissions, food security, and the impact of climate change and environmental degradation on the sustainability of food production and human communities.

In assessing appropriate governmental responses, the report's *Summary for Policymakers* emphasised its holistic approach, combining responding to climate change with promoting sustainable development and societal goals, eradicating hunger and promoting food security.[6]

Importantly, the report urged the development of specific policy solutions in different global regions, and it cautioned against removing land from food production. It foresaw an important role for sustainable types of livestock farming in promoting the balanced diets that could feed a growing global population sustainably; "*Balanced diets, featuring plant-based foods, such as those based on coarse grains, legumes, fruits and vegetables, nuts and seeds, and animal-sourced food produced in resilient, sustainable and low-greenhouse gas emission systems, present major opportunities for adaptation and mitigation while generating significant co-benefits in terms of human health.*"[7]

HCC believes that the Welsh lamb and beef sector can rise to the challenge set by the IPCC. Our country is ideally placed – in terms of climate and topography – to produce high-quality food from land unsuitable for other uses, harnessing abundant natural resources.

Wales already produces lamb and beef in ways which are more sustainable – environmentally, socially and economically – than many models in other countries. By building on this, by further reducing emissions and increasing carbon sequestration, Wales can be an exemplar of the resilient, sustainable and low-emission method of red meat production envisaged by the authors of the IPCC report as being crucial to the global food system of the future.

Wales has an essentially maritime climate, characterised by weather that is often cloudy, wet and windy, but mild. Wales also has an upland and mountainous topography. This landscape results in a large proportion of agricultural land in Wales categorised as 'less favourable areas' (LFA).[8] The climate and terrain, therefore, dictate that the majority of the land in Wales is best suited to pasture and livestock farming. There are 2.1 million hectares of land in Wales, of which 1.86 million hectares are farmed. Of that farmed land, 81 per cent (1.5 million hectares) is under grass.[9]

Ruminants, like sheep and cattle, utilise Wales' agricultural land to convert the grass into meat, on land which in most cases is not suitable to grow any other human-edible food. Overwhelmingly, livestock are raised non-intensively in Wales, with the primary food source being grass.

Too often in public debates, however, the enormous differences in farming systems worldwide is ignored, and the impact of agriculture on the environment is discussed in terms of global averages which can be misleading.

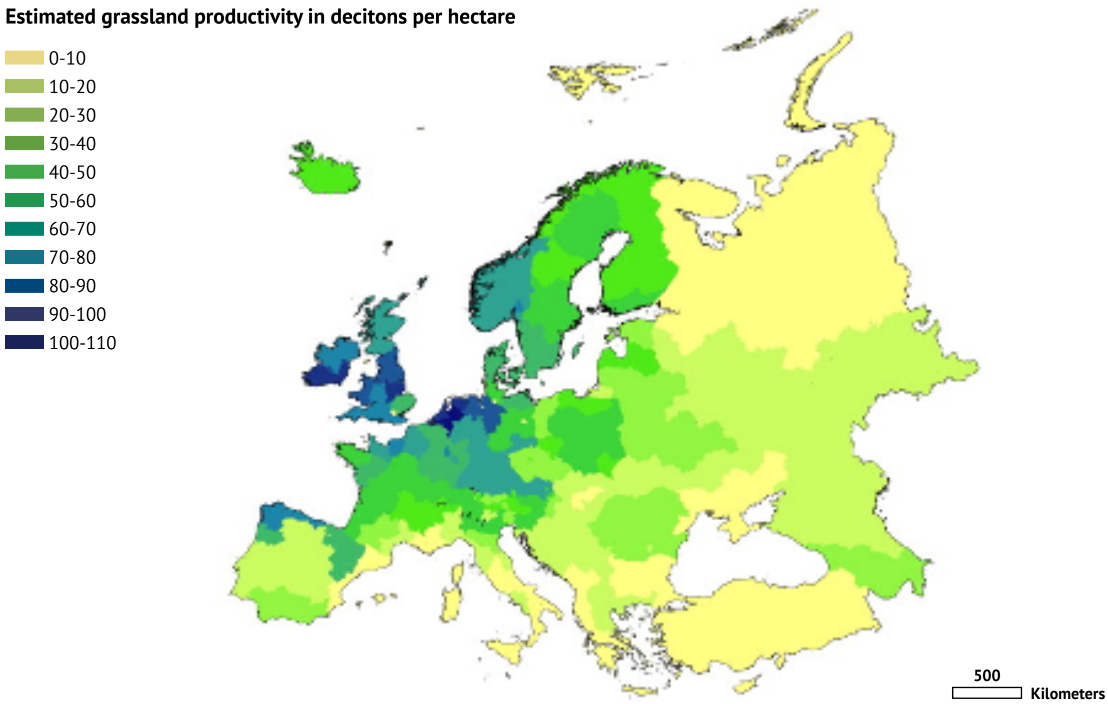
For instance, the demands of food production on fresh water is a much-documented cause of concern. It is estimated that 70 per cent of global fresh-water resources are consumed by agriculture.[10] In some regions this places significant stress on the availability of water for other purposes and can lead to damaging changes to ecosystems.

A frequently-cited statistic is that the production of a kilogram of beef requires on average, over 15,000 litres of water.[11] However, this figure will vary enormously between different systems of production. Also, growing feed for the animals accounts for over 95 per cent of the total water used.

In grass-based systems in water-rich environments, rearing sheep and cattle places vastly less pressure on natural resources than might be the case for intensive farms supplied by feed grown in drier areas of the world.[12]

Livestock agriculture in Wales requires very few artificial inputs. According to Smit et al., Wales ranks among the foremost areas in Europe for grassland productivity.[13] In addition to its suitable climate, for many years the country has been home to world-leading research which has led to significant advantages in yields and grassland management techniques.[14]

Figure 3. Grassland Productivity Across Europe (*1 deciton = 100 kilogrammes*)



Source: H.J. Smit, M.J. Metzger, F. Ewert, 'Spatial distribution of grassland productivity and land use in Europe', Agricultural Systems, 98, 3 (2008), 208-219.

In Wales, low-intensity agriculture which primarily utilises natural grass and rainwater is the norm. The Welsh way of farming is a world away from feed-lot systems, which are linked to environmental degradation and are heavily reliant on soya and other imported feeds.

Intensive farming systems have also become the focus of media criticism for adding to deforestation due to their demand for supplementary feed. However, such coverage has often failed to recognise that most of the lamb and beef produced in Europe, and most available on domestic retail shelves, is not reared in such ways.[15] Welsh farmers are specialists in producing lamb and beef in less intensive systems, on land that has few other productive uses.

The use of this land for rearing livestock, as well as producing protein for human consumption, can also deliver substantial environmental benefits in terms of carbon sequestration, soil health and biodiversity.

There are widely recognised methodological challenges in assessing the carbon sequestration potential of soils, grasses and forestry.[16] However, as well as reducing its own emissions, agriculture has the potential to make a positive direct contribution to reducing atmospheric carbon. Such an option is not presently available to the same scale for other sectors such as transport and industry.

This document, therefore, places significant emphasis on assessing and maximising the sequestration potential of Wales' grassland, hedgerows and related forestry.

Through soil regeneration, livestock agriculture can also contribute positively to the production of vegetables, grains and other arable crops.

Research over recent decades has consistently raised concerns regarding the impact of modern arable farming methods and artificial fertilisers on the condition of soils across the globe. Work at Sheffield University warned that, on the current trajectory, the UK only has approximately 100 harvests remaining, and similar studies have painted an even starker picture in other global regions.[17]

A key part of the solution, according to most approaches to the topic, is increased use of animal manure to regenerate arable soils.[18] In recent years, far more attention has been paid to the principles of regenerative agriculture, and the positive role that sustainable forms of livestock rearing can play in a holistic, integrated food system.[19]

In Wales, livestock grazing has played a significant role in creating diverse wildlife habitats. The continuation of these grazing practices is essential for the ongoing management of areas such as grassland, heathland, wood pasture, floodplain and coastal marshes. All require some grazing to maintain the habitats on which a variety of birds, insects, mammals and reptiles depend for their survival, as all require variation in the structure and composition of the vegetation to complete their life-cycles.

In upland and hill systems in particular, livestock grazing can play a role in maintaining species-rich habitats. It prevents scrub encroachment and controls more aggressive species which would otherwise dominate these areas. The preference by livestock for certain plant species is an important factor in determining a habitat's structure and floristic composition of the vegetation. Livestock grazing removes plant material more gradually than cutting or burning and gives mobile species a better chance to move to other areas within the habitat. Grazing also supports farming activities such as hay-making, which provides active management for valuable meadow habitats, allowing slower-growing grasses to flower and seed.[20]

Different types of livestock graze in different ways, which influences their suitability for grazing individual habitats. The ability to retain sustainable livestock grazing, using correct types and numbers of livestock at the appropriate time of year, is therefore essential to the maintenance of many important wildlife habitats.

The Welsh lamb and beef sector can make a positive and globally-responsible contribution to the challenge of worldwide food security. This role can be achieved by maximising its natural advantages in producing red meat in a sustainable manner, and taking action to reduce emissions further and maximise carbon sequestration and soil renewal.

The United Nations estimates that the current world population of 7.7 billion is expected to reach 9.7 billion by 2050.[21] According to the Food and Agriculture Organization of the United Nations (FAO), the total demand for animal products in developing countries is anticipated to more than double by 2030,[22] and that 60 per cent more food will be needed worldwide by 2050 to feed the increasing global population.[23]

At the same time, under-consumption of dietary energy, protein and micronutrients is still a problem for hundreds of millions of people, mostly in the developing world. There, the concern is focussed on deficits of crucial minerals and vitamins – particularly iron, iodine, vitamin A and zinc – and affect over 2 billion people.[24]

The ability to feed the world's population, while diets are also changing towards animal-source foodstuffs (termed the nutrition transition by Popkin, 1993),[25] is also essential. As low-income countries develop, people's diets tend to move from being high in cereals, starchy staples, and fibre, to more westernised patterns that are high in sugars, fats, and animal-source foods.

However, given the predicted growth in population and anticipated changes in diets, there are potential risks to global food security of applying overly stringent targets to a reduction in greenhouse gas emissions from livestock production. There is a need to balance the perceived negative contribution of livestock to the environment against the positive benefit in terms of food security.[26]

Modelling approaches have concluded that the optimal balance of food supply with global greenhouse gas emissions requires the production and consumption of some red meat in a balanced diet. And, that this red meat should be produced using grass-based systems such as those used in Wales. A 2015 study exploring a strategy where livestock are fed only from grassland and by-products from food production; concluded that a grass-fed system could provide sufficient food and reduce environmental impacts.[27]

1.3 Carbon Off-Shoring

Given the dominance of grass production in Wales, there is also a strong argument to retain productive livestock here to meet the demands of the domestic UK population. Despite an increase in social and political factors exerting considerable influence on consumer purchasing, lamb and beef consumption levels across the UK are currently relatively static, with consumption in 2019 for sheepmeat and beef standing at 3.9 kg and 11.4 kg per capita, respectively (compared to 4.9 kg and 11.4 kg per capita in 2009).[28]

Any further decline of livestock production in the UK (and specifically Wales, which accounts for 11 per cent of the UK beef herd and 28 per cent of the UK sheep flock),[29] would therefore result in UK consumers' demands for red meat being met by additional imports.

Increasing imports of red meat to meet UK consumer demand could undermine the UK's efforts to reduce greenhouse gases globally, as measurements of emissions of imported products are not taken into account in greenhouse gas emission calculations. There would remain, therefore, an invisible – and likely increased – carbon footprint from the emissions produced overseas to produce sheepmeat and beef for consumption in the UK.

The World Wide Fund for Nature (WWF) estimates that about half of UK's true carbon footprint comprises of invisible sources. In 2016, 54 per cent of the UK's carbon footprint was domestically sourced, with the remaining 46 per cent from emissions released overseas to satisfy UK consumption.[30] This overseas proportion of the UK's carbon footprint has also increased substantially from just 14 per cent in 1990. As such, policy that switches the supply of lamb and beef from a domestic source to potentially less sustainable systems overseas, to meet UK carbon emissions targets, is simply off-shoring the emissions, demonstrating a disregard for global social responsibility.

A report for WWF-UK by the University of Leeds Sustainability Research Institute exploring the UK's contribution to climate change shows that of the regions that contributed to the UK carbon footprint in 2016, 10 per cent was from emissions released in the EU. Some 7 per cent was released in China, 5 per cent in Africa, 5 per cent in the Middle East, 4 per cent in the US and 3 per cent in Russia.[31]

Furthermore, the UK (and Wales) has one of the highest standards of animal welfare in the world. Switching agriculture away from meat production in Wales in effect transfers red meat production to other countries with potentially lower welfare standards.

A key conclusion of the UK Committee on Climate Change is that "*agricultural emissions should not be off-shored. Achieving emissions reduction should not be at the expense of producing less food in the UK and increasing imports. As the UK is a relatively low-greenhouse gas producer of ruminant meat, this risks exporting emissions abroad and increasing consumption emissions*".[32]

While some would respond that a UK food strategy should include a major dietary shift away from animal-sourced products, such a conclusion is not supported by evidence on the health impact of red meat.

The Scientific Advisory Committee on Nutrition advises a red meat intake of 70g per day. According to the UK Government's *National Diet and Nutrition Survey*, the average consumption of red meat is very close to this level. Therefore, there is no nutritional reason to encourage the population, as a whole, to eat less meat.

Red meat is naturally rich in protein, and the vitamins and minerals that it contains offer many health benefits. Studies show that red meat provides essential nutrients that help boost health and well-being, including vitamins A, B, and D, iron, magnesium, zinc, selenium and potassium. Furthermore, the types of iron and zinc found in red meat have better absorption than those found in any other dietary sources.[33]

The *National Diet and Nutrition Survey* shows that in young women, there is insufficient dietary intake of vitamins A and B2, calcium, iodine, iron, magnesium, potassium and zinc. These are all provided by red meat.[34] Also, people over sixty years of age require higher levels of vitamin B12; a nutrient that is present in animal foods but not in vegetables.

1.4 Social and Economic Sustainability

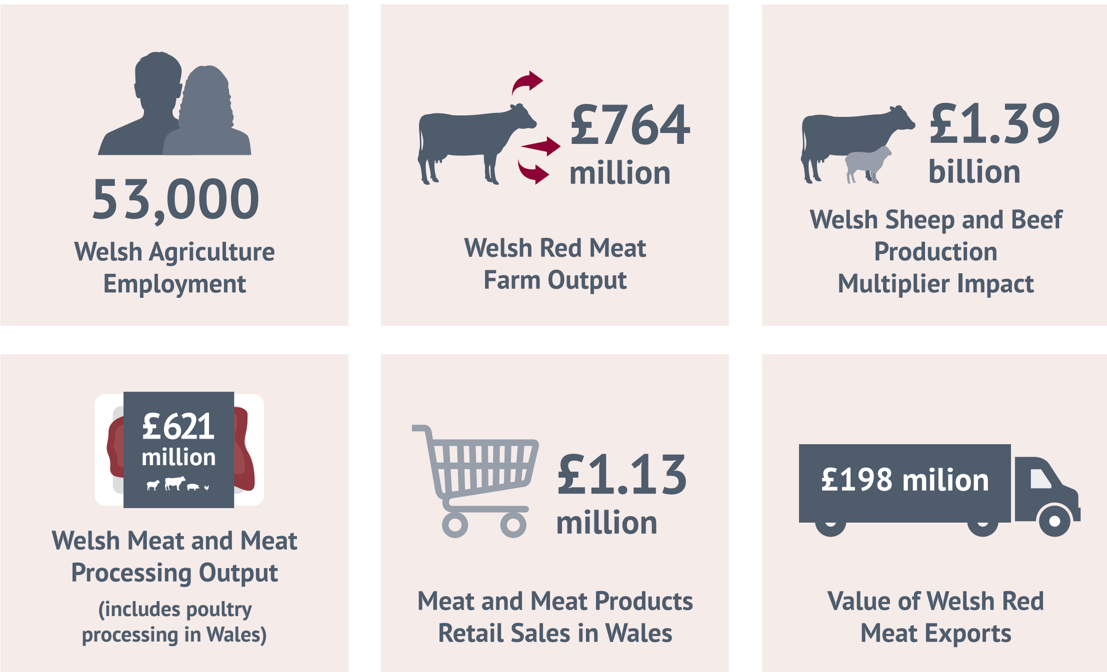
As noted previously, Wales' pioneering Well-Being of Future Generations Act defines sustainability in a broad sense, to include social, economic and linguistic factors which underpin vibrant communities. A productive, sustainable lamb and beef sector makes a contribution in all these areas.

The red meat supply chain is made of up of numerous links in addition to on-farm production, encompassing the upstream provision of farming inputs and downstream processing and retail outlets. The Welsh red meat supply chain works together to utilise its collective expertise to produce high-quality red meat products that consistently meet and exceed market requirements and build consumer trust. Safeguarding the supply of sustainably-farmed livestock protects the sector for future generations.

Sheep and beef farming accounts for around half of Welsh agriculture output, generating a turnover of £764 million (2018). Milk and dairy products account for a further £568 million.[35]

For every £1 of turnover generated by agriculture, around half (46 pence) is spent on intermediary consumption to support production. Excluding additional wage effects, further supply chain linkages (i.e. second round spending effects) generate a multiplier effect of £1.817. As *Table 2* shows, this means that the £764 million generated by Welsh beef and lamb production leads to a direct-multiplier impact on the broader economy of £1.39 billion.[36]

Table 2: Summary of Red Meat Production's Contribution to the Economy



Welsh breeding sheep	4.4 million head
Welsh breeding beef cows	163,800 head
Welsh breeding dairy cows	251,600 head

Estimated Welsh Red Meat Production**

Lamb	86,500 tonnes
Beef	99,500 tonnes

** based on Wales' percentage of UK breeding stock applied to UK tonnage of dressed carcase weight
Source: HCC[37]

Agriculture is a multi-functional industry which is widely recognised as having a range of positive impacts on society.[38] These go well beyond its direct contribution towards employment and effect on traditional economic measurements. Agriculture remains a major driver of economic and community viability, especially in rural areas of Wales,[39] and recent Welsh Government policy has argued strongly that these connections remain valid. Farms and farmers are described as social "anchors" providing a "keystone" role in rural community life.[40]

Farming underpins the Welsh food and drink supply chain. Together, they are worth over £6 billion to the Welsh economy. They are collectively the country's biggest employer with the agricultural and food supply chain estimated to employ 223,100 people across Wales.[41]

The broader impact of agriculture on the rural economy links to estimates of local spend and multiplier effects. Research suggests that family farms in Wales procure over 80 per cent of goods and services from within a 25-mile radius of the holding,[42] and so, make a wider contribution to local economies and communities.

Agriculture also contributes to revenue generated throughout Wales by tourism through the management of the landscape and provision of tourist accommodation and attractions. Over 90 per cent of Welsh land is in the hands of farmers, foresters or other stewards of the landscape.[43] The quality of the Welsh countryside and landscape has been identified as a key motivation for visitors, with over half of UK day visitors (54 per cent) and around two thirds (67 per cent) of those who stayed overnight in Wales listing the landscape as a reason for visiting (2016).[44]

The landscape is also a key component of the Visit Wales campaign. It is largely responsible for attracting around 10 million overnight visitors, 87 million day-visitors and 1 million international visitors to Wales per annum – contributing in the region of £6 billion to the economy each year.[45]

The Wales Tourism Alliance has highlighted the symbiotic relationship between tourism and agriculture. It recognises the vital role that farmers and land managers play in preserving a quality landscape and environment on which tourism relies.[46]

A thriving agricultural sector also contributes to social capital in rural areas.[47] The traditional view of social capital in agricultural communities is based on a farming structure predominantly consisting of small family farms, often in upland and hill areas and concerned with sheep. This typology fits well with the reality of farming in rural Wales where sheep and cattle grazing dominate (35 per cent of active farm holdings) and the average Welsh farm holding at 48 hectares is smaller than in England and Scotland.[48] In this context, social capital in the form of co-operation and mutual support both within the farming community and between farm businesses and the wider community is often essential.

The Wales Rural Observatory found close family and community networks as well as high interconnectedness between networks in rural areas[49] with farmers embedded in a farming culture which embraced a sense of place, history and Welsh nationality.[50]

Social capital amongst rural networks of younger people is often rooted in the agricultural community, especially through the activities of Young Farmers Clubs (YFC). Over 5,000 young people aged between 10 and 26 years are currently members of a YFC. The youth-led movement provides important life skills as well as essential social contact for isolated young people and leadership training opportunities.[51]

The continuity and multi-generational nature of Welsh agriculture help to maintain and enhance both the Welsh language and Welsh culture.[52] The 2011 census showed that 43 per cent of agricultural workers in Wales were fluent Welsh speakers as opposed to a nationwide average of 19 per cent,[53] In its drive towards a million Welsh language speakers the Welsh Government has recognised the importance of agriculture on the language.[54]

1.5 The Way Forward

Wales, therefore, has huge natural advantages as a place to produce high-quality meat in sustainable systems, which the IPCC has argued is necessary to ensure balanced diets and food security.

Its climate and topography mean it is one of the best places in the world to sustain productive grasslands, which can be used to rear livestock without recourse to large-scale additional inputs in terms of feed and fertiliser.

Wales' lamb and beef sector supports substantial productive economic activity, which in turn nourishes vibrant communities. Any significant reductions in livestock agriculture would risk undermining this, as well as potentially off-shoring our emissions to less sustainable systems abroad through increased food imports.

However, there are measures that can be taken to improve sustainability still further, which could enable Welsh agriculture to play an important part in reducing the country's overall impact on climate change.

This document will first examine where Wales stands and where further improvements may be possible. This analysis will use the latest scientific research on emissions and carbon sequestration and draw on detailed research from a cross-section of productive Welsh sheep and beef farms.

It will then propose a range of on-farm and supply chain measures and quantify their potential effectiveness, using the latest methodology to model their impact.

The aim is to show how the Welsh lamb and beef sector can best contribute towards meeting the country's goal of becoming net-zero in terms of greenhouse emissions by 2050. All while maintaining the economic and cultural resilience of communities which depend on agriculture and ensuring the critical mass of production required to maintain Welsh Lamb and Welsh Beef as iconic brands which spearhead the Welsh food and drink industry.

2 Greenhouse Gases and Red Meat Production

The UK has expressed a commitment to end its contribution to climate change through the territorial net-zero emissions target in the Climate Change Act.

In order to do this effectively, a detailed assessment of the current impact of the agriculture sector must be undertaken.

As discussed in Chapter 1, recent ground-breaking research is redefining how we view the relative potency and impact of different greenhouse gases. Methane's short-lived nature means that pasture-based systems where numbers of livestock are stable contribute very little new warming effect.

A modified use of GWP100, called GWP*, has been developed to calculate so-called 'carbon dioxide-warming-equivalent emissions' (CO_2we). This enables methane, nitrous oxide and carbon dioxide emissions to be grouped as CO_2we emissions. Such that the resultant global warming that those emissions produce is approximately the same, whether the original emissions were methane, nitrous oxide or carbon dioxide

It is possible to recalculate the broad emissions of the Welsh sheep and beef sector taking this new research into account.

Table 3: Applying the GWP* Measure to Existing Greenhouse Gas Agriculture Emissions, 2018

	GWP 100	GWP*
Welsh sheep and non-dairy cattle emissions 2018 **	2,907 kt CO_2e	-1,257 kt CO_2we
Of which sheep	1,126 kt CO_2e	-441.3 kt CO_2we
Of which non-dairy cattle **	1,516 kt CO_2e	-944.3 kt CO_2we
Of which urea and dung from all grazing livestock	128.66 kt CO_2e	128.66 kt CO_2we

** Note that non-dairy cattle in this table means all cattle excluding lactating dairy cattle.

Source: Derived from HCC commissioned research of the Wales Greenhouse Gas Inventory by RSK ADAS, 2020 and HCC commissioned research of the GWP* Analysis completed by Cranfield University, 2020.

Under the GWP* calculation, enteric and manure emissions for sheep and cattle in Wales equate to 'negative emissions' of CO_2we. This is because both of these categories are comprised mainly of methane emissions, which are declining over time. This means Welsh ruminants contributed most to global temperatures in the decade or so following that peak in emissions, and the contribution of this sector is now reducing. Whenever CO_2we emissions are negative, this means methane emissions have gone down compared to 20 years prior, and the impact at this time is that of reducing the temperature.

While many scientists are supportive of the potential of a new reporting methodology for methane, it remains that so long as methane is released into the atmosphere, it has an impact on global warming. The near-term benefits of reducing methane would mean a reduction in warming over the next 20 years. This reduction is required to help meet the Paris Agreement target of keeping warming below 1.5°C. To achieve the stated aims for greenhouse gas reduction while also changing the methane calculation would require a very substantial reduction in carbon dioxide and nitrous oxide from both agriculture and more pertinently from other sectors of the economy. The inclusion of methane reducing activity reflects the valuable role of agriculture in helping to mitigate against wider whole economy emissions.

It is vital for the sector that any new information or evidence, such as the work undertaken at the University of Oxford on methane calculations, are incorporated into the UK National Atmospheric Emissions Inventory.

2.1 Sheep and Beef Sector Emissions

The data used in this document primarily comes from the UK National Atmospheric Emissions Inventory (NAEI), with adjustments and assumptions made for Welsh red meat production. This dataset has been used as ultimately it is against these measures that agriculture and red meat production in Wales will be gauged when evaluating greenhouse gas emission targets.

The NAEI captures emissions across the UK, and reports at a regional level. The data shows total Wales greenhouse gas emissions had reduced from 56,000 kt CO_2e in 1990 to 39,000 kt CO_2e in 2018. Table 4 sets out emissions by source.

Table 4: Welsh Emissions by Source 2018

NAEI Source	kt CO_2e in 2019	As percentage of total
Energy Supply	11,500	29%
Business	8,500	22%
Transport	6,200	16%
Agriculture	5,600	14%
Residential	3,700	10%
Industrial Processes	1,900	5%
Waste Management	1,200	3%
Exports	500	1%
Public	300	1%
Land Use, Land Use Change and Forestry	400	
Total	**38,900**	

Source: National Atmospheric Emissions Inventory. Devolved Administrations Greenhouse Gas Reports. 1990-2018.

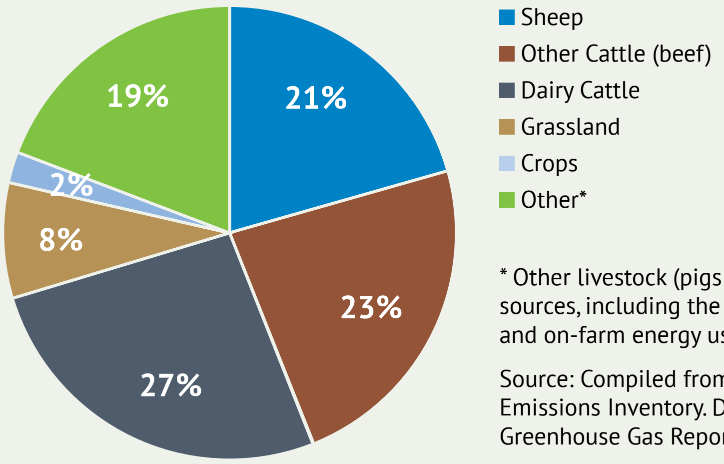
As can be seen from Table 4, 45 per cent of emissions are from energy supply and transport combined (equating to 17,700 kt CO_2e) and around 14 per cent of emissions are from agriculture (equating to 5,600 kt CO_2e). Welsh agriculture emissions have however fallen by 11 per cent from 6,300kt CO_2e in 1990 to 5,600kt CO_2e in 2018.[55]

The NAEI reports by sector, with agriculture a defined sector. However, in addition to agriculture, the NAEI data set also reports on emissions associated with Land Use, Land Use Change and Forestry (LULUCF). This has substantial interplay, as the agriculture activity has a clear impact on land use and land use changes and the carbon sequestration and storage associated with Welsh agriculture.

Around 400kt CO_2e of net emissions are offset through land use, land use change, and forestry. Some activity – such as the conversion of grassland to cropland – releases emissions (emitting 460 kt CO_2e in 2018). In contrast, others such as grassland remaining grassland sequestrates carbon resulting in a removal of 200 kt CO_2e emission in 2018.

As *Figure 4* shows, of the 5,600 kt CO_2e of emissions from Welsh agriculture, just under half (44 per cent) are from sheep and beef production. Around 27 per cent are from the dairy herd, and 19 per cent from other livestock (mainly the poultry and pig sectors) and on-farm energy use.[56] The remaining 10 per cent are from grassland and crop production.

Figure 4: Welsh Agriculture Emissions by Source 2017



* Other livestock (pigs and poultry) and emission sources, including the cultivation of peaty soils and on-farm energy use.

Source: Compiled from the National Atmospheric Emissions Inventory. Devolved Administrations Greenhouse Gas Reports. 1990-2018.

Nearly 90 per cent of Welsh greenhouse gas agriculture emissions are methane (produced by herbivores as a by-product of enteric fermentation in the gut)[57] and nitrous oxide (from grassland soils due to fertiliser and manure applications, as well as urine and dung deposited by grazing livestock). Nitrogen levels applied to grassland (fertiliser) declined significantly between 2000 and 2009, and have since remained at a steady state.[58] The use of nitrogen fertiliser is more prevalent in dairy production, where stocking rates (cows per hectare) are greater. Carbon dioxide emissions are a relatively minor component at 10 per cent and arise from the use of conventional electricity and fossil fuels, for instance, in agricultural machinery.

Both ruminant animals (e.g. sheep and cattle), and non-ruminant animals (e.g. pigs and horses) produce methane, although ruminants are the largest source per unit of feed intake.[59] Methane output relates to the total feed intake. Smaller animals eat less and produce less methane. However, the rate of methane per unit of feed is the same within each livestock type,[60] but varies depending on whether cattle are lactating or non-lactating. Manure methane is linked to the storage of manure and excreta at grazing.

The direct nitrous oxide associated with livestock production relates to the breakdown of nitrogen in livestock manure. The nitrogen content of manure is influenced by the nitrogen content of the feed, the level of nitrogen used in growth (body mass, milk, wool) and the excess nitrogen excreted. Animals living on a high protein diet excrete more nitrogen than those on a high energy diet and excrete a higher proportion as urine as opposed to dung.

Analysis by the UK Committee on Climate Change shows that to stop further increases in temperature contributing to global warming, emissions of methane need to fall by less than one per cent per annum.[61]

Greenhouse gas emissions associated with Welsh livestock primarily relate to the size of animals and variations in the proportion of breeding stock to progeny associated with different farming systems and livestock types.

While many factors determine the productive capacity of different systems across different farm types, it is clear that to improve the greenhouse gas intensity of Welsh Lamb and Welsh Beef, improvements to flock and herd productivity are paramount. Ensuring the breeding animals are at their productive optimum is crucial for reducing the absolute and relative level of emissions associated with red meat production.

Sheep Sector Emissions

In identifying improvements to red meat production that lead to a reduction in greenhouse gas emissions, it is essential to evaluate the calculation of emission figures. The process would also gain insight into activities that are mutually-beneficial to lowering emission figures and improving profitability.

Direct greenhouse gas emissions associated with the Welsh sheep sector are dominated by methane. A reason for this would be that direct emissions for the following tables are only those that arise directly from the animal therefore nitrous oxide emissions for the production of grass are excluded. The level of nitrous oxide emission is proportionately lower than in a cattle system. The reason is sheep tend to be fed less protein-rich diets and because they spend the majority of their time outside, the nitrogen in their urine is absorbed quickly by soils and not released as nitrous oxide.

Table 5: Direct Greenhouse Gas Emissions Associated with the Welsh Sheep Sector 2017

NAEI Source	Methane (CH_4)	Nitrous oxide (N_2O)	Greenhouse Gases Total	Per Head of Animal
	kt CO_2e			
Ewe	726	76	801	0.000161
Fat lamb	149	19	168	0.000053
Ram	17	2	19	0.000184
Replacement ewe	75	7	82	0.000092
Store lamb	89	10	99	0.000087
Total	**1055**	**114**	**1,176**	**0.000114**

Source: Derived from HCC commissioned research of the Wales Greenhouse Gas Inventory by RSK ADAS, 2020.

Beef Sector Emissions

With greater emissions associated with cows (see *Table 6*), ensuring breeding animals are at their productive optimum is critical for reducing the overall emissions associated with the production of beef. Factors including animal health and welfare, breeding efficiency and the use of superior genetics are crucial to improving the greenhouse gas intensity of Welsh Beef and production emissions level.

Table 6: Greenhouse Gas Emissions from the Welsh Beef Herd Presented as kt CO_2e

	Methane (CH_4)	Nitrous oxide (N_2O)	Total Emissions	Per head of animal
	kt CO_2e			
Beef females for slaughter	229	48	277	0.0017
Bulls for breeding	26	5	31	0.0020
Cereal-fed bull	62	18	80	0.0019
Cows in the herd (that have bred)	369	63	432	0.0026
Heifers for breeding	103	21	124	0.0017
Steers	303	64	366	0.0017
Total	**1,093**	**219**	**1,312**	**0.0019**

Source: Derived from HCC commissioned research of the Wales Greenhouse Gas Inventory by RSK ADAS, 2020.

Table 7 sets out the emissions directly associated with dairy cattle. As shown, only the female cattle involved in the dairy system are attributed to dairy cattle emissions. Male cattle (steers and bulls) are allocated to the beef sector as they enter the beef supply chain. Given the role of dairy beef within the red meat supply chain, improving the quality of the dairy progeny for the beef system would support the lowering of greenhouse gas intensity of Welsh Beef.[62]

Table 7: Greenhouse Gas Emissions from Welsh Dairy Cattle 2017

	Methane (CH_4)	Nitrous oxide (N_2O)	Total Emissions	Per head of animal
	kt CO_2e			
Dairy Calves Female	88	18	105	0.0014
Dairy Replacements Female	55	10	65	0.0017
Dairy In-calf Heifers	128	24	152	0.0018
Dairy Cows	1023	148	1170	0.0047
Total	**1,055**	**199**	**1,490**	**0.0033**

Source: Derived from HCC commissioned research of the Wales Greenhouse Gas Inventory by RSK ADAS, 2020.

In general, given the higher feed needs of lactating dairy cows compared with beef cows, the level of emissions per cow are significantly higher than that of the beef herd (0.0047 kt CO_2e compared with 0.0026 kt CO_2e).

2.2 Carbon Sequestration and Storage

Carbon sequestration is the process of increasing the carbon content of a carbon reservoir other than the atmosphere. Biological approaches to sequestration include direct removal of carbon dioxide from the atmosphere through the accumulation of carbon in biomass, and the subsequent release of carbon into soils from plant roots.[63]

Agriculture and land management can offset carbon dioxide in the atmosphere through sequestration, removing carbon dioxide from the atmosphere and storing it in soil, wooded landscapes and semi-natural habitats, primarily through photosynthesis. It is due to this unique process that agriculture – and Welsh agriculture in particular – can help address issues of climate change by absorbing carbon dioxide. This process could have a significant positive contribution to lower Wales' overall greenhouse gas emissions.

Carbon Sequestration in Grassland Systems

Globally, soils contain about three times the amount of carbon in vegetation and twice that in the atmosphere.[64] In the UK, soils store over 95 per cent of terrestrial carbon,[65] and in Wales, this figure is estimated at 150 million tonnes.[66] Land management choices can either maintain or increase the carbon store for long periods, or result in net emissions by altering the balance between carbon sequestration and carbon losses. For instance, peatlands represent a vast store of carbon in Wales. However, due to many being in a degraded state, it is estimated that they are a significant source of the country's annual carbon emissions;[67] whereas peatlands in favourable condition can sequester an estimated 200 kg C/ha/year.[68] Therefore, land use and management choices can have an important role in determining the amount of carbon released into the atmosphere or stored in the soil, meaning the significance of agricultural land management on carbon emissions should not be underplayed.[69]

While some of the carbon that enters soils will be mineralised and broken down during microbial processes, there will still be a gradual increase in soil carbon over time. Land-use change (e.g. the conversion of arable land to pastures, or afforestation) and practices that enhance soil carbon in agriculture (e.g. addition of organic amendments such as manures) also play an essential part in increasing the storage of carbon in soils.[70]

Whether agricultural soils are a carbon sink or source depends on several wide-ranging variables, including climate, soil type, land use/management, water availability and, most importantly, the actual organic matter content of the soil.[71]

However, estimating sequestration accurately is difficult. Changes in soil carbon tend to occur over many years, and the potential for sequestration is very dependent on soil type.[72] Management of those soils also has a notable impact on the rate of carbon sequestration, and collectively, these factors mean that predicting the sequestration potential of grassland systems is challenging. However, although challenging, sequestration in soils (and within on-farm biomass) should not be discounted, as it is part of the overall farm carbon balance.

Soils under permanent pasture are known to be a considerable store of carbon, with carbon assimilated from the cycling of root growth and death, followed by relatively slow decay, especially where rates of microbial turnover are subdued (e.g. cold, anoxic environments). Ostle et al. estimate that UK grasslands (including semi-natural) sequester 240 ± 200 kg C/ha/year, while croplands lose 140 ± 100 kg C/ha/year.[73] Wales has a relatively high prevalence of permanent pastures that are rarely cultivated, meaning that such systems should, in many cases, have built considerable stocks of carbon. Dung inputs from grazing animals on permanent pastures may also enhance soil organic carbon levels.[74] While the nutrient inputs facilitate associated biomass growth and the related above-ground carbon assimilation, a proportion of which (dead leaf matter) will be returned to the soil and thereby contributing to soil carbon.[75]

Permanent pastures generally also have deeper-rooting systems than annual crops as plant species grow a larger rooting network over time, thus will accumulate deeper layers of carbon sequestration in soils.[76]

Generally, fertiliser application rates on grassland systems typical in much of Wales are low,[77] which means that the greenhouse gas emissions associated with both the production (carbon dioxide from fossil fuel burning) and use (nitrous oxide from soils) of fertilisers are reduced. Dependency on artificial fertiliser can be further reduced where pasture systems contain clover or other legumes. The inclusion of legumes can also increase the protein content of pasture, meaning that the need for high-protein feeds grown elsewhere, such as soya, is reduced.

The removal of carbon dioxide over hundreds of years means that a huge amount of carbon is stored in Welsh grasslands. The UK National Atmospheric Emissions Inventory shows that the retention of existing grassland removed around 280kt CO_2e of emissions from Wales in 2018, demonstrating the vital role that grassland has in Welsh carbon sequestration.

Grazing and Soil Health

There is no doubt that the return of organic carbon to soils is of great benefit to the planet by removing carbon dioxide from the atmosphere and improving biological functioning. However, the quantity of additional carbon that can be stored in UK soils is currently unknown. It depends on the capacity of different soil systems to retain additional carbon, which depends on inherent soil characteristics (for example, texture, clay and pH) and management practices (for example, fertiliser, grazing and tillage intensities).[78]

Various farming practices can be undertaken which improve soil health and encourage carbon sequestration and storage. Examples include minimising cultivation (both in terms of frequency and depth), using perennial crops which allow organic matter to build up, having diverse cropping systems, and minimising soil compaction. Research has shown the grassland soils in the UK have a similar soil organic carbon (SOC) to clay ratio as forestry land in good soil health.[79] Whereas 40 per cent of arable soil was considered degraded, only 7 per cent of grassland soils were considered degraded.

Soil carbon, however, is not stored permanently. Turn-over of soil organic matter occurs continuously over a range of timescales and is sensitive to management and climate factors, resulting in some soils being a net source or net sink of organic carbon. As many UK soils are relatively rich in organic carbon when compared to those elsewhere, there may be challenges but also opportunities to manage these soils associated with maintaining or increasing existing soil organic carbon stocks. For grasslands which may have reached equilibrium grazing management will play a vital role in maintaining these carbon stocks as the main terrestrial carbon store.

Increasing soil carbon storage improves overall soil health and water holding capacity through improved physical microscale structure. Grassland soil through its higher SOC has improved physical structure (more numerous and more connected soil pores) which increases both water storage and hydraulic conductivity (the ability of water and gases to move through the soil). Limiting organic carbon inputs and tillage degrade this structure, and the hydraulic conductivity and water holding capacity are reduced as a consequence.[80] This structure is important because it allows oxygen to move through the soil, limiting the volume of anoxic space (with low oxygen concentrations). Low oxygen forces shift microbial metabolism and result in nutrient losses from soils, particularly of nitrogen as nitrous oxide. In high carbon, well-structured and more oxygenated soils such as grasslands, microbes assimilate nutrients into biomass more effectively, and nutrients are therefore retained in soil rather than lost.

The proportion of SOC a soil can retain before plateau is reached is a function of its clay content. Where some soils do not sequestrate further carbon by being at the optimum biological health and water holding capacity, they play an additional critical role in delivering important ecosystems. Maintaining the carbon stored in these soils is crucial to ensuring that greenhouse gases are not released into the atmosphere.[81]

Therefore, increasing soil organic carbon will contribute to net-zero carbon targets either directly through carbon capture or indirectly via soil health. The world's longest-running experiments at Rothamsted Research (some over 175 years) demonstrate that animal manures and grasslands are the best approaches to return carbon and therefore health to the soil.[82]

Table 8 sets out the changes to SOC from land-use changes. Negative figures represent a release of greenhouse gases into the atmosphere, and positive figures represent sequestration and the removal of greenhouse gases from the atmosphere. As shown, changing from either permanent grassland to any other use, or changing from forestry to arable or temporary grassland reduces the soil organic carbon, releasing greenhouse gases into the atmosphere. The land-use change that has the greatest positive impact on soil carbon is changing from temporary grass to permanent grass, estimated to lock 7.9 tonnes of CO_2e equivalent per hectare per year in the soils.

Table 8: Estimates of Change in SOC Stocks and Nitrous Oxide Emissions Resulting from Land-Use Change on Mineral and Organic-Mineral Soils

	Mean Greenhouse Gas Emissions (t CO_2e/ha-^{1}/yr-^{1})
Permanent grass to arable	-9.3
Permanent grass to temporary grass	-7.9
Permanent grass to forestry	-2.25
Arable to permanent grass	3.91
Arable to temporary grass	0.39
Arable to forestry	1.59
Temporary grass to permanent grass	7.9
Temporary grass to arable	-1.54
Temporary grass to forestry	1.59
Forestry to permanent grass	1.54
Forestry to arable	-6.16
Forestry to temporary grass	-6.16

Source: Smith P, Bhogal A, Edgington P, Black H, Barraclough D, Worrall F, Hillier J & Merrington G. 2010. Consequences of feasible future agricultural land-use change on soil organic carbon stocks and greenhouse gas emissions in Great Britain.

This carbon storage and sequestration is not captured in the agriculture output in the national greenhouse gas inventory, but as a separate element within LULUCF. When reviewing Welsh agriculture's progress in reducing carbon emissions, it is important to consider its impact on LULUCF as well as the agriculture element of the greenhouse gas inventory.

In Wales, ambitious targets to enhance woodland cover on farms are largely driven by the Welsh Government's greenhouse gas emission reduction targets. The carbon uptake by growing trees can be counted to off-set emissions elsewhere, so reducing net emissions.

The evidence for the potential of trees to reduce net emissions is clear: their large above-ground biomass can store a significant amount of carbon, whilst their enhanced root systems facilitate the sequestration of carbon into soils. However, there exists considerable uncertainty about the potential and rate of sequestration in woodland, with factors such as species planted, rotation length, soil types, climate, and management bearing significantly on results.[83] Whilst research shows that afforestation could certainly play an important part in helping farms off-set their greenhouse gas emissions, it is crucial it is carried out with due consideration of the broad range of potential impacts.

Disturbance of carbon-rich soils for the purpose of afforestation can lead to increased carbon emissions and erosion losses from soils. These emissions may take many years to be off-set from the increased biomass growth per year offered by trees over pasture. Similarly, where trees are planted on organic-rich soils, typically peats, the subsequent drying of soils leads to microbial breakdown and oxidation of carbon, generating carbon losses.[84] Such effects may be exacerbated under changes in precipitation patterns and extreme weather events such as drought predicted under a climate-changed future.

Consideration should also be given to potential indirect increases in carbon (or "carbon leakage") from inconsiderate afforestation. There is a need to recognise the risk of soil carbon losses occurring when land-use change to increase carbon storage (e.g. afforestation) is offset by compensatory land use conversions elsewhere that result in net carbon release.[85] Inappropriate afforestation of productive land may mean that more land is used elsewhere to generate the same yield of product.

Targeted increases in woodland cover on Welsh farms can be advantageous as it can offer many environmental benefits over and above carbon sequestration, and in many cases, benefits to the economic viability of farm businesses. However, the emphasis should be that of integration with, as opposed to displacing, existing farm systems, and a full assessment of the overall impacts on-farm carbon balance is needed.[86]

In addition to carbon sequestration and soil health, energy generation forms an additional potential positive contribution of Welsh agriculture to mitigating climate change. By 2018-19, 18 per cent of farms in Wales had installed renewable energy.[87] However, this is not reflected in the Agriculture section of the *UK Greenhouse Gas Inventory*. Instead, it is captured within the Energy subsector. Further development of installed renewable energy capacity on farms helps to offset carbon emissions associated with red meat production and should be reflected in the red meat greenhouse gas footprint.

Like almost all economic activity, beef and lamb production, if considered in isolation from the broader implications of land management, will be a net producer of greenhouse gases. The sector should not, however, be viewed only through the simplistic measure of the amount of greenhouse gases emitted, as this would not consider the highly complex and inter-dependent platform (i.e. the farm) on which the production of beef and lamb occurs. Some farms in Wales may already be carbon neutral through activities such as the production of renewable energy and carbon sequestration, and this should be considered when looking at current performance and levels.

2.3 On-Farm Audits and Analysis

Measuring the greenhouse gases from agriculture is more complicated than for most other sectors. Whilst others review the carbon dioxide associated with fossil fuel consumption, in agriculture, emissions relate to the natural biological processes, which vary greatly depending on a wide range of environmental and production processes. There are two main ways in which the greenhouse emissions associated with UK agricultural production are presented – National Inventory Data and Lifecycle Assessments.

- The National Inventory, following methodological agreements set out by the Intergovernmental Panel on Climate Change (IPCC), uses emission factors to capture the impact of sector activity. The Inventory focuses on the on-farm activity of agriculture. The majority of direct emissions from ruminants, such as methane and nitrous oxide, are based on both UK specific measurements of emission factors and activity data such as fertiliser inputs and animal weights.
- A Lifecycle Assessment approach typically reviews all the elements that contribute to production both within the focus territory (e.g. UK) and outside. There are several models, which differ by the complexity of information required and how precisely the model can account for on-farm and production variances. However, most lifecycle approaches do not consider the carbon sequestration that takes place on farms.

As part of the analysis of the current carbon footprint of sheep and beef farming in Wales, HCC has worked with Bangor University, in collaboration with the University of Limerick, to analyse detailed data from a sample of 20 Welsh farms. The farms form a cross-section of agricultural businesses, including those in upland and lowland areas, and those keeping cattle, sheep or both.

Given that Welsh agriculture activity has both a positive and negative impact on greenhouse gas emissions, for this assessment, an updated version of the Bangor University Carbon Footprint tool was used. This uses a combination of IPCC (2006; Tier 1) guidelines for emission calculations and a summary of the improved methods (Tier 2) recently developed for UK agriculture following the completion of an extensive seven-year government funded research programme to improve the reporting of greenhouse gas emissions and track the effects of mitigation measures. The improvements have included significant revisions to nitrous oxide and methane emission factors, based on measurements at representative sites across the UK, and the incorporation of UK animal feeding system models and surveys of agricultural practice to better represent changes over time.[88]

The tool, which is validated to PAS2050 standards, takes into account both greenhouse gas emissions and carbon sequestration that happens on farms, up to the “farm gate”. Model outputs are expressed as greenhouse gas emissions per unit of product (e.g. kg of lamb liveweight). The model also provides estimates of the amount of carbon sequestered on each farm per annum by soils, woodlands, individual trees and hedgerows.

A comparison of this analysis with previous estimates of greenhouse gas emissions from livestock agriculture in Britain suggests that Welsh farms could potentially have a lower carbon footprint than has been hitherto assumed, particularly if sequestration effects are taken into account. Table 9 sets out the results from two sources of UK agriculture lifecycle approaches to greenhouse gases.[89]

Table 9: UK agriculture lifecycle approaches to Greenhouse gases

	Centre for Innovation Excellence in Livestock (CIEL)	Bangor University	Bangor University
	Emissions (kg CO_2e/kg liveweight) Without sequestration effect	Emissions (kg CO_2e/kg product) Without sequestration effect	Emissions (kg CO_2e/kg product) Including sequestration
Hill Sheep	17.9	10.1	7.6
Upland Sheep	12.9	12.5	10.5
Lowland Sheep	10.9	11.5	9.5
Hill Beef	21.2* / 16.0**	14.0	10.7
Upland Beef		11.7	8.8
Lowland Beef		15.5	13.7

* Carbon footprint of suckler herd on white clover and perennial ryegrass mixed sward

** Carbon footprint for beef production during finishing on white clover and perennial ryegrass mixed sward

Source: HCC, using data from the commissioned research from Bangor University, in collaboration with the University of Limerick; and from the Centre for Innovation Excellence in Livestock. Net zero carbon and UK livestock (2020).

It is important to note that it is difficult to compare the outputs of the studies directly. However, the variance itself illustrates the breadth of results obtained through lifecycle approaches. Notably, the Bangor University study results show that it is possible for a hill sheep system to have a low CO_2e per unit of output, significantly lower than captured in other industry studies.

The carbon footprints of these selected Welsh farms are amongst the lowest reported for lamb and beef producing countries. Comparing the figures derived from the Bangor study to global values is difficult given that data obtained from different studies have different assumptions and methodologies. However, a 2018 meta-analysis by the University of Oxford sought to compare the farm stage emissions of various studies across the world.

This study showed that the farm stage detail of beef (from the beef herd) from 35 studies from twelve different countries had a range of 25.5kg – 119.7kg CO_2e/kg meat. Another study has suggested that the Western Europe and Global footprint for beef production from the suckler herd was 32.0kg and 37.3kg CO_2e/kg liveweight respectively.[90] The farm stage detail for mutton and lamb from 12 studies in seven different lamb-producing countries had a range of 11.9kg to 60.9kg CO_2e/kg meat according to the Oxford meta-analysis, but with most of the values falling between 20-35.

Whilst caution must be exercised in directly comparing these figures, the Bangor University study does indicate that Welsh lamb and beef producers have the potential to be some of the most sustainable production systems globally.

There are many ways in which Welsh farms can reduce their carbon footprint, which deliver the co-benefits of improving efficiency and productivity. Supporting farms to achieve lower emission systems such as those captured through the Bangor University study would ensure the overall impact of Welsh livestock production is reduced while also maintaining production, economic activity and increasing sustainability.

The Bangor University lifecycle audits also highlight the vital role that carbon sequestration has in reducing the overall emissions associated with livestock production. Having an effective mechanism for capturing the impact of sequestration on farm emissions would help the industry account for this value, and make better use of the sequestration potential of their farming units.

Despite the results for the 20 participating farms appearing to be at the lower end of those reported in previous studies, there was still a considerable range of results between the largest and smallest footprint for both beef and lamb. Such a range in values is not unexpected, and reflect the geographical and management differences between different farms, factors that all collectively contribute to the variability in data.

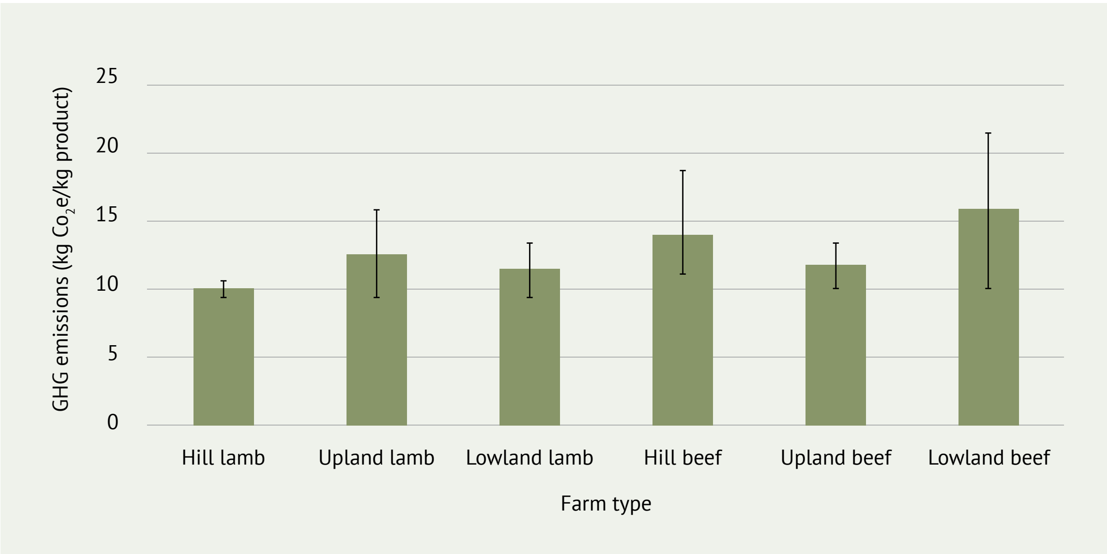
Analysis of these variances can help illustrate where best practice exists, and contribute to establishing which on-farm policies or interventions may be effective in reducing emissions or maximising carbon sequestration.

Emissions

As is to be expected, enteric fermentation accounted for the overwhelming proportion of emissions in both sheep and beef farms. For beef systems, manure management and upstream emissions (for the production of feed) also accounted for notable proportions of the total. Given the generally greater use of fertiliser inputs in cattle systems, emissions of nitrous oxide from soils were greater in beef production relative to sheep. The data shows there is variation in the estimated footprint per farm type between the farms studied, with emissions per kg of product generally higher for beef than for lamb.

As can be seen from the figure below, beef produced in lowland systems had the largest greenhouse gas emissions per kg of product, which reflected the greater use of inputs such as fertilisers and creep feed – but which achieved only a relatively small increase in outputs. Beef produced in hill systems had similar emissions on average, which, as opposed to being a function of fertiliser inputs, reflected lower growth rates and longer finishing times. On the other hand, hill lamb, although lower in terms of output weights than lowland lamb, tended to be farmed in very low-input systems.

Figure 5: Average greenhouse gas emissions per unit product across the study farms



N.B. The T-bars are '± standard error of the mean'.

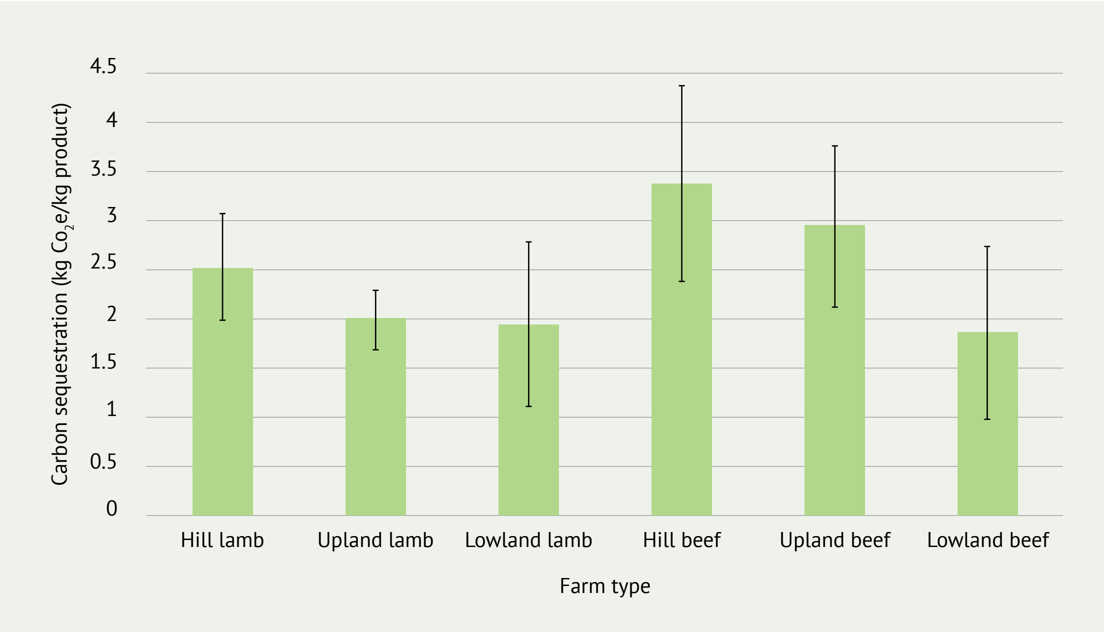
Source: HCC commissioned research from Bangor University, in collaboration with the University of Limerick.

Enteric methane emissions and nitrous oxide emissions arising from excreta deposition and manure application to soil were two of the most important contributors to emissions across all farm types. A well-managed flock or herd will optimise livestock growth rates, reducing their days on farm and the associated emissions. This also necessitates fewer inputs, such as feed and medicine.

Sequestration

The greater emissions for some production systems will be at least partly off-set by the enhanced sequestration in such systems. In this study, sequestration was highest for hill and upland farms.

Figure 6: Average carbon sequestration across the study farms



N.B. The T-bars are '± standard error of the mean'.

Source: HCC commissioned research from Bangor University, in collaboration with the University of Limerick.

Although soils were a notable source of nitrous oxide, the sequestration of carbon within grassland systems was also the largest offset of emissions for all farm types. It should be remembered that the rates of sequestration in soils can be highly variable, and depend on climate, soil type, land management, water availability and, most importantly, the actual organic matter content of the soil. The values reported here are, therefore, best-estimates with the data available.

The capacity to make significant further gains in sequestration may be limited in soils under permanent grasslands as they are likely to often be at a state of carbon equilibrium. However, many of the participating farms were implementing measures that could be promoting further sequestration of carbon in soils. Firstly, dung inputs from grazing animals on permanent pastures may enhance soil organic carbon levels. Also, the nutrient inputs from grazing animals facilitate biomass growth, and the associated above-ground carbon assimilation, a proportion of which (dead leaf matter) will be returned to the soil and thereby contributing to soil carbon.

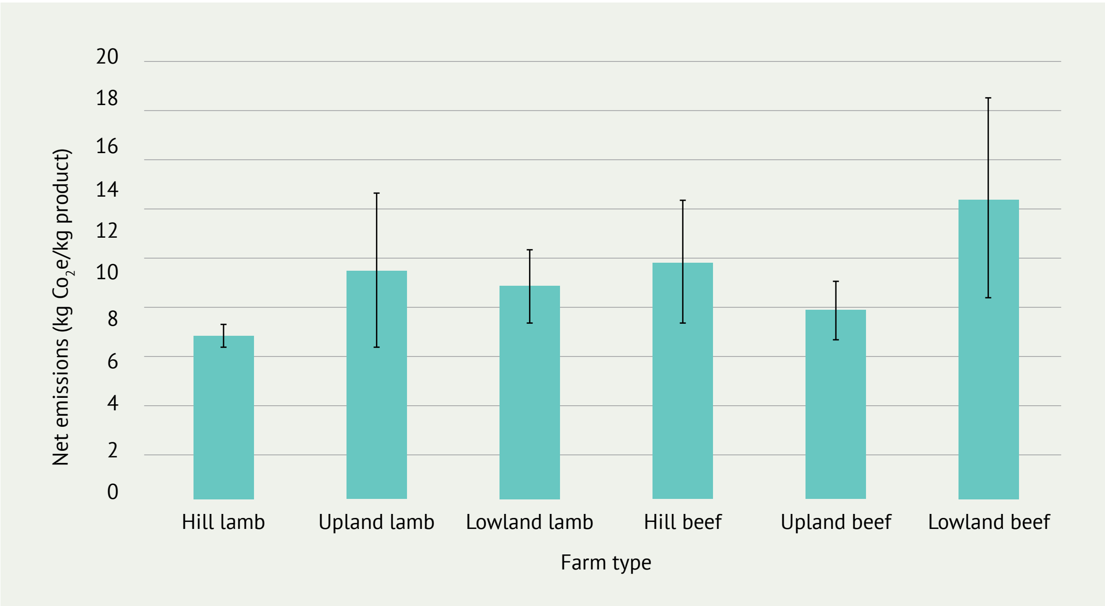
All of the participating farms were practising a rotational grazing approach in at least parts of their holdings. Compared to set-stocked systems, rotational systems allow 'rest' periods for grass to recover post-grazing, which can enhance overall grass yields if grazing occurs at the optimal grass growth stage. In turn, as well as increasing above-ground biomass, this should increase root growth and therefore, carbon inputs to soil; though further research is needed to validate this.

As an average across farms, comparatively few emissions were sequestered in woodland and hedgerows. Strategic planting of trees and hedgerows could help increase carbon sequestration both above- and below-ground (soil). Further opportunities to increase tree cover in a way that complements, and indeed enhances livestock performance (e.g. through shelter provision) could be encouraged in Wales as a strategy to reduce net emissions from Welsh livestock systems.

Net emissions

On balance, the results found that net emissions (carbon emissions minus sequestration) were marginally greatest for lamb from upland farms, and beef from lowland farms.

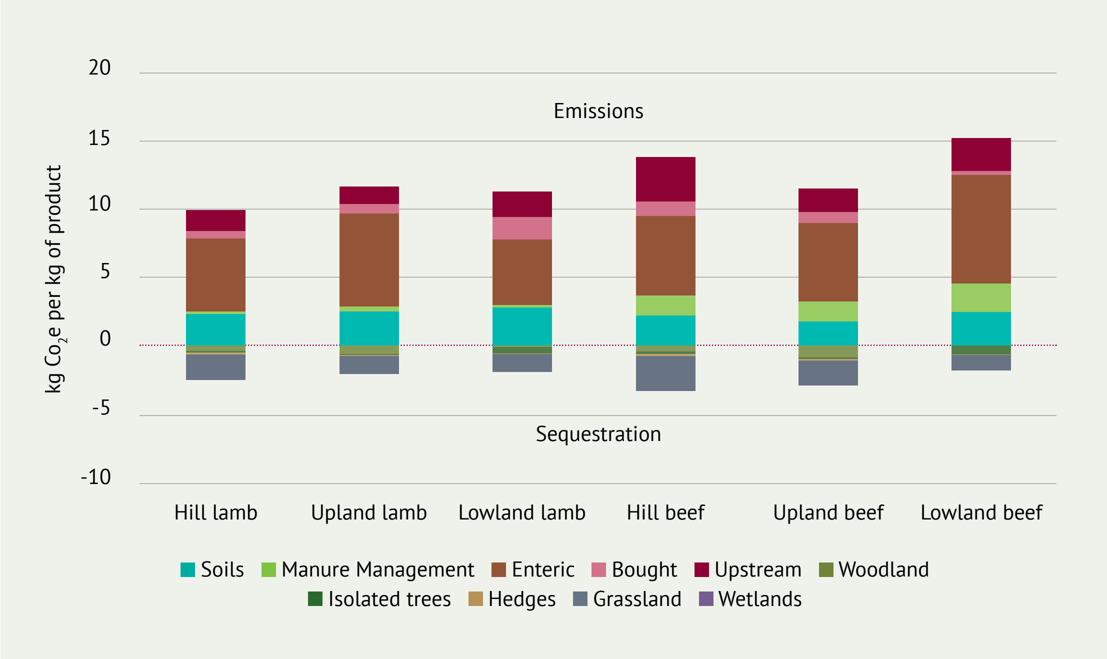
Figure 7: Average net carbon emissions across the study farms



N.B. The T-bars are '± standard error of the mean'.

Source: HCC commissioned research from Bangor University, in collaboration with the University of Limerick.

Figure 8: Average carbon footprints for the study farms, broken down by greenhouse gas sources



Source: HCC commissioned research from Bangor University, in collaboration with the University of Limerick.

Other considerations

As is typical of sheep and beef farms, energy usage on the participating holdings was generally low, and considerably less than would be expected on more intensive production systems (e.g. dairy or pigs). As a proportion of the farms' overall greenhouse gas balance, energy usage therefore accounted for a small proportion of total emissions. This is especially the case due to the increasing decarbonisation of grid electricity.

Two of the farms had invested in renewable energy technologies (wind turbine, photovoltaic panels, and an anaerobic digestion (AD) plant), which reduced the usage of electricity on-farm and therefore reduced emissions. However, under current greenhouse gas reporting frameworks, farmers do not gain any benefits or credit for reducing direct energy consumption, so consequently, the emissions saved were not counted in this study. Nevertheless, by producing renewable energy which is then supplied into the national grid, farms can help the broader economy move towards becoming net zero.

Water-use data was not collected in this survey but is typically low on sheep and beef farms relative to other food sectors. Where farms have access to private water sources, it is also worth noting that this too will contribute to a reduction in greenhouse gas emissions through the avoidance of energy expenditure associated with the treatment and delivery of mains water.

The information collected through these carbon audits provides a snapshot of the emissions currently associated with sheep and beef production systems on a selection of farms in Wales. Collecting and monitoring this data is key for the industry to progress as it will identify opportunities for technical improvements that will ultimately reduce emissions and also increased profitability.

Work remains to be done at an international level to arrive at an agreed methodology for measuring sequestration. There is still a considerable discrepancy between figures estimating how much carbon is being released or trapped by the complex processes. However, it is important to take account of the sequestration inherent in grassland and other farmland practices to fully understand greenhouse gas emissions associated with production.

2.4 Wider Supply Chain

The red meat supply chain is committed to reducing its impact on the environment and improving its sustainability credentials. The cross-industry vision '*Meat in a Net Zero World*' sets out a UK meat industry commitment to reduce greenhouse gas emissions and waste.[91]

From the point of receipt at an abattoir, through cutting, processing and packing into the final product, very little goes to waste. Currently, processors report that up to 2 per cent of throughput ends up as 'wasted food' (excluding the inedible parts never intended for human consumption). The majority of this food waste is used for renewable energy generation via anaerobic digestion or is spread on land as fertiliser. While waste levels are very low, resources like energy, fuel and water are used in processing and efforts are focused on reducing the amount – and impacts of – energy and water consumed.

Leading meat processing businesses have committed to adopting actions within the WRAP and IGD Food Waste Reduction Roadmap. These call on businesses to set an ambitious food waste reduction target, report on progress and take action to reduce food waste. As well as the intake of animals, the processing sector uses other resources – e.g. water and energy. Leading businesses have been focusing effort on improving energy efficiency, switching to renewables, reducing water consumption and improving water quality.

In the *Meat in a Net Zero World*, there is a commitment that 75 per cent of the UK's meat processing capacity will take action to:

- Reduce food waste in processing operations by 50 per cent by 2030.
- Reduce emissions from processing operations.
- Improve the efficiency of water use in processing operations and actively support wider water stewardship in key sourcing areas.[92]

Significant progress has already been achieved with 14 of the UK's largest processors signed up to Food Waste Reduction Roadmap. Between 2017 and 2018, food waste was reduced by around 10,000 tonnes, including more than 1,000 tonnes (or 5 million meal portions) redistributed to local communities.[93] Greenhouse gas emissions from meat processing decreased by 10 per cent between 2015 and 2017, [94] with energy intensity of meat processing falling from 7.0 TJ/£m in 2015 to 6.6 TJ/£m in 2018.[95]

In conclusion, the new research presented in this document suggests that net emissions from livestock farming in Wales may be lower than previously assumed, particularly if carbon sequestration is taken into account. It certainly shows that the potential exists for genuinely sustainable, low-intensity agriculture which can both produce high-quality food and contribute positively to reducing the country's net greenhouse gas emissions.

3 Pathways Towards Sustainability

Wales can already point to important ways in which its systems for producing lamb and beef are sustainable in comparison with many others in the world. But, the sector is also determined to minimise emissions and maximise positive contributions such as carbon sequestration and soil regeneration.

This document sets out key actions to reduce the overall impact of red meat production on global warming. It looks to drive productivity improvements that will enable more output to be realised for each unit of greenhouse gas emitted. This will help realise both a further reduction in the greenhouse gas intensity of Welsh red meat and the absolute level of greenhouse gases emitted from agriculture.

3.1 On-Farm Mitigations

The greenhouse gas emissions relating to Welsh red meat are predominantly associated with livestock. The more productively the animals are farmed, the lower the greenhouse gas intensity of red meat production. Improving productivity so that more can be produced with fewer inputs provides the mutual benefit of improving farm profitability and environmental sustainability.

As shown by the UK National Atmospheric Emissions Inventory, breeding animals (cows and ewes) contribute more greenhouse per head than other smaller animals (lambs and calves). Ensuring the productive use of breeding stock is critical to reducing the greenhouse intensity of livestock production. This could enable the same level of red meat output to be maintained or increased, while potentially reducing the number of breeding animals required.

Solutions that are suitable for farm units of hill and upland areas will be different from those in lowland areas. There are also interdependencies within farm structures, illustrated by practices such as the buying and selling of store animals, overwintering and crop production.

We must also ensure that we can future-proof the industry to cope with the droughts, heavy rainfall, storms and flooding that are an inevitable part of the increasingly unpredictable and extreme changes in climate.

There are very few quick fixes – rather a series of incremental changes that taken together with have a significant impact on the emissions of Welsh red meat production. It is recognised that many of the changes needed will take a long time before their effects are visible at farm level and even longer before the impact will be reflected in national performance indicators. This document, therefore, reflects the long-term investment needed by the sector, with early indicators taking up to five years to achieve and the medium to long term benefit taking 10-15 years to realise.

Many of the measures needed are not new, but their application within the diverse range of livestock systems in Wales are within the industry's capabilities and must be prioritised.

The activities cannot be taken in isolation. Progress must be made in all areas within the potential of the land and the livestock in each farming system. Many of these activities are inter-related, and together these can have a significant impact on the economic and environmental performance of sheep and beef enterprises.

Optimising Health, Welfare and Breeding Capacity

Optimising animal health and welfare is one of the simplest and most effective ways to maximising the efficiency and the outputs from Welsh flocks and herds. Whether beef or sheep, upland or lowland, active health planning undertaken in conjunction with the farm vet and taking into account herd and flock performance from the previous season ensures that issues can be identified and actions taken to improve fertility, reduce losses and to optimise growth and development. This proactive approach to disease prevention will also help to reduce the use of antibiotics on Welsh sheep and beef farms.

By improving the health of both breeding stock and finishing stock, the amount of meat produced per cow or ewe is maximised. The result is, animals can be marketed earlier, leading to a more productive and profitable enterprise while also lowering greenhouse gas emissions.

Genetic Improvement of Livestock

Genetic improvement generates efficiencies of production and livestock that are better suited to market requirements, and its impact is cumulative over time, bringing long-term benefits. This has also shown to bring environmental benefits in terms of reduced greenhouse gas emissions by improving growth rates, thereby reducing methane emissions over the animal's lifetime and having improved feed conversion efficiency.

With the increasing availability of performance recorded breeding stock and opportunities to direct herd improvements through the use of sexed semen, genetic improvement is a relatively simple way to achieve measurable improvements across all production systems.

Soil and Nutrient Management and Carbon Capture

Increasing soil organic matter (of which approximately 45 per cent is carbon) can also bring about many positive impacts on soil quality. Included is improving water infiltration, and the retention of water and nutrients; enhancing soil temperature and thus plant productivity, and increasing the resilience of soils to compaction from machinery and livestock. Increasing the rate of carbon sequestration within Welsh red meat production would bring about significant benefits in offsetting red meat emissions and in farm productivity.

Knowing the composition and condition of the soils on Welsh sheep and beef farms is also crucial so that producers can make the most from their soil and better understand how soil can help make farm businesses more profitable and more sustainable.

Livestock Nutrition

Correct and targeted nutrition is the key to producing more, and better quality, calves per cow and lambs per ewe. This ensures there is less waste and less associated emissions. It, therefore, plays an essential and underpinning role in achieving both economic and environmental sustainability on Welsh sheep and beef farms.

Grazing and Pasture Management

Good grazing management balances the amount of grass grazed with the amount of grass grown. Similarly, making full use of silage crops and preventing silage waste when feeding livestock has the potential to maximise the use of grass crops. These have obvious economic and environmental benefits, such as reducing the need for bought-in feed.

Selecting grass and forage mixes to suit production needs is key. Swards for grazing need to maintain productivity during the grazing season and provide persistent, dense ground cover.

Selection for Slaughter

Selecting animals for slaughter at their optimum finish reduces both direct on-farm emissions and further supply chain waste, which has a dual benefit of improving the environmental and financial sustainability of Welsh agriculture.

Renewables and Energy Efficiency

Non-intensive Welsh Beef and Welsh Lamb production does not draw heavily upon electricity or fossil fuels. Nevertheless, the Welsh red meat sector can contribute to national targets by installing and using renewable energy, reducing fuel use, and being more energy efficient.

According to the Welsh Government Farm Business Survey, the proportion of Welsh farms with diversified renewable energy activity has increased to 18 per cent between 2010-2011 and 2018-19.[96]

3.2 Calculating the Potential for Reducing Emissions

To quantify the interventions noted here, HCC commissioned detailed research from RSK ADAS to examine the further positive contribution that Welsh livestock agriculture can make towards meeting the climate challenge.

As will be shown, improvements in animal performance measures have the potential to markedly reduce the intensity of greenhouse gas emissions, especially methane. This includes improvements such as addressing overall feed intake, reducing finishing time, increasing the number of animals finished per breeding animal, and reducing the number of replacement animals carried on farm.

Data from Welsh farms shows that there is substantial scope to improve the productive outputs of farms so that more output per head is achieved from the breeding stock. In 2018, data from the *Red Meat Benchmarking Project* shows that the top quartile of farms produced over two thirds more lambs for sale and a third more calves per cow than those in the lowest quartile.[97] Increasing the output per head within the productive capacity of farms, without increasing bought-in inputs such as feed and fertilisers, would drive improvements in farm sustainability from both an environmental and financial perspective.

As some Welsh farms are already achieving the higher performance measures, it is assumed that the wider adoption of new-to-farm practices could deliver an improved performance measure without compromising the improvement of any other measure.

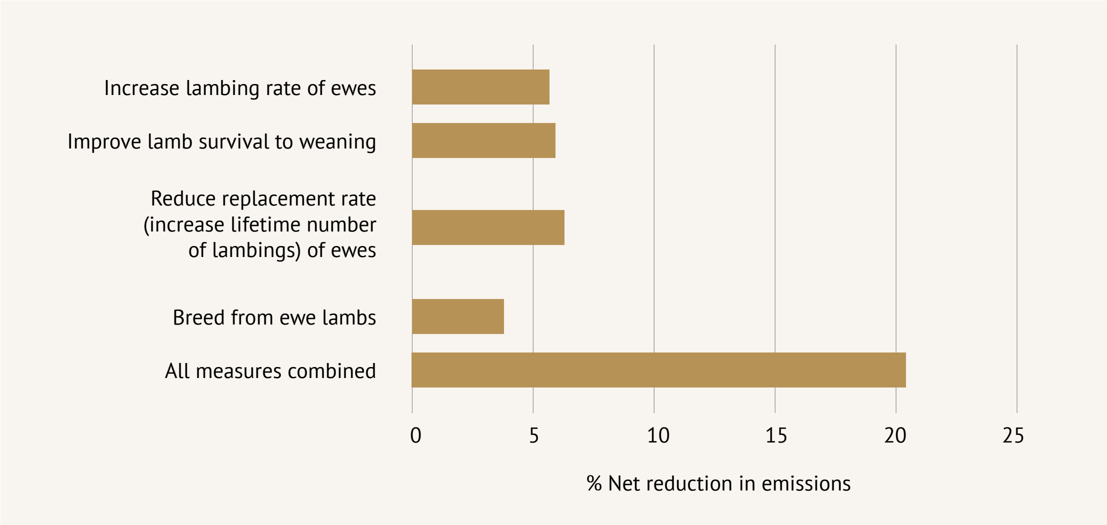
The improvement scenarios investigated are based on an assumption of maintaining baseline levels of prime meat production, responding to demand for high quality Welsh red meat and contributing to global food security.

Baseline nitrous oxide and methane emissions from the sheep and beef sectors in Wales were calculated using the improved and integrated Agricultural Ammonia and Greenhouse Gas Inventory (AAGGI) using farm activity data for 2017. The emission calculations in this analysis included a share of the emissions arising from fertilisation of improved grassland for grazing and silage production. However, the calculations excluded carbon dioxide emissions arising from on-farm energy use, embedded in the manufacture of inputs (included fertilisers and purchase feeds), and carbon sequestration. The emissions values presented are, therefore, only a partial reflection of Welsh red meat production.

When expressed on a carbon dioxide equivalent basis, GWP100, baseline total emissions were 1,325 kt CO_2e from sheep and 1,444 kt CO_2e from beef, and when combined represented 49 per cent of total emissions from the entire Welsh agricultural sector. Methane emissions from enteric fermentation and manure management accounted for the majority (78 per cent) of emissions from the combined sheep and beef sectors, followed by nitrous oxide emissions from manufactured fertiliser applications to grass (10 per cent), manure management (7 per cent) and excreta returns at grazing (5 per cent).[98]

For the sheep sector (see *Figure 9*), a combination of gains in all performance measures delivered an emissions reduction of 20.4 per cent. A selection of measures individually delivered a 5.7 per cent reduction from the production of additional lambs per mature ewe put to the ram. Also, there is a 5.9 per cent emissions reduction from improved lamb survival; a 4 per cent reduction from the widespread adoption of breeding from ewe lambs; and a 6.1 per cent reduction from extending the productive lifetime of a mature ewe.

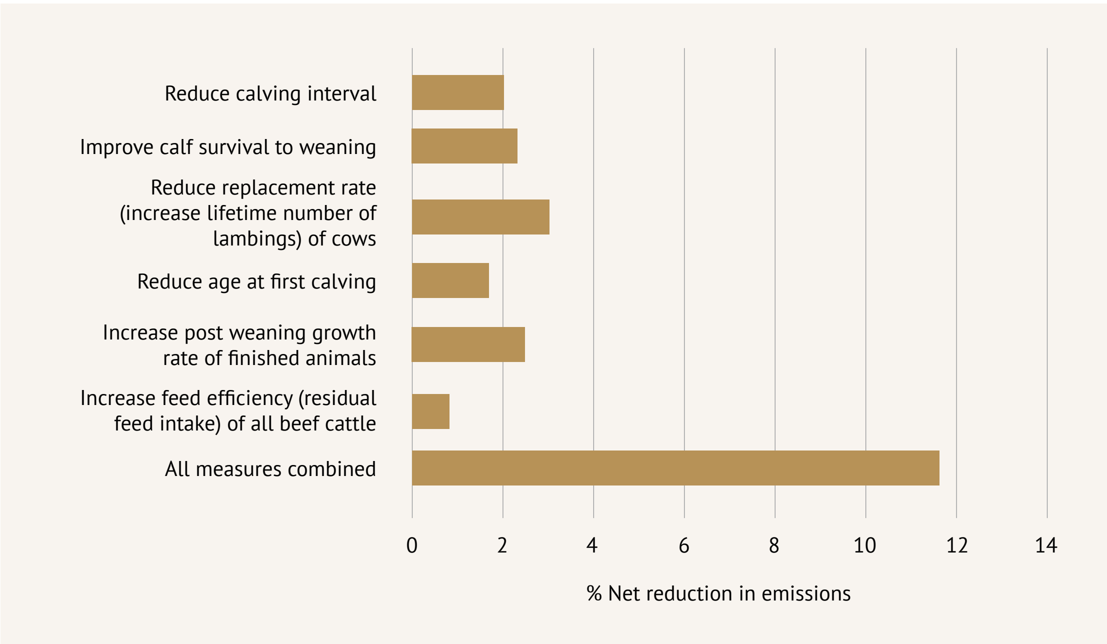
Figure 9: Net Effect of Sheep Sector Performance Improvement on Greenhouse Gas Emissions (while maintaining same level of prime lamb output)



Source: HCC Commissioned Research by RSK ADAS. 2020.

For the beef sector, a combination of gains in all performance measures delivered an emissions reduction of 11.6 per cent (see *Figure 10*). A selection of measures individually delivered a 2.1 per cent reduction from a reduction in calving interval from 426 to 400 days; a 2.5 per cent reduction from a 10 per cent increase in post-weaning growth rate; a 1.7 per cent reduction as age at first calving was reduced from 34 to 28 months; and a 2.2 per cent emission reduction from improved calf survival. Potential gains in the beef sector were diluted by a large (45 per cent) contribution of calves sourced from the dairy herd that did not benefit from beef suckler cow improvements in calf rearing.

Figure 10: Net Effect of Beef Sector Performance Improvement on Greenhouse Gas Emissions (while maintaining same level of prime beef output)



Source: HCC Commissioned Research by RSK ADAS. 2020.

As demonstrated by Table 10, a 20 per cent reduction in sheep sector emissions and an 11 per cent reduction in beef sector emissions (all other things being equal) would see Welsh agriculture emissions reduce by around 7.5 per cent, while the total volume of prime lamb and prime beef output would remain constant.

Table 10: Estimated Net Effect of Improvements in Sheep and Beef Emissions on Welsh Agriculture Emissions

	2017 Baseline	Scenario emissions	Percentage change
Sheep	1,325	1,060	-20%
Beef	1,444	1,285	-11%
All Other	2,865	2,865	0
Total	**5,634**	**5,210**	**-7.5%**

Source: Derived from HCC Commissioned Research by RSK ADAS. 2020.

When compared to literature values for the full carbon footprint of lamb and beef produced in Wales, the combined performance measure reductions in nitrous oxide and methane emissions represent a potential 5 per cent to 10 per cent reduction in emission intensity.

3.3 Wider Supply Chain Mitigations

There is also an important role for the wider Welsh red meat industry in reducing greenhouse emissions.

The diversity of scale of Welsh red meat abattoirs and processing facilities presents different challenges but also offers considerable opportunity to align with industry best practices and demonstrate progress.

HCC is a signatory of *Meat in a Net Zero World* and will look to work with the meat processing sector to support its actions to reduce the emissions and waste and promote the good practice already underway in the industry. As a relatively concentrated sector, the scope to achieve the ambitious targets are well within reach, with key partners already signed up and committed.

Irrespective of size, each processing site in Wales has a responsibility to:

- Review efficiency and environmental management. Larger processors will already have environmental management systems in place to improve efficiency and reduce management and disposal costs. Smaller processors should develop an environmental management plan to review and reduce aspects such as carbon, energy, waste, effluent and packaging.
- Reduce the use of natural resources, predominantly water usage.
- Increase energy efficiency and the use of renewable energy sources such as wind turbines or solar power.
- Reduce waste and consider new opportunities and technologies for maximising meat yields and explore markets and further processing of both edible and non-edible product including practical and cost-effective mechanisms for the re-use, recycling, recovery and redistribution of waste. This includes opportunities to create energy from waste and reduce the levels of waste that might go to landfill. It is recognised that the recycling and reuse of soiled materials presents a considerable challenge for Welsh red meat processors.
- Increase the use of sustainably sourced packaging. Packaging presents a considerable challenge for the red meat supply chain with packaging materials, predominantly plastics. It is crucial for maintaining hygiene, and preventing microbial contamination while maintaining the physical, chemical and sensorial qualities of beef and lamb. Alternative, innovative packaging must be robust enough to maintain all of these and secure shelf-life of product throughout the distribution and marketing process.
- Livestock sourcing. Sustainable processing starts with the sourcing of healthy livestock that meet market requirements. Communication and promotion of standards of animal health and welfare to suppliers will help reduce carcass losses due to bruises, abscesses, lameness and supply of dirty livestock; and support the more efficient production of livestock.

Progress in some of these areas is dependent on factors beyond the scope and the control of our Welsh red meat processing sector – this includes the ability to develop waste processing capability in Wales including rendering facilities and for plastics.

4 Conclusions

This document began by acknowledging the urgency of climate change and the food security crisis that the world faces.

Given the scale of the problem, it is incumbent on each country and each economic sector within those countries to engage seriously with how it can contribute to mitigating the huge challenges.

This document has examined the 'Welsh Way' of lamb and beef production in the context of new policy and research in the field of climate science, and undertaken detailed research on the current situation on a representative sample of Welsh farms. It has also explored the potential for further improvement.

Conclusions may be summarised as follows:

1. **Policy regarding agriculture and climate change should take into account new research on the relative impact of different greenhouse gases.**

   Influential new work on the short-lived nature of methane as a climate gas offers the opportunity for a more accurate and nuanced assessment of the impact of livestock agriculture.

2. **Whether old or new methane calculations are used, there is potential for agriculture to reduce its emissions and increase its positive contribution to mitigating climate change.**

   While the Welsh red meat sector is already adapting systems and seeking to mitigate emissions (Welsh agriculture emissions fell by 11 per cent between 1990 and 2018), there is room for further improvement; a challenge the industry is ready to face.

3. **By taking advantage of its natural advantages, the 'Welsh Way' of producing lamb and beef can be a global exemplar of a sustainable, low-emissions system.**

   Wales already has a good story to tell. Our sheep and beef sectors produce quality food on land which is largely unsuitable for other productive purposes, in non-intensive ways which depend on fewer additional inputs, therefore placing less stress on land and water resources elsewhere in the world. Although it is challenging to compare studies which use varying methodologies, the evidence suggests that emissions in Wales are already among the lowest of red meat producing countries.

4. **The impact of hill farming, in particular, may be lower than previous studies have reported.**

   Research undertaken for this study, evaluating the emissions of a representative cross-section of Welsh farms using new and more thorough methodologies, has suggested that the climate impact of sheep and beef farming here is less than was previously thought. Sequestration must also be taken fully into account. Soils represent a hugely important store of carbon. Given that the overwhelming proportion of land in Wales is managed for agricultural purposes, this puts the sector in a really important position: soils could be a notable source or sink of carbon, depending on how they are managed. There is, therefore, a need for sequestration on agricultural land to be given the same focus as emissions, as it plays a notable part in the carbon balance of farms.

5. **Radical changes in land-use do not offer the most effective way to maximise rural Wales' contribution to mitigating climate change.**

   Maintaining a critical mass of livestock production helps ensure the economic and cultural sustainability of Wales. It also assists Wales – as a country which is ideally placed to produce high-quality food from marginal land using few additional inputs - in meeting its global food security obligations and its duty not to 'off-shore' its emissions to more vulnerable global regions. Limited changes of land use, for instance through targeted forestation or renewable energy generation, have a role to play. However, such changes can also have a negative short-term impact, so any such interventions need to be well-researched and integrated within farm systems.

6. **Wales should prioritise efficiency measures which reduce emissions while maintaining production.**

   As outlined in Chapter 3, there exist a number of incremental shifts – in animal health management, breeding, supply chain efficiencies and other measures – which can further improve the sustainability of Wales' livestock sector. Alone, the impact of each of these measures is small, but together they form an ambitious programme aimed at maximising the positive impact of sheep and beef farming on sustainability.

7. **A sustainable Welsh lamb and beef industry can also have positive benefits in terms of soil health and biodiversity.**

   Although the methods of measuring such contributions are evolving, agricultural policy should, as well as having a central goal of mitigating greenhouse gas emissions, pay due attention to the related challenges of improving biodiversity and maintaining healthy soils.

Wales, with its natural advantages of climate and topography, has a responsibility to be a world leader in sustainable sheep and beef farming.

The solution, we would conclude, lies in maintaining a stable sheep and cattle population and focusing on continually improving our practices with sustainability central to our thinking. This can be achieved by extending best practice throughout the country, and investing in a wide range of measures that can reduce emissions, increase efficiency, promote carbon sequestration, and encourage biodiversity and the generation of renewable energy.

Notes and References

1 M. Cain, J. Lynch, M.R. Allen, J.S. Fuglestvedt, D.J. Frame, A.H. Macey. Improved calculation of warming-equivalent emissions for short-lived climate pollutants, Climate and Atmospheric Science (2019).

2 University of Oxford. New methane emissions metric proposed for climate change policy. https://www.oxfordmartin.ox.ac.uk/news/2018-news-climate-pollutants-gwp/ (2018).

3 F. Mitloehner, E. Kebreab, and M. Boccadoro. Methane, Cows and Climate Change, University of California Davis White Paper (2020).

4 United Nations. What is the United Nations Framework Convention on Climate Change? https://unfccc.int/process-and-meetings/the-convention/what-is-the-united-nations-framework-convention-on-climate-change

United Nations. What is the Kyoto Protocol? https://unfccc.int/kyoto_protocol.

European Commission. Kyoto 1st commitment period (2008–12). https://ec.europa.eu/clima/policies/strategies/progress/kyoto_1_en#:~:text=The%20 1997%20Kyoto%20Protocol%20%E2%80%93%20an,treaty%20to%20reduce%20 greenhouse%20emissions

European Commission. Paris Agreement. https://ec.europa.eu/clima/policies/international/negotiations/paris_en#:~:text=The%20 Paris%20Agreement%20sets%20out,support%20them%20in%20their%20efforts

5 UK Parliament Climate Change Act (2008). https://www.legislation.gov.uk/ukpga/2008/27/contents

UK Parliament: Climate Change Act 2008 (2050 Target Amendment) Order 2019. https://www.legislation.gov.uk/uksi/2019/1056/contents/made

UK Committee on Climate Change. Net Zero – The UK's contribution to stopping global warming (2019).

Welsh Government. Environment (Wales) Act 2016 Factsheet: Climate Change. https://gov.wales/sites/default/files/publications/2019-06/environment-wales-act-2016-climate-change.pdf

6 Intergovernmental Panel on Climate Change. Special Report: Climate Change and Land (2019) https://www.ipcc.ch/srccl/chapter/summary-for-policymakers/

7 Intergovernmental Panel on Climate Change. Special Report: Climate Change and Land (2019) https://www.ipcc.ch/srccl/chapter/summary-for-policymakers/

8 Less favourable areas (LFA): an area with natural handicaps (lack of water, climate, short crop season and tendencies of depopulation), or that is mountainous or hilly, as defined by its altitude and slope.

9 Welsh Government. *Farming Facts and Figures, Wales* 2019.

10 Intergovernmental Panel on Climate Change. Special Report: Climate Change and Land (2019) https://www.ipcc.ch/srccl/chapter/summary-for-policymakers/

11 A.K. Chapagain and A.Y. Hoekstra. *The global component of freshwater demand and supply*, Water International 33, 1. (2008).

12 B.G. Ridoutt, P. Sanguansri, M. Nolan, N. Marks. *Meat Consumption and Water Scarcity: Beware of Generalisations*, Journal of Cleaner Production, 28. (2012).

13 H.J. Smit, M.J. Metzger, F. Ewert. Spatial distribution of grassland productivity and land use in Europe, *Agricultural Systems*, 98, 3. (2008).

[14] Aberystwyth has been the home of pioneering plant breeding research, specialising in productive grasslands, since 1919, latterly as part of Aberystwyth University's Institute of Biological and Rural Sciences (IBERS). The centre was recently the subject of a major investment in a new innovation centre, and grassland research continues to be a core part of HCC's research and development activity, as evidenced by its involvement in the multi-agency GrassCheckGB project (www.grasscheckgb.co.uk).

[15] BBC documentary. Meat: A Threat to Our Planet? First broadcast in November 2019, was found to have breached impartiality guidelines on these grounds; https://www.bbc.co.uk/contact/ecu/meat-a-threat-to-our-planet-bbc-one-25-november-2019

[16] R.T. Conant. *Challenges and Opportunities for Carbon Sequestration in Grassland Systems*, Integrated Crop Management, 9. (2010).

[17] United Nations Food and Agriculture Organisation. *Status of the World's Soil Resources*. (2015).

[18] Research at Sheffield University's Grantham Centre. http://grantham.sheffield.ac.uk/soil-loss-an-unfolding-global-disaster/

[19] McAuliffe GA, Takahashi T, Lee MRF. *Applications of nutritional functional units in commodity-level life cycle assessment (LCA) of agri-food system*s. International Journal of Life Cycle Assessment 25 (2020).

D. Rodgers & R. Wolff, Sacred Cow: The Case for (Better) Meat (2020);

D.R. Montgomery. Growing a Revolution: Bringing our Soil Back to Life (2017)

N. Masters. For the Love of Soil (2019).

[20] English Nature. *The importance of livestock grazing for wildlife conservation: working today for nature tomorrow.* (2006).

[21] United Nations. https://www.un.org/development/desa/en/news/population/world-population-prospects-2019.html

[22] Food and Agriculture Organization of the United Nations. Livestock Production. http://www.fao.org/3/y4252e/y4252e07.htm

[23] Food and Agriculture Organization of the United Nations. Nikos Alexandratos and Jelle Bruinsma. *World Agriculture towards 2030/2050: The 2012 Revision*. ESA Working Paper No. 12-03 (2012).

[24] Overseas Development Institute. Steve Wiggins and Sharada Keats. *Future diets in the developing world Questions, answers and gaps.* (2017).

[25] BM Popkin. *Nutritional Patterns and Transitions.* Population and Development Review 19.1 (1993).

[26] M. Gill, P. Smith and J. M. Wilkinson. *Mitigating climate change: the role of domestic livestock.* Animal, Volume 4, Issue 3. (2010).

[27] Christian Schader, Adrian Muller, Nadia El-Hage Scialabba, Judith Hecht, Anne Isensee, Karl-Heinz Erb, Pete Smith, Harinder P. S. Makkar, Peter Klocke, Florian Leiber, Patrizia Schwegler, Matthias Stolze and Urs Niggli. *Impacts of feeding less food-competing feedstuffs to livestock on global food system sustainability*. Journal of the Royal Society Interface. (2015).

[28] Organisation for Economic Co-operation and Development. Meat consumption. https://data.oecd.org/agroutput/meat-consumption.htm

[29] Department for Environment, Food and Rural Affairs (England), Environment and Rural Affairs (Northern Ireland), Welsh Government and Scottish Government. *Agriculture in the United Kingdom* 2019.

[30] World Wide Fund for Nature. *Carbon Footprint: Exploring the UK's contribution to climate change.* (2020).

[31] World Wide Fund for Nature. *Carbon Footprint: Exploring the UK's contribution to climate change.* (2020).

[32] Committee on Climate Change. Land use: *Policies for a Net Zero U*K. (2020).

[33] Hybu Cig Cymru Meat and Health based on the Meat Advisory Panel (now Food Advisory Board) nutritional factsheets. (2020).

[34] Professor Robert Pickard. Hybu Cig Cymru commissioned paper on meat in the diet. (2020).

[35] Welsh Government. *Aggregate agricultural output and income*, 2019. (2020).

[36] Based on the Loentief Inverse figures from the Office for National Statistics. *UK input-output analytical tables: 2015 detailed*. (2019).

[37] Welsh Government. *June 2019 Survey of Agriculture and Horticulture: Results for Wales*. (2019).

Welsh Government. *Aggregate agricultural output and income*, 2019. (2020).

Office for National Statistics. *UK input-output analytical tables: 2015 detailed*. (2019).

Welsh Government. *Economic Appraisal of the Welsh Food and Drink sector – Update 2018*. (2019).

Kantar Worldpanel 2017 (extracted from the Welsh Government Appraisal of the Welsh Food and Drink Sector. (2019).

Hybu Cig Cymru calculations of HM Revenue and Customs data. (2019).

UK Government, Department for Environment, Food and Rural Affairs. *UK Home fed Meat Production, Trade and Supplies* (Q2 2020).

[38] Hill, B and Bradley D. *Evaluating Brexit's impact on the social contributions made by agriculture.* (2019).

[39] Dwyer, J. *The Implications of Brexit for Agriculture, Rural Areas and Land Use in Wales. Public Policy Institute for Wales*. (2018).

[40] Welsh Government. *Brexit and our land: Securing the future of Welsh farming.* (2018).

Welsh Government. *Response to Brexit and our land: Securing the future of Welsh farming consultation.* (2019).

Welsh Government. *Sustainable farming and our land*. (2019).

[41] Amaeth Cymru. *The future of agriculture in Wales: the way forward.* (2017).

[42] Amaeth Cymru. *The future of agriculture in Wales: the way forward.* (2017).

[43] Welsh Government. *Brexit and our land: Securing the future of Welsh farming*. (2018).

[44] Welsh Government. Wales Visitor Survey 2016. https://gov.wales/wales-visitor-survey-2016 (2017).

[45] Welsh Government. *Wales Tourism Performance Report: January to June 2019*. (2019).

[46] National Assembly for Wales. *Evidence from Wales Tourism Alliance to the Inquiry into the Future of Agricultural and Rural Development Policies in Wales. Climate Change,* Environment and Rural Affairs Committee. (2016).

[47] Social capital is defined by the Organisation for Economic Co-operation and Development as *"networks together with shared norms, values and understandings that facilitate co-operation within or among groups"*.

Organisation for Economic Co-operation and Development Insights. Human Capital. https://www.oecd.org/insights/37966934.pdf

[48] All Party Parliamentary Group for Hill Farming. *A Manifesto for the uplands*. https://www.farminguk.com/news/hill-farming-parliamentary-group-launches_51312.html (2019)

[49] Wales Rural Observatory. *Rural Household Survey*. (2013).

[50] Wales Rural Observatory. *An analysis of the socio-economic impact of CAP reforms on Rural Wales*. Phase 6 report. Conclusions and policy recommendations. (2013).

[51] YFC Wales. https://yfc.wales/about-us/

[52] Wales Rural Observatory. Deep Rural Localities. 2009.

[53] Dr Liz Bickerton. HCC commissioned literature review. *The Contribution of a Strong Agriculture Sector to Vibrant Rural Communities.* (2020).

[54] Office for National Statistics, 2011 Census data.

[55] Welsh Government. *Cymraeg 2050: A Million Welsh Speakers Action Plan 2019–20.*

[56] Data has been extracted from the Inventory, drawing out the estimated greenhouse gas emissions associated with Welsh agriculture, drawing on a detailed breakdown of emissions by livestock lifestage, breed type and farm type.

National Atmospheric Emissions Inventory. *Devolved Administrations Greenhouse Gas Reports.* (1990-2018).

[57] National Admospheric Emission Inventory. Devolved Administrations Greenhouse Gas Report. The Welsh pig sector is small in comparison with the Welsh lamb and beef sectors, with only 3,300 breeding pigs, reared on 1,335 holdings (2019).

Hybu Cig Cymru. *Little Book of Meat Facts – Compendium of Welsh Red Meat and Livestock Industry Statistics 2020.*

[58] Enteric fermentation is a digestive process whereby carbohydrates are broken down by microorganisms into simple molecules.

[59] UK Government, Department for Environment, Food and Rural Affairs. *The British Survey of Fertiliser Practice. (2020).*

[60] UK Government, Department for Business, Energy and Industrial Strategy. *Greenhouse Gas Inventory, 1990 to 2017.*

https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1905151122_ukghgi-90-17_Main_Issue_2_final.pdf (2019).

[61] UK Government, Department for Environment, Food and Rural Affairs. *Improvements to the National Inventory: methane. Evidence Project Final Report.*

http://randd.defra.gov.uk/Document.aspx?Document=13308_AC0115FinalReportMay2014.doc (2014)

[62] UK Climate Change Committee. *Land use: Policies for a Net Zero*. (2020).

[63] Emissions are shared between the dairy and meat output.

[64] Hybu Cig Cymru commissioned research by A. Prysor Williams, School of Natural Sciences, Bangor University. *Carbon sequestration in grassland systems*. (2020).

[65] Smith P. *Soils as carbon sinks: the global context.* Soil Use and Management 20. (2004).

[66] Dawson JJC, Smith P. *Carbon losses from soil and its consequences for land-use management.* Science of the Total Environment 382. (2007).

[67] Environment Agency Wales. Wade R. *Soils and their management in light of climate change.* (2008).

[68] Taylor E, Smyth MA, Moxey A, and Williams AP. *Barriers, opportunities and recommendations for supporting peatland restoration and sustainable management through the Peatland Code in Wales; a Crichton Carbon Centre report for Snowdonia National Park.* (2020).

[69] Billett MF, Palmer SM, Hope D, Deacon C, Storeton-West R, Hargreaves KJ, Flechard C, Fowler D. *Linking land–atmosphere–stream carbon fluxes in a lowland peatland system. Global Biogeochemical Cycles, 18.* (2004).

[70] Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, et al. Agriculture (2007), in: Metz, B., Davidson, O.R., Bosch, P.R., Dave, R. and Meyer, L.A. (Eds.). Climate Change 2007: *Mitigation. Cambridge University Press, Cambridge & New York* (2007).

[71] Dawson JJC, Smith P. *Carbon losses from soil and its consequences for land-use management. Science of the Total Environment 382*. (2007).

[72] Freibauer A, Rounsevell MDA, Smith P, Verhagen J. *Carbon sequestration in the agricultural soils of Europe. Geoderma 122.* (2004).

[73] Ostle NJ, Levy PE, Evans CD, Smith P. *UK land use and soil carbon sequestration. Land Use Policy 26.* (2009).

[74] Ostle NJ, Levy PE, Evans CD, Smith P. *UK land use and soil carbon sequestration. Land Use Policy 26.* (2009).

[75] Dawson JJC, Smith P. *Carbon losses from soil and its consequences for land-use management. Science of the Total Environment 382.* (2007).

Gilmullina A, Rumpel C, Blagodatskaya E, Chabb *A. Management of grasslands by mowing versus grazing – impacts on soil organic matter quality and microbial functioning*. Applied Soil Ecology 156. (2020).

[76] Leake JR, Ostle NJ, Rangel-Castro JI, Johnson D. *Carbon fluxes from plants through soil organisms determined by field* CO_2 *pulse-labelling in an upland grassland. Applied Soil Ecology 33.* (2006).

[77] Thorup-Kristensen K, Halberg N, Nicolaisen M, Olesen JE, Crews TE, Hinsinger P, Pierret A, Dresbøll DB. *Digging Deeper for Agricultural Resources, the Value of Deep Rooting. Trends in Plant Science 25*. (2020).

[78] UK Government, Department for Environment, Food and Rural Affairs. *British Survey of Fertiliser Practice.* (2019).

[79] Prof Michael Lee, Prof Steve McGrath and Prof Andrew Neal – Rothamsted Research. Findings of the Soil to Nutrition ISP programme supported by the Biotechnology and Biological Sciences Research Council (BBS/E/C/000I0310, BBS/E/C/000I0320).

[80] Jonah M. Prout, Keith D. Shepherd, Steve P. McGrath, Guy J. D. Kirk and Stephan M. Haefele. *What is a good level of soil organic matter? An index based on organic carbon to clay ratio.* European Journal of Soil Science. (2020).

[81] Andrew L. Neal, Aurélie Bacq-Labreuil, Xiaoxian Zhang, Ian M. Clark, Kevin Coleman, Sacha J. Mooney, Karl Ritz and John W. Crawford. *Soil as an extended composite phenotype of the microbial metagenome. Nature Research.* (2020).

[82] Prof Michael Lee, Prof Steve McGrath and Prof Andrew Neal – Rothamsted Research. Findings of the Soil to Nutrition ISP programme supported by the Biotechnology and Biological Sciences Research Council (BBS/E/C/000I0310, BBS/E/C/000I0320).

[83] Paul Poulton, Johnny Johnston, Andy Macdonald, Rodger White and David Powlson. *Major limitations to achieving "4 per 1000" increases in soil organic carbon stock in temperate regions: Evidence from long-term experiments at Rothamsted Research*, United Kingdom. Global Change Biology. (2017).

[84] Ostle NJ, Levy PE, Evans CD, Smith P. UK *land use and soil carbon sequestration.* Land Use Policy 26. (2009).

[85] Ostle NJ, Levy PE, Evans CD, Smith P. UK *land use and soil carbon sequestration.* Land Use Policy 26. (2009).

[86] Ostle NJ, Levy PE, Evans CD, Smith P. UK *land use and soil carbon sequestration.* Land Use Policy 26. (2009).

[87] Hybu Cig Cymru commissioned research by A. Prysor Williams, School of Natural Sciences, Bangor University. *Carbon sequestration in grassland systems*. (2020).

[88] Welsh Government. *Farm incomes in Wales*, April 2018 to March 2019. (2019).

[89] Note that the Bangor University model does not take account of any renewable energy produced on farm.

[90] D. O'Brien, J. Herron, J. Andurand, S. Caré, P. Martinez, L. Migliorati, M. Moro, G. Pirlo, and J-B Dollé, 'Life Beef Carbon: a common framework for quantifying grass and corn based beef farms' carbon footprints', *Animal*, 14 (2020);

University of Oxford, Life-cycle environmental impacts of food and drink products; https://ora.ox.ac.uk/objects/uuid:a63fb28c-98f8-4313-add6-e9eca99320a5

[91] Centre for Innovation Excellence in Livestock. Net zero carbon and UK livestock. https://www.cielivestock.co.uk/net-zero-carbon-and-uk-livestock/ (2020)

[92] Waste and Resources Action Programme. Meat in a Net Zero World. https://wrap.org.uk/sites/files/wrap/Meat_in_a_Net_Zero_world_publication_0.pdf

[93] Waste and Resources Action Programme. The Courtauld Commitment 2025 Water Ambition. https://wrap.org.uk/content/courtauld-2025-water-ambition

[94] Waste and Resources Action Programme. Meat in a Net Zero World. https://wrap.org.uk/sites/files/wrap/Meat_in_a_Net_Zero_world_publication_0.pdf

[95] Waste and Resources Action Programme. Meat in a Net Zero World. https://wrap.org.uk/sites/files/wrap/Meat_in_a_Net_Zero_world_publication_0.pdf

[96] Terajoule (TJ): a unit of energy.

Office for National Statistics. Energy use: by industry reallocated to final consumer and energy intensity, 1990 to 2018. https://www.ons.gov.uk/economy/environmentalaccounts/datasets/ukenvironmentalaccountsenergyreallocatedenergyconsumptionandenergy intensityunitedkingdom/current

[97] Hybu Cig Cymru commissioned research by A. Prysor Williams, School of Natural Sciences, Bangor University. *Carbon sequestration in grassland systems*. (2020).

[98] Welsh Government. *Farm incomes in Wales, April 2018 to March* 2019.

[99] Hybu Cig Cymru. *Red Meat Benchmarking Project* (2018).

[100] Baseline values of performance measures were sourced from national surveys, and scenario values were selected to represent individually achievable gains as evidenced by the better performing enterprises in the national surveys. The effects of improved animal performance measures that changed the relative numbers of finishing, replacement and breeding livestock were calculated by appropriate adjustments to the numbers of animals in the Agricultural Ammonia and Greenhouse Gas Inventory (AAGGI) activity database. The effects of change in individual animal growth rate and residual feed intake were calculated by re-parameterising the AAGGI emission models.

Glossary

AAGGI	Agricultural Ammonia and Greenhouse Gas Inventory
CIEL	Centre for Innovation Excellence in Livestock
DECITONS	A unit of weight, 1 deciton = 100 kilogrammes
FAO	Food and Agriculture Organization of the United Nations
GWP	Global Warming Potential
GWP100	The de facto way of converting non-CO_2 emissions to CO_2e is to multiply the gas by its GWP100 (global warming potential over 100 years).
IGD	Institute of Grocery Distribution
LULUCF	Land Use, Land Use Change and Forestry
NAEI	National Atmospheric Emissions Inventory
SOC	Soil Organic Carbon
WRAP	Waste and Resources Action Programme
WWF	World Wide Fund for Nature
YFC	Young Farmers Clubs

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