Cost-Benefit Analysis:

Nitrogen Climate Smart

Compiled For

NCS
NITROGEN CLIMATE SMART

Produced By:
The Andersons Centre
Floor 3, The Tower,
Pera Business Park,
Melton Mowbray
Leicestershire,
LE13 0PB

Produced By:
James Webster-Rusk
01664 503 200
07717 088 409
JWebsterRusk@theandersonscentre.co.uk

Date: 11 October 2024

The Andersons Centre

Executive Summary

The Nitrogen Climate Smart (NCS) project is a £5.9 million initiative led by the Processors and Growers Research Organisation (PGRO) and funded by UK Research and Innovation (UKRI). The project aims to reduce the UK's agricultural emissions by 1.5 million tonnes of CO_2e annually, representing 54% of the sector's maximum potential reduction. Central to the project is increasing the cultivation of pulses and legumes in UK crop rotations to 20% and replacing up to 50% of imported soymeal in livestock feed with domestically grown, climate-friendly alternatives.

This cost-benefit analysis (CBA) evaluates the financial and environmental impacts of these proposed changes, following the framework outlined in HM Treasury's *Green Book*. The analysis covers various farming sectors including arable, pigs, dairy, grazing livestock, and poultry, assessing both baseline and projected scenarios. The two key objectives of this work are to identify the best scenario for optimizing environmental impact and financial return for farmers and to determine the carbon cost-benefit of transitioning to increased pulse production in the UK.

Key findings indicate that while increasing the proportion of pulses in crop rotations has the potential to significantly reduce emissions, the present lack of direct financial benefits for farmers may not outweigh the costs without further incentives. For example, the analysis shows that the environmental benefit from reducing carbon emissions in arable farming yields a social benefit of £132 million, but this is outweighed by a £166 million cost to farmers. However, additional nitrogen savings from legume crops may tip the balance in favour of the change, providing a more favourable benefit-cost ratio (1.2:1).

In the livestock sector, particularly in pig farming, replacing soymeal with UK-grown legumes could lead to significant environmental gains. If soymeal linked to land-use change is replaced, the resulting carbon savings could offset the financial losses, offering a benefit-cost ratio of 3.8:1. To enable the emissions savings, industry needs to find a way to monetise the benefit.

This initial report serves as the first of three CBAs to be conducted throughout the project's lifecycle, with further refinement expected as more data becomes available from ongoing trials.

CONTENTS

1. Introduction

1.1. The Project

The Nitrogen Climate Smart (NCS) project is £5.9 million farmer-led research programme, being implemented across the UK by a research consortium led by the Processors and Growers Research Organisation (PGRO) and funded by UK Research and Innovation (UKRI).

The main aim of the project is to enable UK agriculture to bring about a reduction of 1.5Mt CO_2e per annum in its combined emissions. This is circa 54% of the maximum potential for the industry.

The ambitions of the project are to increase pulses and legume cropping in arable rotations to 20% across the UK and to develop and test new feed rations. This will help livestock farmers to substitute up to 50% of imported soya meal used in feed with more climate-friendly home-grown pulses and legumes.

It is envisaged that through these there will be significant benefits for both crop and livestock productivity, including cost savings of over £1 billion per year.

To measure the likelihood of success of the project relative to a baseline scenario it is necessary to conduct a Cost-Benefit Analysis (CBA). The CBA forms a key part of Work Package (WP) 5. The two key objectives of WP5 are.

- To establish the best scenario for delivering optimum environmental impact and financial return on investment for the farmer/ grower.
- To establish the carbon cost-benefit analysis of transitioning to increased production of legumes and pulses in the UK, alongside changes in livestock diets in favour of home-grown legumes and pulses and away from soyabean meal.

The deliverables of WP5 include.

- The collation of external and project data,
- Cost-Benefit Analysis,
- Feasibility report on exploitation of processes and end uses,
- Policy Report for the Department of Environment, Food and Rural Affairs (Defra).

There are obvious synergies between all the objectives and deliverables within the WP which merit close alignment of methodologies. Given the final, and arguably key, deliverable of this WP is the Policy Report, it is deemed appropriate to follow The Green Book[1], in delivering this evaluation.

The Green Book is published by HM Treasury and provides central government guidance on appraisal and evaluation.

1.2. Cost-Benefit Analysis

A cost-benefit analysis (CBA) is a key evaluation tool for projects which are required to demonstrate value for money. The CBA is an objective analysis of the full range of benefits delivered by a project, relative to the full range of costs incurred in its delivery. For a CBA to be successful, it is important to determine at the outset the metrics which will be used. The metric is the approach for comparing the costs with the benefits, to determine whether a project demonstrates "value for money". The metric for this CBA is outlined in chapter 2, more detail of the metric selection is covered in the Cost-Benefit Analysis Protocol document.

Chapter 3 outlines the baseline scenario from which adjustments are to be made to determine the costs and benefits of increasing domestic pulses in rotations and reducing the volume of imported soyabeans and soyabean derivatives. Chapter 4 outlines the changes which result from increasing pulses and the associated costs and benefits. Chapter 5 summarises the results from the 2024 CBA. Chapter 6 includes a discussion of the gaps in the initial CBA which require further coverage in the second and third CBAs.

1.3. Timeline for Conducting Cost-Benefit Analysis

Over the course of the NCS project, the CBA will be run three times, incorporating the latest available data from the project. In line with the Project Plan document a Cost-Benefit Analysis will be completed by the following dates.

- 30/09/2024
- 30/09/2025
- 30/09/2026

1.4. This Report

This report is split into 8 sections. Sections 2 to Section 6 highlight the relative economic and environmental baseline for different sectors of UK farming. These include arable, livestock feed, pig farming, dairy, grazing livestock and poultry.

The final section, section 7 summarises the findings of sections 2-6, including a discussion of the relevant findings and areas for future research.

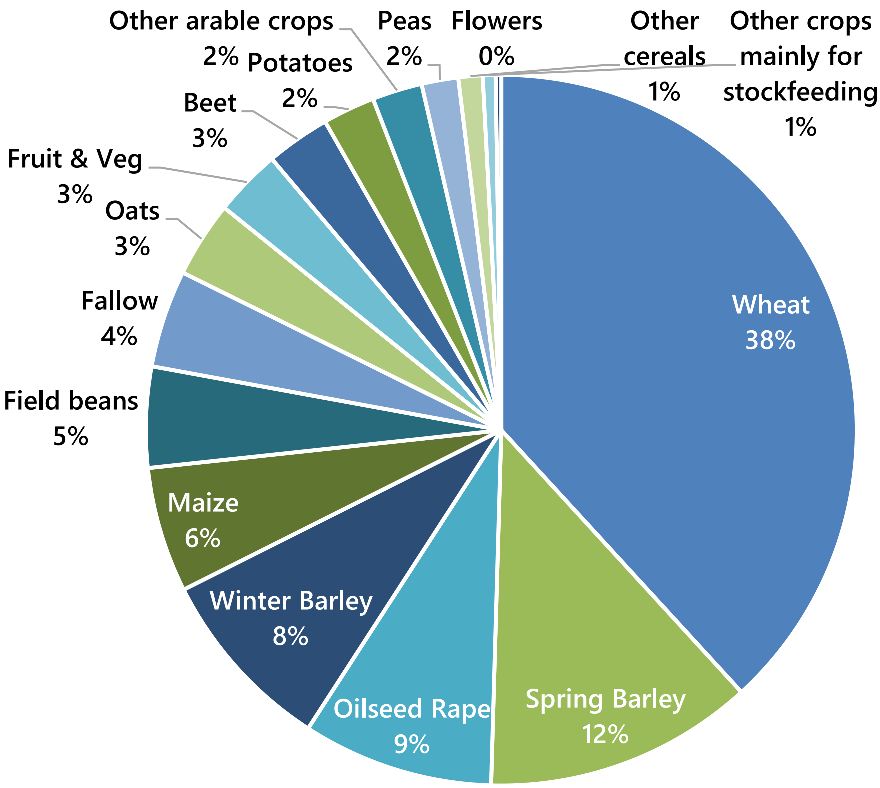
2. Arable Farming

2.1. The UK Arable Baseline

The primary aim of this project is to reduce emissions through an increase in production and consumption of combinable proteins. The five-year average (2019-2023) area is 185 thousand hectares of field beans and 67 thousand hectares of peas. The project aims to increase the area to 20% of UK combinable crop rotations (772 thousand hectares). The present area of UK pulses accounts for around 6% of the combinable crop area on UK holdings.

The breakdown of UK cropping, as sourced from the areas claimed under the Basic Payment Scheme (BPS), is shown in Figure 2-1. This information is used to inform the gross margin for the arable model farm in this cost benefit analysis.

Figure 2-1 Area of UK crops



Source: Department for Environment, Food, and Rural Affairs; Rural Payments Agency

As the highest performing cash crop for some considerable time, it is unsurprising that wheat remains the dominantly grown crop in the UK. On average between 2019/20 and 2023/24, UK production of wheat has been in the region of 13.9Mt. Demand for the crop has been circa 14.4Mt, the subsequent deficit of

500kt is important to the future of domestic combinable pulse consumption as pulses will seek to capture some of this demand.

Break crops (primarily oilseed rape, pulses, and oats) have been grown in far greater volumes historically, however, challenging crop economics and persistent pest pressure, most notably for oilseed rape, has resulted in significant area and production declines.

UK pulse production tonnage has been historically volatile, primarily due to the variation in area. The variation in pulse area has been driven by the relatively small market for the crop, driving large swings in price relative to availability, Defra estimates five-year average UK production of dry peas and faba beans combined at 793 thousand tonnes. Usage by animal feed compounders is on average 145 thousand tonnes, with exports totalling 171 thousand tonnes, this suggests a total of around 477 thousand tonnes combined for home blending, free stocks, or domestic human consumption, is presently available in the UK. Of course, this assumes that the yield statistics published by Defra are representative of actual yields, but the usage figures feel intrinsically low.

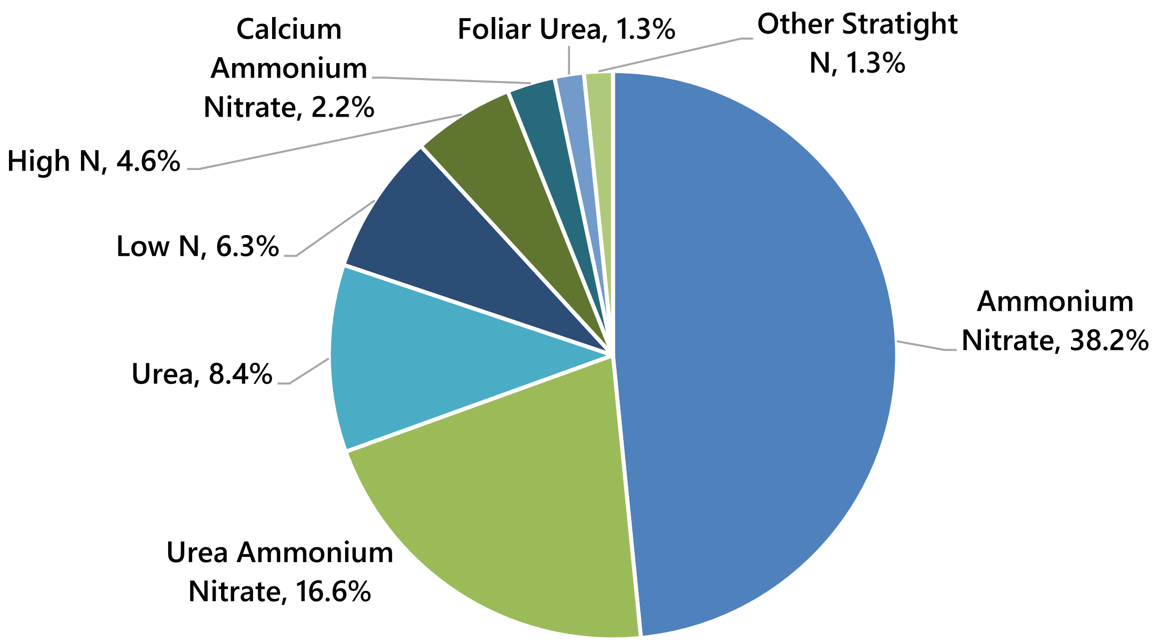
2.1.1. Environmental Impact of Arable Production

The primary aim of this project is to reduce the level of emissions produced by agriculture in the United Kingdom. For this to be a success it should be achieved with minimal carbon leakage. The 2023 Agri-climate report[2] highlights that UK agriculture emissions in 2021 were around 47.9Mt of CO_2e per annum, the report gives no specific coverage to the emissions of the arable sector, instead focussing on livestock, covered later in this report. The main sources of emissions within the arable sector relate to the use of fertiliser, direct soil N_2O release and fuel use[3].

Fertiliser usage is a key component of UK arable farming emissions. Over the past 10 years (2014-2023) fertiliser usage has averaged 134 kilograms of Nitrogen per arable hectare according to Defra. This is based on survey returns in the British Survey of Fertiliser Practice. This is lower than the figure used in this CBA. The CBA is built up from a series of crop margins, multiplied across the UK cropped area. The crop margins are calculated using the industry standard for fertiliser recommendations, RB209, and Defra data for crop areas. Some assumptions have been made by the authors of this paper with regard to the area of crops grown for human consumption and animal feed. Using this basis for calculating the nitrogen usage, suggests an average of 160 kilograms per hectare across the combinable crop hectarage. Multiplying this up across UK arable crop areas suggests a total of 618 thousand tonnes of nitrogen usage per year. This figure relates to the weight of nutrients applied, rather than the weight of product applied.

It is important to distinguish between the different types of fertilisers which are used across the UK, different products have different emission factors. Figure 2-2 shows the percentage breakdown of fertiliser use by product, as percentage of total nitrogen fertiliser use across winter cereals, spring cereals and oilseed rape. It is apparent that ammonium nitrate (AN) is the leading product for arable enterprises, with urea ammonium nitrate (UAN), the second-choice product. This may change over time due to the introduction of a ban on spreading urea-based products, without a urease inhibitor, outside of a window from 15th January to 31st March, introduced from 1st April 2024.

Figure 2-2 Graphical representation of nitrogen fertiliser use by product on winter cereals, springs cereals, OSR and other tillage, 2019-23 (% of total)



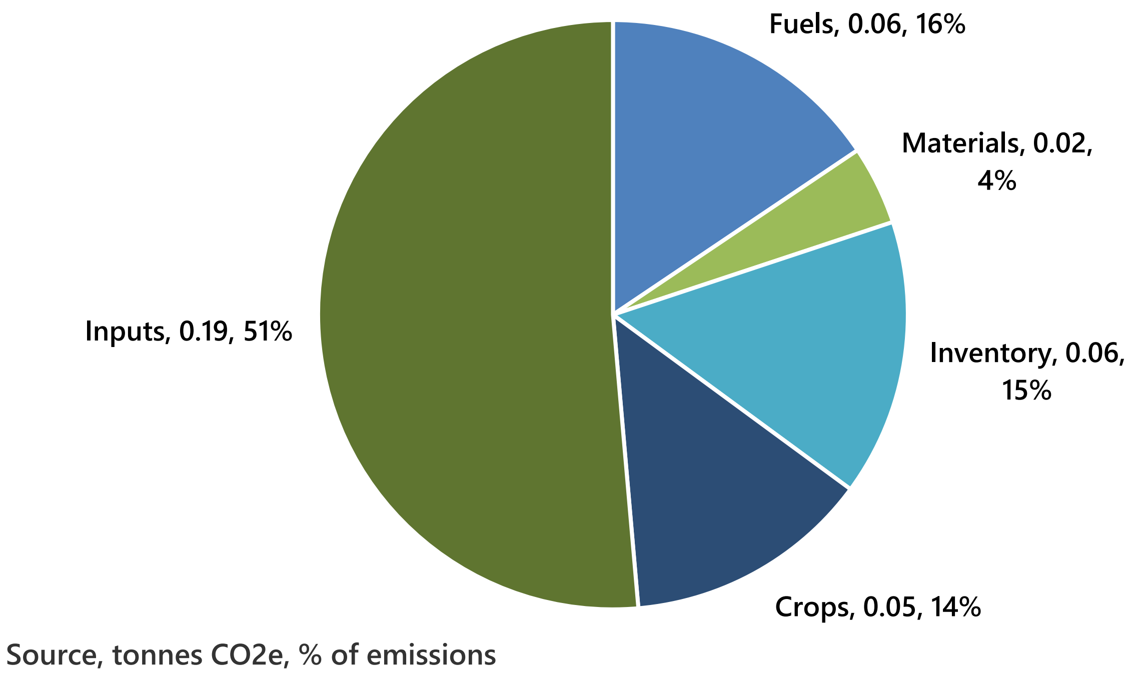
Source: British Survey of Fertiliser Practice, Defra

As well as looking at the fertiliser products being used, it is also important to look at the origin of fertiliser used in the UK, the Agricultural Industries Confederation (AIC) estimates that 40% of UK nitrogen fertiliser use is product manufactured in the UK. This aligns with analysis conducted for this project, looking at usage of fertiliser relative import levels across the five harvests ending in 2023. This broad analysis finds that approximately 63% of UK nitrogen fertiliser is imported, primarily from the EU. Different origins of fertiliser have different emission factors. Applying the emissions factors based upon the origin of nitrogen fertiliser to a calculated weight of fertiliser applied for the model farm in this project, using the Farm Carbon Toolkit (FCT), it is estimated that emissions associated with fertiliser in the pre-change rotation are 1.185 tCO_2e per hectare.

At an average yield across the model farm of 6.73 tonnes per hectare, this suggests emissions of 0.176 tCO_2e per tonne of output, from nitrogen fertilisers alone. This is across a rotation including wheat, barley, oilseed rape, oats and pulses. The UK is likely to have a broader rotation than this however data on the production of these crops is minimal and less likely to reflective of the "typical" arable enterprise.

If we assume that there is no reduction in nitrogen application to the crop following pulses, applying the Green Book value for carbon emissions to the emissions of the combinable crop rotation gives a present social cost of carbon emissions associated with fertiliser use in UK arable production of £42.42 per tonne of output.

Figure 2-3 Model Farm Emissions by Source, per tonne of output, pre-change



Source: Farm Carbon Toolkit, The Andersons Centre

The total emissions of the model farm are shown in Figure 2-3. Excluding inventory (equipment) and materials, emissions are estimated to be 1,298 tCO_2e, equivalent to 2.16 tCO_2e per hectare or 0.322 tCO_2e per tonne of product. Inventory emissions are excluded in this instance as they account for the emissions associated with farm machinery. Through the FCT, emissions associated with machinery are fully depreciated in the year of acquisition. Therefore, including these emissions does not give an accurate reflection of the impact of cropping change.

Applying the Green Book value for carbon emissions gives a social cost of the emissions associated with arable farming in the UK, based on the Loam Farm model, of £77.51 per tonne of grain output, excluding emissions from inventory. It should be noted that this also excludes any sequestration that could offset the emissions from the enterprise.

The Defra publication, Agriculture in the UK, estimates the volume of harvested production of cereals, oilseeds and pulses at 24.7 million tonnes per year. Applying the emission metrics calculate here to that figure suggests that emissions from UK arable production are 7.9 million tonnes of CO_2e per year, with a social cost of carbon of £1.91 billion.

To determine how the emissions of the arable farm model compare with wider industry, the FCT benchmarking function has been considered. The benchmarking function shows how the model compares to other reports within the FCT. The arable model is shown to be in the bottom 20% of cereal farms on an emissions per hectare basis. However, the important metric is the emissions per tonne of output. When this metric is analysed, the arable model farm is shown to be in the bottom 40% of farms, with emissions 0.107 tCO_2e/ tonne higher than the median level. There are some low yielding farms within the wider FCT data set, and as such the arable farm is assumed to still be a good representation the emissions of the wider sector, especially given this analysis does not include data relating to carbon sequestration.

2.1.2. Economics of Arable Enterprises

The baseline environmental and economic scenario for arable enterprises is calculated using the Andersons Loam Farm model farm. The model has been run by Andersons since the 1990s and is used to chart the fortunes of arable farms in relation to market and policy changes.

The farm is a slightly above average performing enterprise, notionally in the East of England, with clay loam soils. It operates across 600 hectares, with approximately 60% of this land rented. For the purposes of this project the rotation of loam farm has been altered from the one historically used. The rotation used in this project is not realistic for a UK enterprise, as it weights the 600 ha of cropping across a wide range of crop groups and qualities. This has been done to allow for a more realistic representation of UK agriculture to be given. Output prices and costs are based upon five-year average levels, using industry sourced data. Fertiliser rates are based upon RB209, other costs are based upon industry standards, taken from The Farm Management Pocketbook.

The fixed cost picture for the model is an average of the five crop years ending 2023-24, with figures based on modelling by The Andersons Centre. No income has been included for agri-environment schemes or the Basic Payment Scheme, although this will be considered in the policy paper and is included in the discussion at the end of this paper.

The breakdown of crops has been calculated according to data published by Defra for the main crop groups. The area planted to wheat, winter and spring barley, oats, oilseed rape and pulses is determined by the five-year average area (2019-2023) claimed under the Basic Payment Scheme in England. The split of these crops is represented in Figure 2-1 (page 6). The area of these crops is then allocated according to spring and winter crops, and the end market of each crop. This is calculated through data published by AHDB, Maltsters Association of Great Britain and other industry sources. Some Andersons assumptions have also been required, most notably around proportions of second wheat.

The baseline economic performance for the arable model farm is shown below in Table 2-1. The rotation used in this analysis results in a gross margin of £988 per hectare, and pre-rent and finance surplus of £405 per ha. It should be noted that this analysis encapsulates a period when both costs and output prices were elevated by the ongoing conflict in Ukraine. However, five-year averages have been used to normalise these values.

Table 2-1 Arable Model Farm Baseline (Pre-Change) Scenario

	£ per farm	£ per hectare	£ per tonne
Crop Output	950,207	1,584	235
Variable Costs	357,633	596	89
Gross Margin	**592,575**	**988**	**147**
Labour	36,340	61	9
Power and Machinery	250,786	418	62
Admin	32,486	54	8
Property	30,110	50	7
Total Overheads	349,722	583	87
Pre-Rent & Finance Surplus	**242,853**	**405**	**60**
Rent, Finance & Drawings	135,000	225	48
Margin from Production	**49,527**	**83**	**12**

Source: The Andersons Centre

To allow for comparison to be made between the carbon measure and the margin for the arable businesses it is important to also consider the margin on a pounds per tonne basis. Using the 6.73 tonne per hectare yield average for the model farm gives a gross margin of £147 per tonne, and a pre-rent and finance surplus of £60 per tonne.

Applying the pre-rent and finance surplus to the volume of UK production of cereals, oilseed rape and pulses, gives a value for arable production of £1.48 billion.

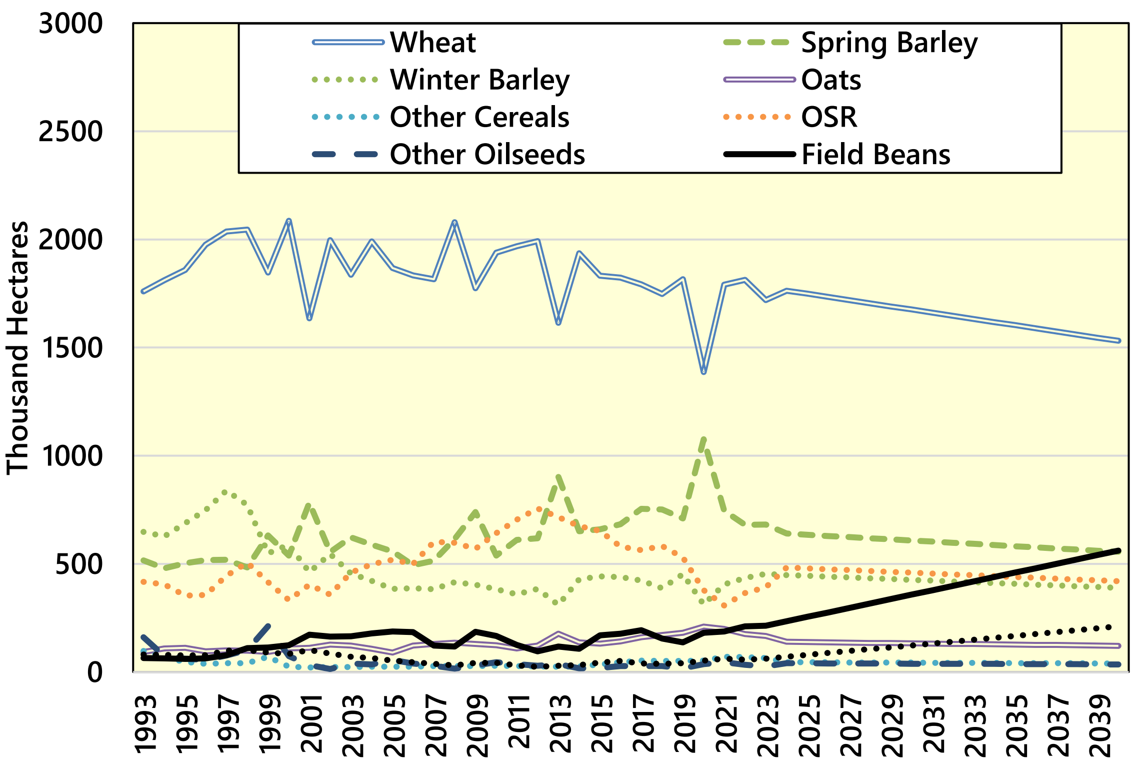
2.2. Arable Change Scenario

The primary change examined for the arable enterprise is a move from 6% pulse cropping to a figure closer to 20% pulse cropping. To assess the impact on other crops an analysis was conducted using the long-term trends in crop areas published by Defra.

The methodology for this analysis involves fixing the area of peas and beans at 20% of the total cropped area in the UK. The respective area of each crop is determined by the historic split, so that beans account for approximately 73% of the area of pulses and, peas the remaining 27%. The split of the remaining crops (wheat, spring barley, winter barley, oats, other cereals, oilseed rape, and other oilseeds) is then held steady across the total area of cropping at 3.86 million hectares. An exponential moving average is used to weight the split of cropping more heavily in favour of recent years, than cropping trends that have been seen further in the past.

The results of this analysis are shown in Figure 2-4, below. The change to increased pulses will not be imminent, therefore the analysis assumes a steady transition through to 2040. The area of all crops, except pulses, fall by 15.6%. The area of pea and bean crops increase by 284%.

Figure 2-4 Crop area changes reaching 20% pulses in 2040



Source: Defra, Andersons

The subsequent area of cereal crops would still provide sufficient wheat and barley to satisfy human consumption demand and a proportion of animal feed demand with limited need to increase the level of imports, provided the increased pulse area displaces demand for feed grains as well as feed proteins The modelled oilseed rape area is significantly above the level presently being grown in the UK.

The results of this analysis are applied to the model farm's rotation, adjusting the area, and so inputs, of each crop. The resulting physical data is input into the FCT and a footprint for the adjusted rotation is calculated.

The new rotation results in a reduction in carbon footprint of 89 tonnes of CO_2e across the farm, a 6.9% reduction in the level of emissions for the model farm, excluding emissions associated with inventory items.

In this analysis the change in emissions within the model results from a 13% reduction in the emissions associated with crop inputs (fertilisers and chemicals), this is somewhat offset by an increase in the emissions associated with NO2 and CO2 emissions from organic fertility and biomass.

The adjusted rotation results in emissions per hectare of 2.02 tCO_2e, down 0.15tCO_2e/ha from the original rotation, this equates to 0.321 tCO_2e per tonne of output. This is based on yield reducing from 6.73t/ha in the original analysis to 6.29 t/ha under the changed rotation.

The social cost of carbon under the new rotation is £77.25 per tonne of output. Multiplying this up to account for all of UK arable production gives a total carbon emission of arable production resulting from the new rotation of 7.39 million tonnes of CO_2e, a saving of 0.55 million tonnes.

The social cost of carbon emissions in the new rotation is £1.78 billion. This drives a saving in social cost of £132 million.

While there is a clear societal benefit to reducing carbon emissions through changing rotations, the ability to do this is contingent on other drivers and the cost implications that this has for the wider industry.

First and foremost are the revenue implications for the farmer. Adjusting the rotation to include a greater level of pulses, all other things being equal, results in a reduction in the profitability of the average arable enterprise. The figures for the model farm are given in

Table 2-2, below.

Table 2-2 Arable Model Farm Baseline (Post-Change) Scenario

	£ per farm	£ per hectare	£ per tonne
Crop Output	897,231	1,495	238
Variable Costs	333,416	556	88
Gross Margin	**563,815**	**940**	**149**
Labour	36,340	61	10
Power and Machinery	250,786	418	66
Admin	32,486	54	9
Property	30,110	50	8
Total Overheads	349,722	583	93
Pre-Rent & Finance Surplus	**214,093**	**357**	**57**
Rent, Finance & Drawings	135,000	225	51
Margin from Production	**20,767**	**35**	**6**

The adjusted rotation results in a gross margin of £940 per hectare, £48 per hectare lower than the baseline rotation. This is driven by an £89 per hectare fall in output, partly compensated for by a £40 per hectare fall in variable costs. The overhead costs are unchanged in the pre- and post-change scenarios, therefore the overall impact on the pre-rent and finance surplus is also a decline of £48 per hectare to £357 per hectare.

Again, dividing the margins by the output (6.29t/ha) allows us to compare the outputs of the emissions analysis and that of the financial analysis. The gross margin is higher in the per tonne analysis, owing to lower overall production, however, this also has the effect of concentrating the cost of overheads across the farm. As a result, the pre-rent and finance surplus is £3 per tonne lower, at £57 per tonne, than the pre-change scenario.

Multiplying this up across a UK wide production scenario of 23.06 million tonnes, suggests that the pre-rent and finance profitability of arable cropping under the change scenario is £1.31 billion. This is £166 million lower than in the pre-change scenario.

The benefit is a social gain from carbon emissions of £132 million, and the cost is a loss to farmers of £166 million. The social benefit is less than the cost to farmers, as such there is no incentive for farmers to make this change, or for this change to be otherwise incentivised without a greater saving in emissions resulting from the changed rotation.

2.2.1. Additional Nitrogen Savings

Through the course of the project, it is anticipated that there will be further insight into the impact of pulses inclusions on the wider rotation. This is expected to include a greater understanding of the nitrogen left in the soil which is available to the following cereal crop. Accuracy around this information could help to deliver greater incentive to farmers to utilise pulses in the rotation in greater levels, owing to the saving in cost.

To investigate the possible impact of a saving in nitrogen required following a pulse crop, a further analysis of the model farm was conducted. In analysing the reports from *Legume Futures,* it is apparent that there is a potential Nitrogen fixation of up to 30kg, following a pulse crop. This is rarely accounted for by farmers, who continue to apply full rate fertiliser following pulses.

However, if we were to assume a 30kg/ha reduction in the level of fertiliser applied following a pulse crop then there is further potential to both improve the reduction in emissions, but also to improve the economic performance of arable cropping.

Applying a 30kg/ha saving across the 122 hectares of pulses being grown on the model farm results in a further reduction of 2.2% in the level of emissions, all other things being equal. Multiplying this up in a similar fashion to the previous arable analysis results in a total social cost of emissions of £1.74 billion, £171 million below the baseline social cost, assuming that there is no change to yield of the following crop.

Regarding the economics of the nutrient saving, a reduction of 30kg of N across 122 hectares, would result in a variable cost saving of £4,868 across the farm, equivalent to £8 per hectare or £1.29 per tonne. As a result of the reduction in costs the proposition of increasing pulses is more favourable to farmers. Moreover, the social benefit of increasing pulses in the arable rotation outweighs the cost to farmers where fertiliser applications can be further reduced. The cost to arable farming of increasing pulses in the rotation where further savings in fertiliser application are made, is a reduction in pre-rent and finance surplus of £143 million. This is less than the resultant saving in emissions.

2.3. Arable Discussion

The next steps for the arable enterprise will involve incorporating the results of the trials conducted through the NCS project, the results of these trials will deliver further insight into the physical, financial and climactic performance of pulses. This will allow for further refinement of this analysis, and a more comprehensive CBA will be produced as a result.

The presently available environmental schemes and the impact that these may have on the economics of farm businesses will also need to be considered. This includes elements such legume fallow, which is both rotational and has a margin which could be viewed as competitive with traditional break crops. Whilst this may be attractive from an environmental standpoint it is not conducive to maintaining food production, which is a key target for government. Similarly, we must consider payments which generate extra income for cereals and not for break crops, such as no use of insecticide.

3. Pigs

The results for the pig sector are based upon analysis previously conducted for the Green Pig Project[4]. The Green Pig project evaluated the environmental consequences of using home-grown legumes as a protein source in pig diets. The research was conducted between July 2008 and October 2012.

3.1. The UK Pig Farming Baseline

3.1.1. Pig Farming Environment Baseline

The UK pig farming environmental baseline is determined by evaluating the environmental implications of changing from a ration which includes a high volume of soyabean meal, to a ration which includes a high volume of UK grown peas and beans. The Green Pig project determined the coefficients for the environmental impact of different diets.

The Green Pig Life Cycle assessment highlights the array of different carbon footprints that could be associated with pig feed production, largely driven by the choice of protein and fat ingredient and the origin of those products. The implications of diet on the global warming potential of pig production are far greater where the feed source is associated with land use change, for example Brazilian soyabean meal from land associated with deforestation. Where this is the case the GWP of the diet can be as much 1.36 times higher than the same diet with ingredients which are not the result of land use change (LUC).

The baseline diet for the Green Pig project includes 98 grams of soyabean meal per kilogram of food, for growing pigs and 47.6 grams of soyabean meal per kilogram for the finisher diet. The LUC diet has a GWP of 2.52kg CO_2e per kilogram of live weight gain (LWG), in this circumstance emissions from soyabean meal account for almost 28% of the total greenhouse gas emissions associated with the diet. However, where the diet uses soyabean meal from non-LUC sources the GWP of the diet falls to just 1.85kg CO_2e per kilogram of LWG. With non-LUC the emissions from soyabean meal account for just 2% of the total greenhouse gasses associated with the diet.

In the UK, the five-year average production of pig meat is 1 million tonnes, dressed carcase weight. Using a refence killing out percentage from AHDB of approximately 76% suggest five-year average liveweight production in the UK of 1.32 million tonnes.

Multiplying the life cycle assessment figure for the soyabean meal diet, using LUC sourced soyabeans, by the liveweight production of pigs, suggests total emissions associated with pig production of 3.33 million tonnes of CO_2e per annum. Using this figure suggests a social cost of the carbon emissions from pig production of £803 million.

Since the Green Pig work was completed there have been significant developments in the animal feed market. From 31 December 2024, EU Deforestation-Free Regulation[1] (EUDR) comes into effect, meaning that supply chains must demonstrate that products imported, have not been produced on land which has been the subject of deforestation since 31 December 2020. This includes soyabeans and fractions of soyabeans. This has implication for the UK market, with any products produced in the UK for export into the EU also having to meet these requirements, this includes the feeding of cattle and beef exported to the EU. Moreover, a large proportion of UK soyabean meal imports are transhipped from the Netherlands, which would also need to be compliant with the EUDR.

Using the non-LUC baseline coefficient (1.85kg CO_2e/kg LWG), gives a figure of total emissions from pig production of 2.44 million tonnes of CO_2e per annum. This has a baseline social cost of £589 million, using the Green Book value of £241 per tonne of CO_2e.

3.1.2. Pig Farming Economic Baseline

The economic implications of changing the diets of pigs, through the Green Pig project, were not explored to the extent that sectors are being considered in the NCS project. The Green Pig Project does highlight that the return per pig on the soyabean meal diet, during one of the trials conducted was £125.89 per pig. In isolation within this project that figure is relatively meaningless, as it does not provide a scale which is comparable to that used in the emissions calculations.

As such, a model pig farm is used here, to determine the pre-rent and finance surplus of a typical pig farm. The data used in the model is based upon reference data from Defra, AHDB, The Farm Management Pocketbook, and wider industry sources, including Andersons' estimations.

The model farm is breeder-finisher unit, with 350 sows, finishing 9,231 pigs a year at an average finished carcase weight of 88 kilograms, to a cutter specification. The fixed costs picture is based on an average of the fixed costs in the model, run by Andersons, from 2019/20 to 2023/24. This excludes 2021/22 which was an especially challenging year for pig producers, owing to a large backlog of pigs on farm. This year has been omitted, to provide a more representative picture of pig farming in a normalised year.

[1] Regulation - 2023/1115 - EN - EUR-Lex (europa.eu)

The model is based upon a march year end. The baseline economic performance for the pig model farm is shown below in Table 3-1. The gross margin of the enterprise is 40.8 pence per kilogram finished, the pre-rent and finance surplus 11.9 pence per kilogram.

Table 3-1 Pig Model Farm Baseline (Pre-Change) Scenario

	£ per farm	£ per sow	P per kg
Pig Sales Output	1,421,488	4,061.4	175.3
Herd Depreciation	31.902	91.1	3.9
Output less depr.	1,389,586	3,970.2	171.4
Variable Costs	1,058,608	3,024.6	130.6
Gross Margin	**330,978**	**945.7**	**40.8**
Labour	59,013	168.6	7.3
Power and Machinery	82,273	235.1	10.1
Admin	25,650	73.3	3.2
Property	67,208	192.0	8.3
Total Overheads	234,143	669.0	28.9
Pre-Rent & Finance Surplus	**96,835**	**276.7**	**11.9**
Rent, Finance & Drawings	79,750	685.9	9.8
Margin from Production	**17,085**	**-409.2**	**2.1**

Source: The Andersons Centre

Applying the pre-rent and finance surplus to the volume of UK pigmeat production gives a value for pig production of £120 million.

3.2. Pig Change Scenario

The Green Pig Project explored several different diets for growing and finishing pigs, which replaced soyabeans with peas and beans. In each case, the diet was balanced nutritionally, to reduce the impact on performance. The balancing of the diet involved adjustments primarily to the volume of amino acids which were used.

The diets from the project are shown in Table 3-2, below.

Table 3-2 The ingredient composition (g/kg) of the conventional grower and finisher diets used in the LCA for the large-scale pig experiment carried out during the Green Pig Project

Period	Grower			Finisher		
Type	Soya	Peas	Beans	Soya	Peas	Beans
SBM	98.0	0.0	0.0	47.6	0.0	0.0
Peas	0.0	300.0	0.0	0.0	300.0	0.0
Beans	0.0	0.0	300.0	0.0	0.0	300.0
Barley	250.1	249.8	150.4	249.9	240.2	250.0
Wheat	322.0	146.0	271.0	257.0	100.0	101.0
OSR Meal	110.0	110.0	110.0	125.0	125.0	125.0
Wheatfeed	25.8	0.0	0.0	150.0	79.0	35.3
Fat Suppl.	3.0	4.7	6.9	3.0	3.0	3.0
Minvit	27.1	25.7	25.7	27.6	27.7	27.0
Lysine	6.6	5.1	5.9	6.8	3.0	3.3
Methionine	1.0	1.8	2.3	0.9	1.2	1.3
Threonine	1.3	1.6	1.8	1.2	0.9	0.9
Biscuit 136	80.0	80.0	80.0	56.0	44.8	78.0
DDGS	75.0	75.0	75.0	75.0	75.0	75.0

Source: Green Pig Project

The relative carbon footprint associated with each diet, calculated through a lifecycle assessment, is given as 1.78kg CO_2e/kg LWG and 1.79kg CO_2e/kg LWG for the pean and bean diet respectively. The report describes this as not being significantly different to the non-LUC SBM diet. However, a significant difference is observed relative to the LUC SBM diet.

Multiplying the diet carbon footprints by the liveweight of pig production in the UK on an annual basis suggests that switching to the pea or bean would result in a saving of emissions of 0.09 million tonnes of CO_2e and 0.08 million tonnes of CO_2e respectively, for non-LUC diets. This reduces the relative social cost of emissions associated with pig production falls by £22.3 million and £19.1 million respectively.

Where LUC takes place, the emissions saving rises to 0.97 million tonnes of CO_2e and 0.96 million tonnes of CO_2e. In this case the relative social cost of emissions associated with pig production falls by £235.7 million and £232.5 million, resulting from the pea and bean diets respectively.

From an economic standpoint, the structure of the model farm is revisited and the cost of formulating the pea and bean diets, relative to the costs of the SBM diet is used to determine the change in costs for pig enterprises. The average cost of the pea and bean diets is 2% lower for the grower diet, than the SBM baseline, and 1% lower for the finisher diet than the SBM baseline.

In the absence of any performance changes, a move to a diet which is higher in pulses than it is in soyabean meal would appear to be an obvious thing to do. Not only does it deliver an environmental improvement, but the diet is also cheaper on a raw ingredient basis. This gives no account of any additional costs of processing.

The paper associated with objective six of the Green Pig product does highlight some marginal performance differences. The results of the trial highlight that 79% of the slaughtered pigs fed the SBM control diet met contract specifications. For peas and beans 70% and 76%, respectively, met the contract specifications. The model pig farm assumes that the output of the model is 7.6% reduced under the change scenario. The report highlights that there are no significant negative effects on slaughter and carcass metrics resulting from the inclusion of pulses and peas at the expense of SBM. This implies that there may be some other, non-diet related, factors at play.

Applying a 1.8% reduction in costs to grower feeds, a 1.2% reduction in costs to finisher feed, and a 7.6% reduction in finisher output, results in a pre-rent and finance loss of 0.1 ppkg. Without a loss to productivity, as suggested by the broader Green Pig report, the pre-rent and finance surplus would be 13.2 ppkg. This is represented in Table 3-3 below.

Table 3-3 Pig Model Farm Baseline (Post-Change) Scenario

	£ per farm	£ per sow	P per kg
Pig Sales Output	1,313,527	4,061.4	175.3
Herd Depreciation	31.902	91.1	3.9
Output less depr.	1,281,625	3,661.8	158.1
Variable Costs	1,048,653	2,996.2	129.3
Gross Margin	**232,971**	**665.6**	**28.7**
Labour	59,013	168.6	7.3
Power and Machinery	82,273	235.1	10.1
Admin	25,650	73.3	3.2
Property	67,208	192.0	8.3
Total Overheads	234,143	669.0	28.9
Pre-Rent & Finance Surplus	**-1,172**	**-3.3**	**-0.1**
Rent, Finance & Drawings	79,750	685.9	9.8
Margin from Production	**-80,922**	**-689**	**-10.0**

Source: Andersons

The results highlight how sensitive the pig sector is to changes in productivity and the risk associated with a greater number of pigs falling out of specification.

The resultant losses for the pig sector, were there to be a loss of 7.6% in the number of pigs meeting specification – whilst maintaining overall industry output – is a £1.0 million loss from the sector. This compares with the pre-change scenario of £119.5 million pre-rent and finance surplus.

The dominant factor regarding the pig industry is any negative impact on the number of pigs meeting specification, and the scale of such impact. Where the number of pigs meeting specification falls by 7.6%, the impact of cheaper, marginally more environmentally friendly feed, is more than offset by the reduction in revenue. In this circumstance the scale of increased costs are almost six times greater than the environmental benefit.

3.2.1. Pigs – Bean-led diet

The optimum may fall in the use of feed beans, rather than peas in diets. The research shows that while the environmental impact of the bean led diet may be greater than that of the pea led diet, the impact on farm profitability may be less.

The resultant social cost of emissions from a bean led diet relative to the previous analysis which used an average of the pea and bean led diet, is only £2 million greater, at £19.1 million less than the SBM baseline, where no LUC takes place. The emissions saving of using a bean led diet relative to SBM is just 79 thousand tonnes of CO_2e, in the non-LUC example, but 964 thousand tonnes where SBM comes from sources associated with LUC. However, the resultant impact of this diet on margins is reduced compared to the averaged pea and bean led diets.

The bean diet is calculated to be 0.99% more expensive than the SBM diet for growing pigs, however, it is 0.35% cheaper for finishing pigs. Earlier in this report it is highlighted that on the bean led diet, 76% of pigs met specification compared with 79% of pigs on the SBM diet. This is a decline of 3.8%. Table 3-4, below, shows the cost of production for pigs using the changed diet.

Table 3-4 Pig Model Farm Baseline (Post-Change) Scenario

	£ per farm	£ per sow	P per kg
Pig Sales Output	1,367,508	3,907.2	168.6
Herd Depreciation	31.902	91.1	3.9
Output less depr.	1,335,605	3,816.0	164.7
Variable Costs	1,058,588	3,024.5	130.5
Gross Margin	**277,017**	**791.5**	**34.2**
Labour	59,013	168.6	7.3
Power and Machinery	82,273	235.1	10.1
Admin	25,650	73.3	3.2
Property	67,208	192.0	8.3
Total Overheads	234,143	669.0	28.9
Pre-Rent & Finance Surplus	**42,874**	**122.5**	**5.9**
Rent, Finance & Drawings	79,750	685.9	9.8

Margin from Production	**-36,876**	**-563**	**-4.5**

With the bean-led diet, the total output from pig production, using the output figures highlighted in the baseline scenario, is £59.3 million, a fall of £60.8 million from the baseline scenario. In this circumstance the costs of changing the diet from the baseline are more than three times the environmental benefit in the non-LUC example. However, where LUC is considered, the environmental benefit is almost four times the cost to the farmer of making such a change. This highlights the volatility of emissions dependent on the source of feed material.

3.3. Pigs Discussion

It is worth considering, at this stage, what the requirement would be for beans were the diet of pigs to switch from SBM-led to bean-led. In Great Britain, total pig feed production in the five years ending June 2024 was 2 million tonnes.

The calculated bean diet included 30% beans, as such 600 thousand tonnes of beans would be required to make a wholesale switch in GB pig feed production.

4. Dairy

It is not yet clear what changes will be made to dairy diets, and the subsequent impact on emissions and cost of production during the next three years of this project. As such on the baseline scenario is outlined here.

4.1. The UK Dairy Farming Baseline

4.1.1. Environmental Impact of Dairy Farming

According to the Department for Energy Security and Net Zero emissions from enteric fermentation and waste management in dairy cattle accounted for 18% of total emissions from agriculture, on average between 2018 and 2022. What is more, much of the emissions come from methane. According to the sixth IPCC assessment report emissions from non-fossil methane are 27 times more potent than emissions from carbon dioxide[5] when measured over 100 years. This method of accounting for emissions uses the GWP100 methodology.

Tackling ruminant livestock emissions has been a large focus of efforts to reduce the overall carbon footprint globally. The work undertaken through this project will look at the role which peas and beans can play in supporting a reduction in ruminant emissions.

To determine the potential scope for reducing dairy emissions, The Andersons Centre's dairy model farm has been analysed using FCT. The Dairy model farm is 132 hectares with 220 milking Friesian cows calving all-year round, and 49 dairy heifers. The milking herd produces 7,430 litres per head per year on constituent contract. The herd is seeking to maximise milk production from forage although uses 1.9 tonnes of concentrates per head, per year.

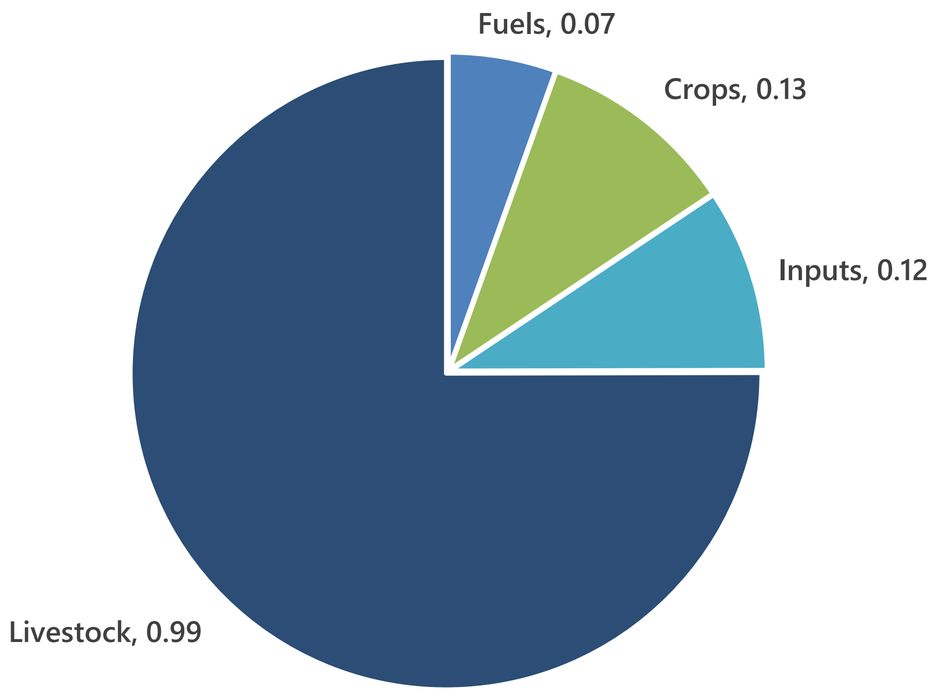
The baseline diet uses a standard milking cow concentrate figure from the FCT, with 18 per cent crude protein.

The forage on the farm is a mix of 44 hectares of grass silage, 22 hectares of maize silage and 66 hectares of grazed grass. The farm uses 79 tonnes of purchased nitrogen fertiliser per year, on top of spreading slurry across the forage ground.

It is assumed that the dairy herd spends 55% of their time housed or in yards. Of this time spent housed, 90% of the animal waste is assumed to be slurry and 10% farmyard manure.

The emissions for the normalised dairy farm are shown in Figure 4-1, below. For the purposes of this analysist the milk butterfat and protein produced by the farm have been assumed to be the five-year national average for the five-years ending March 2023, at 4.19% and 3.37% respectively. This allows for a fat and protein corrected milk (FCPM) emissions figure to be applied across UK output.

Figure 4-1 Baseline emissions, by source for model dairy farm (kgCO_2e/ kg FPCM)



Source: Farm Carbon Toolkit, Andersons

It is evident from the results of the carbon footprint analysis, that most emissions on the farm are associated with enteric fermentation and waste management. That said approximately 25% of emissions are associated with the production of forage.

The calculator gives the value of emissions per kilogram FPCM at 1.32 kg CO_2e. This has a social cost of carbon of approximately £318 per tonne (approx. one thousand litres) of milk produced. Applying this to the annual level of UK milk production, 14.9 billion litres, suggests a social cost of carbon associated with milk production in the region of £4.75 billion per annum.

To determine how the emissions of the dairy farm model compare with wider industry, the FCT benchmarking function has been considered. The benchmarking function shows how the model compares to other reports within the FCT. The dairy model is shown to be in the top 30% of farms on an emissions per hectare basis. However, the important metric is the emissions per kilogram of output. When this metric is analysed, the dairy model farm is shown to be fractionally above the median level. This suggests that the results are representative of the wider dairy industry on an output basis.

4.1.2. Economics of Dairy Farms

The baseline environmental and economic scenario for dairy enterprises is calculated using the Andersons Friesian Farm model farm. The Friesian Farm model has been run by Andersons for many years. For the purposes of this analysis, data is compiled based on five-year averages to March 2024, using data from a variety of sources, including AHDB, Defra, other industry sources, and Andersons’s assumptions.

The economic performance of the farm is shown in Table 4-1

Table 4-1 Dairy Model Farm Baseline (Pre-Change) Scenario

	£ per farm	£ per ha	P per litre
Total Output	610,393	4,230	34.6
Variable Costs	261,884	1,984	16.0
Gross Margin	**348,509**	**2,640**	**21.3**
Labour	38,528	292	2.4
Power and Machinery	105,754	801	6.5
Admin	17,215	130	1.1
Property	28,121	213	1.7
Total Overheads	189,617	1437	11.6
Pre-Rent & Finance Surplus	**158,892**	**1204**	**9.7**
Rent, Finance & Drawings	96,497	315	5..9
Margin from Production	**62,395**	**473**	**3.8**

Source: The Andersons Centre

The baseline economic performance for the dairy model farm, shows the business producing a gross margin of 21.3 pence per litre, on 1.64 million litres of milk per year. Once fixed costs are considered this represents a pre-rent and finance surplus of 9.7 pence per litre.

Multiplying this figure up across the total figure for UK milk production (14.9 billion litres) suggests the pre-rent and finance surplus of the UK dairy sector to be in the region of £1.45 billion.

4.2. Dairy Change Scenario

The dairy change scenario will be produced at a later point in the project, once more detail is known about the research goals and outcomes.

5. Grazing Livestock

It is not yet clear what changes will be made to grazing livestock diets, and the subsequent impact on emissions and cost of production during the next three years of this project. As such on the baseline scenario is outlined here.

5.1. The UK Grazing Livestock Farming Baseline

5.1.1. Environmental Impact of Grazing Livestock

Producing a single model farm to assess the environmental impact of grazing livestock farming is challenging. There is such wide variety in systems from lowland grazing to grazing moorland, store production to finishing, the differences between cattle and sheep production and of the breeds within each system.

The Department for Energy Security and Net Zero identifies the five-year average (2018-22) level of CO_2e emissions associated with beef cattle and sheep enteric fermentation and waste management to be 19.4 million tonnes of CO_2e. This is not to mention other emissions that exist with in livestock production and from land use and land use change. Based on 19.4 million tonnes of CO_2e the total social cost of emissions associated with grazing livestock is £4.68 billon.

Over the same five-year period, from 2018 to 2022, the UK produced 1.21 million tonnes of deadweight cattle and sheepmeat. This suggests a figure of 16 tonnes of CO_2e per tonne of cattle and sheepmeat produced including bones and trimming.

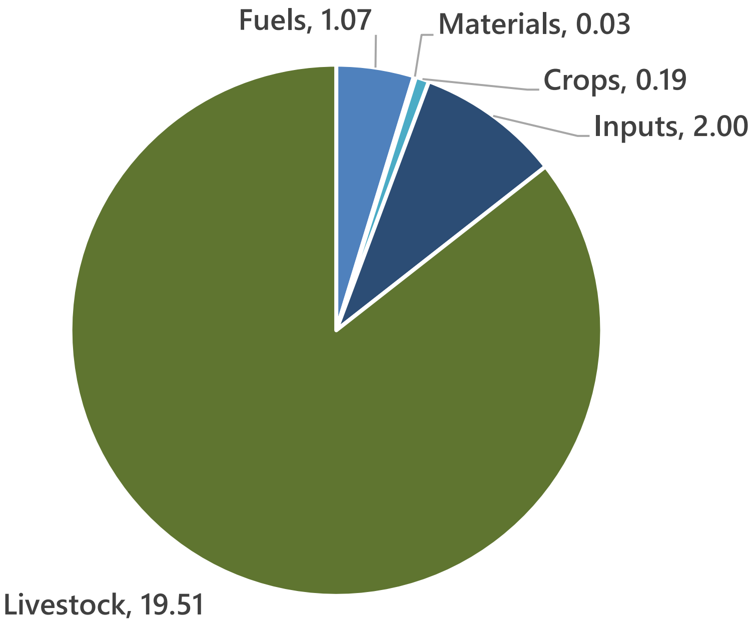
This figure is lower than the benchmark figures suggested by AHDB. An AHDB analysis using the carbon calculator, Agrecalc, suggests that emissions of beef production are 22.1-32.4 kg CO_2e per kilogram deadweight, depending on whether the beef comes from the dairy or beef herd. For sheepmeat the AHDB figures show emissions per kilogram of meat deadweight to be 29.5 kg CO_2e per kilogram.

For the analysis in the NCS project, The Andersons Centre proposes to use its Meadow Farm model. Meadow Farm is a traditional mixed farm, it runs many enterprises including arable production, managed through a stubble-to-stubble contract, a 60 head spring calving suckler herd, a 35 head dairy bull-beef herd and 500 ewe spring lambing sheep flock.

As with the other model farms, the important metric for carbon footprinting is not the emissions on an area basis, but on an output basis. The model farm emits 22.8 tCO_2e per tonne of deadweight sold, this is marginally below the median level identified through the benchmarking function with FCT.

Figure 5-1 shows the breakdown of The Andersons Centre grazing livestock model farm emissions. It is very clear that the bulk of emissions are borne from livestock. The livestock emissions include feed and bedding, but not the home fed wheat and barley as these are included in the "crops" category. Feed and bedding account for approximately 35 tonnes of the annual carbon footprint of the model farm, this equates to 0.75t CO_2e/ tonne of deadweight sold.

Figure 5-1 Baseline emissions, by source for grazing livestock farm (tCO_2e/ t dwt)



Source: The Andersons Centre, Farm Carbon Toolkit

Taking the emissions from the model farm and applying them to grazing livestock output gives a total carbon footprint of 28.0 million tonnes of CO_2e. This figure is arguably too high, as it includes the emissions associated with the cropping taking place on the model farm. The total area of cropping is already accounted for within this analysis.

Using just the figure for livestock emissions (i.e., the emissions associated with feed, bedding and enteric fermentation and manure management), suggests a carbon footprint of 24.0 million tonnes of CO_2e. Applying the social cost CO_2e emissions to this value suggests a baseline emissions cost from livestock production of £5.78 billion. This is the figure which will be used as the baseline for subsequent analysis.

This assumes that livestock production takes place exclusively in the lowlands. Of course, this is not true. However, there are not accurate estimates available of the volume of meat produced from uplands versus lowland animals. The NFU suggests that 44% of breeding ewes and 40% of beef cows are in the uplands[6]. However, this still does not give an accurate representation of meat production, as many upland lambs are subsequently finished in lowland areas.

5.1.2. Economics of Mixed Grazing Livestock Farming

As with determining an appropriate carbon footprint, determining a figure for the financial position of grazing livestock farms is challenging. For the purposes of this analysis the mixed grazing model farm, as used for the carbon footprint, is used.

As with other model farms used within this analysis, performance figures are based on industry benchmarks and published reference material, as well as some assumptions made by The Andersons Centre. Price and cost data is based upon publicly available information, including from AHDB, Defra and The Farm Management Pocketbook. Some elements of the costs of the model are based on assumptions made by The Andersons Centre, these are typically five-year averages of the Meadow Farm Model which Andersons have been running since 2009.

The baseline financial picture for the grazing farm is given in Table 5-1, below. For the purposes of this analysis, the arable enterprise has been retained in the costings.

Table 5-1 Mixed Grazing Farm Baseline (Pre-Change) Scenario

	£ per farm	£ per ha	£ per kg DWT
Livestock Output	180,524	1,479.7	3.80
Livestock Variable Costs	84,954	696.3	1.79
Arable Output	42,120	1300.8	0.89
Arable Variable Costs	14,986	462.8	0.32
Gross Margin	**222,644**	**794.8**	**2.58**
Labour	8,974	58.1	0.19
Power and Machinery	52,255	338.5	1.10
Admin	12,011	77.8	0.25
Property	13,989	90.6	0.29
Total Overheads	87,229	565.0	1.84
Pre-Rent & Finance Surplus	**35,476**	**229.8**	**0.75**
Rent, Finance & Drawings	50,800	329.1	1.07
Margin from Production	**-15,32**	**-99.3**	**-0.32**

Source: The Andersons Centre

The grazing livestock model farm is producing a pre-rent & finance surplus of £0.75 per kilogram of deadweight produced. This is an aggregated figure across the beef enterprises, sheep enterprise and arable enterprise. The level of rent, finance and drawings exceed the pre-rent and finance surplus leading to a loss from production of £0.32 per kilogram. This highlights the well reported challenge of grazing livestock producers generating a business surplus in the absence of farm support.

Multiplying the pre-rent and finance surplus across the five-year average level of beef and sheepmeat production in the UK suggests the pre-rent and finance surplus of the grazing livestock industry is £923 million. As highlighted above, this is contingent on the erroneous assumption that all livestock output is borne from the lowlands.

The focus of this project is on the role that pulses can play and as such the project's implications are thought to be greater for the lowlands than the uplands. As such during the project a more accurate baseline should be sought for the level of output pertaining to the uplands.

5.2. Grazing Livestock Change Scenario

The grazing livestock change scenario will be produced at a later point in the project, once more detail is known about the research goals and outcomes.

6. Poultry

It is not yet clear what changes will be made to poultry diets, and the subsequent impact on emissions and cost of production during the next three years of this project. As such on the baseline scenario is outlined here. The Andersons Centre does not routinely run a poultry model farm, as such for the purposes of accuracy in the analysis of poultry cost of production, figures from the Farm Business Survey have been used.

The poultry section is split into two sections, the first considers the emissions associated with broiler production, the second considers the emissions from free-range layer production.

6.1. The UK Broiler Farming Baseline

6.1.1. The UK Broiler Environmental Baseline

The analysis of broiler production is based upon the "non-contract" broiler production schedule in the Farm Business Survey. The calculation is based upon a five-year average analysis between 2018/19 and 2022/23. The broiler enterprise has an average number of birds on farm of 229 thousand per year. Birds are assumed to have a deadweight of 2.3 kilograms, this is in line with figures published by Defra across the same reference period[7].

A large proportion of the emissions from poultry are associated with feed. There is limited published information relating to the current diets of broiler poultry in the UK. A diet based upon a life cycle assessment conducted by Leinonen et al. (2012a)[8] is used, although some changes have been made to protein source in light of the available feed ingredients on the Farm Carbon Toolkit website. This includes the substitution of fish meal for soyabean meal.

Other inputs have been calculated by dividing the cost per farm in the Farm Business Survey, by a reference price for the category, e.g., the volume of fuel and electricity.

For the purposes of this analysis, the output metric for broiler farming is tonnes CO_2e per tonne of meat produced. The calculated carbon footprint for the broiler farming enterprise is 2.68 tCO_2e per tonne of poultry meat (deadweight). This is some way below the benchmark mean value quoted by The Farm Carbon Toolkit. This Is also below the value for emissions quoted in Leinonen et al. The Leinonen study estimates a total carbon footprint of "standard" broiler production of 4.41 kg of CO_2e per kg of expected edible carcase weight.

Multiplying the carbon footprint as calculated through Farm Carbon Toolkit by the total production of broiler meat in the UK suggests emissions from production of 4.65 million tonnes of CO_2e, with an estimated social cost of carbon of £1.12 billion.

Using the values calculated by Leinonen et al. suggests a total carbon footprint of broiler production of 7.65 million tonnes of CO_2e, at a cost of £1.84 billion.

Without further analysis and scrutiny of the model it is hard to know which value is closer to the true value. The level of throughput is far lower in the Leinonen study, and it includes more elements in its analysis of emissions. However, since the research was conducted in 2012 it is also true that emissions factors are likely to have altered significantly. For the time being an average of the two values is used in this analysis.

6.1.2. The UK Broiler Economic Baseline

The economic baseline for broiler production is calculated using values from the Farm Business Survey. The survey is based on an average sample of 21 non-contract broiler farms. The financial performance of non-contract broiler enterprises is summarised in Table 6-1, below.

Table 6-1 Broiler Farm Baseline (Pre-Change) Scenario

	£ per farm	£ per bird	£ per kg DWT
Poultry Output	2,512,907	1.56	0.64
Other Output	340,266	0.21	0.09
Variable Costs	1,954,588	1.21	0.50
Of which feed	1,780,752	1.11	0.46

Gross Margin	**898,585**	**0.56**	**0.23**
Labour	116,831	0.07	0.03
Power and Machinery	335,090	0.21	0.09
Pre-Rent & Finance Profit	**446,664**	**0.28**	**0.12**
Rent, Finance & Other	222,491	0.14	0.05
Farm Business Income	**209,373**	**0.13**	**0.05**

Source: Farm Business Survey

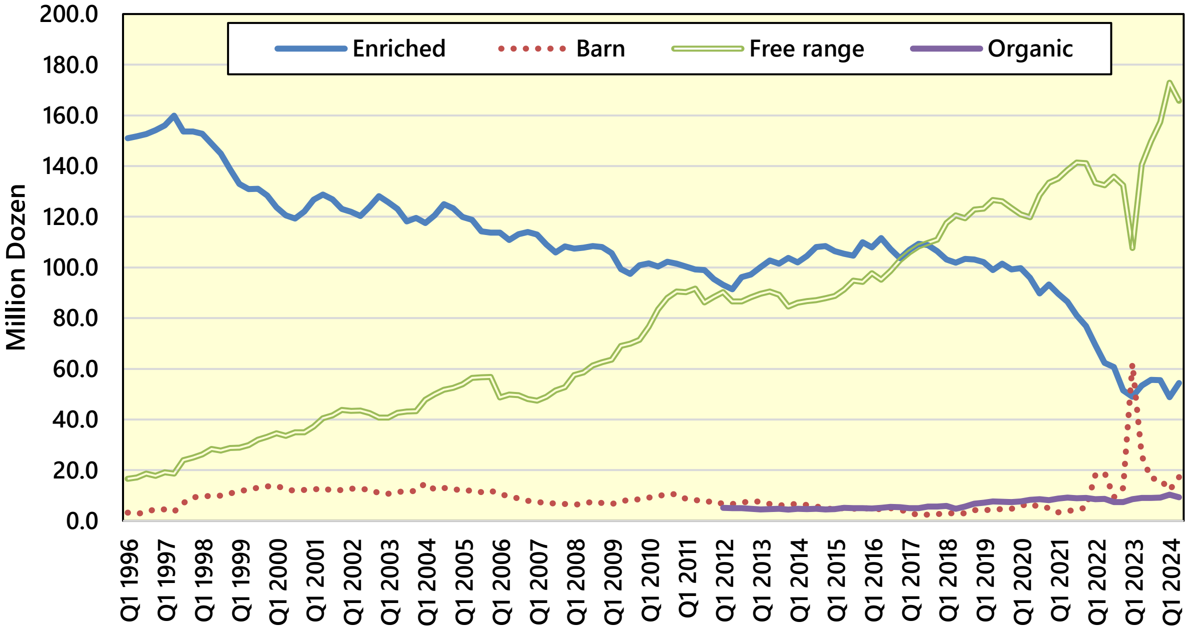
The figures from Farm Business Survey show a pre-rent & finance of £0.12/ kg deadweight. Multiplying this across broiler production in the UK suggests a total pre-rent & finance profit for the sector of £208 million.

6.2. The UK Layer Baseline

6.2.1. The UK Layer Environmental Baseline

There are a variety of different poultry laying systems in the UK, each with a different environmental impact. For the purposes of this analysis the focus is on free-range laying systems. Over the past decade, the proportion of eggs packed from free range systems has increased from 35% of the market to 67% in quarter two of 2024. This trend is expected to continue with only avian influenza impacts in 2023 causing significant deviation from the trend (see Figure 6-1).

Figure 6-1 UK egg packers' intake, by system, million dozen



Source: Defra

Some significant research has previously been conducted into the carbon footprint of the different production systems. Leinonen et al. (2012b)[9] highlight the global warming potential of cage, standard, free range and organic laying systems in the UK, these were calculated using a cradle-to-gate lifecycle assessment and are summarised in Table 6-2, below.

Table 6-2 Global Warming Potential (tonnes of CO_2e) for three egg laying systems, per tonne of eggs

Material or Activity	Cage	Barn	Free Range	Organic
Feed and Water	2.10	2.22	2.36	2.41
Electricity	0.24	0.48	0.20	0.24
Gas and Oil	0.09	0.14	0.18	0.18
Housing and Land	0.38	0.48	0.50	0.54
Manure and Bedding	0.11	0.13	0.14	0.06
Breeder	0.05	0.04	0.03	0.04
Pullet	0.51	0.55	0.57	0.60

Layer	2.36	2.86	2.78	2.78
Total	2.92	3.45	3.38	3.42

Source: Leinonen et al. (2012b)

Figures used the lifecycle assessment have been incorporated into an analysis of the emissions from a free-range layer unit as presented in the Farm Business Survey. The system calculated is based upon a 19,236 hen unit, laying 25 dozen eggs, per bird, per year. The diet for the unit is calculated based on the diet assumptions from Leinonen et al. although some elements have been adjusted due to the limitations of the available feed types in Farm Carbon Toolkit.

The diet is assumed to contain 115 tonnes of SBM, plus a further 56 tonne allocation of SBM in lieu of sunflowers. The calculated carbon footprint per tonne of eggs produced, at an average weight of 63.5 grams per egg, is calculated to be 3.10 tCO_2e. This is 8% below the free-range level determined by Leinonen et al. but the analysis through Farm Carbon Toolkit is limited to energy, feed, manure, bedding and livestock emissions. In addition, the calculation through Farm Carbon Toolkit, does sit fractionally below the uncertainty range calculated by Leinonen et al (0.27tCO_2e/ tonne of eggs).

UK egg production averaged approximately 11.1 billion eggs per year, between 2018/19 and 2022/23. Again, assuming an average egg weight of 63.5 grams, this equates to approximately 704.5 thousand tonnes of eggs. At 3.1 tCO_2e per tonne of eggs, the emissions from UK egg production are estimated at 2.18 million tonnes of CO_2e, at a social cost of carbon of £241 per tonne, this equates to £525 million.

6.2.2. The UK Free Range Layer Economic Baseline

The economic baseline for free range layer production is calculated using values from the Farm Business Survey. The survey is based on an average sample of 30 free range layer farms. The financial performance of those enterprises is summarised in Table 6-3, below.

Table 6-3 Layer Farm Baseline (Pre-Change) Scenario

	£ per farm	£ per doz
Poultry Output	410,513	0.85
Other Output	77,103	0.15
Variable Costs	277,873	0.57
Of which feed	253,986	0.52

Gross Margin	**209,743**	**0.43**
Labour	61,013	0.13
Power and Machinery	55,241	0.11
Pre-Rent & Finance Profit	**94,489**	**0.19**
Rent, Finance & Other	71,967	0.15
Farm Business Income	**39,109**	**0.07**

Source: Farm Business Survey

The figures from Farm Business Survey show a pre-rent & finance of £0.19 per dozen eggs. Multiplying this across egg production in the UK suggests a total pre-rent & finance profit for the sector of £176 million.

7. Conclusions and Discussion

This report is the first of three that will be delivered during this project. Given results from other work packages are expected in the coming quarters, this analysis presented here will change. As more information and evidence comes to light, the accuracy of the change scenarios will improve, and further confidence can be placed in the benefit-cost ratios of increasing the level of pulses in arable production and in livestock consumption.

This cost-benefit analysis finds that cost for farmers of increasing pulses to 20% of combinable crop rotations outweighs the environmental benefit, without further incentives. This is based upon increasing the level of pulses in rotations without taking account of any benefit from residual nitrogen or other rotational benefits that may be identified later in the project.

However, where a 30 kg/ha saving can be made in the level of nitrogen applied to the following wheat crop, the benefits outweigh the cost to farmers by a ratio of 1.2:1. This is still relatively small ratio but based on this analysis would deliver a reduction in UK arable emission, ceteris paribus, of 0.7 million tonnes of CO_2e.

A further sensitivity analysis should be undertaken in future iterations of this report, to identify the sensitivity of these results to the area of pulses grown and to the yield of crops.

For this analysis to hold true, the market for pulses must maintain its current balance of supply and demand. This is contingent on there being sufficient growth in demand from the livestock sector. So far, this analysis has only considered the impact of increased pulse consumption in the pig sector. The pig sector analysis was completed over a decade ago as part of the green pig project.

The primary finding was that where no land use change soyabean meal is used in diets, the relative shift to pulses has negligible benefit for emissions. However, where land use change in soyabean meal is considered, relative to a diet that replaces soyabean meal with beans, the saving that can be seen in emissions outweighs the reduction in the profit of pig farming by a factor of 3.8:1.

This cost-benefit analysis shows early signs that the environmental merit of increasing pulse production in the UK outweighs the cost to farmers of doing so, potentially signalling the need for intervention to move agriculture towards net zero.

Table 7-1 Summary of results from Cost-Benefit Analysis

	Baseline Scenario		Change Scenario		Difference		
	Emissions £M(MtCO$_2$e)	Pre-Rent & Finance Profit (£M)	Emissions £M(MtCO$_2$e)	Pre-Rent & Finance Profit (£M)	Social Benefit Emissions £M	Farmer Cost Pre-Rent & Finance Profit (£M)	Benefit-Cost Ratio
Arable	1,912 (7.9)	1,481	1,781 (7.4)	1,314	131	166	0.8:1
Arable (+30Kg N Saving)	1,912 (7.9)	1,481	1,741 (7.2)	1,337	172	143	1.2:1
Non-LUC Pigs (Pea-Bean avg.)	589 (2.4)	120	569 (2.4)	-1	21	121	0.2:1
LUC Pigs (Bean Diet)	803 (3.3)	120	570 (2.4)	59	233	61	3.8:1
Non-LUC Pigs (Bean Diet)	589 (2.4)	120	570 (2.4)	59	19	61	0.3:1
Dairy	4,749 (19.7)	1,449	-	-	-	-	-
Grazing L'stock	5,785 (24.0)	923	-	-	-	-	-
Poultry – Broilers	1,419 (6.1)	208	-	-	-	-	-
Poultry - Eggs	525 (2.2)	176					

References

[2] See Agri-climate report 2023 - GOV.UK (www.gov.uk)
[3] See CHAP_Net_Zero_Report_0822.pdf (chap-solutions.co.uk)
[4] See Report of Objective 2 (pgro.org)
[5] See Microsoft Word - Global-Warming-Potential-Values.docx (ghgprotocol.org)
[6] See What are the uplands? About British uplands farming (countrysideonline.co.uk)
[7] See Latest poultry and poultry meat statistics - GOV.UK (www.gov.uk)
[8] See Predicting the environmental impacts of chicken systems in the United Kingdom through a life cycle assessment: Broiler production systems (sciencedirectassets.com)
[9] See Predicting the environmental impacts of chicken systems in the United Kingdom through a life cycle assessment: Egg production systems (sciencedirectassets.com)