Suckler Beef Climate Change Group

Farm Carbon Case Studies

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Executive Summary

(i) This study, conducted by SRUC, supports the work of the Scottish Government's Suckler Beef Climate Group, chaired by Jim Walker by assessing the potential for carbon emission reductions on 'Average' Scottish suckler beef farms through the adoption of a range of technical improvements and carbon mitigation measures.

(ii) In this analysis, work has been focused on the Breeder-Finisher units as this farming system encompasses the complete beef production chain from breeding through to slaughter. Details of the main assumptions, data sources and references are included in this report.

(iii) The results of the farming system modelling exercise indicate that by implementing a series of measures, in sequence, there is the potential for Rearer Finisher units to cut carbon emissions by up to 37.6% from the defined baseline level.

(iv) In the sequential or "stacked" scenarios below, the measures which generated the greatest reductions in carbon emissions included:

- Reducing age at slaughter to 18 months,
- Reducing age at first calving from 3yrs to 2yrs,
- Improving grassland management,
- Use of nitrification inhibitors in artificial fertiliser.

Table A – Carbon emissions of beef production by measure

Scenario	Carbon emissions per kg beef	Individual change from preceding measure		Cumulative change from baseline	
	(kg CO2e/ kg dwt)	*(kg CO2e/ kg dwt)*	*(%)*	*(kg CO2e/ kg dwt)*	*(%)*
S1. Baseline CTS Average	35.73				
ST2. Increase calves reared	35.23	-0.50	-1.4%	-0.50	-1.4%
ST3. Reduce age at 1st calving to 2 years	32.80	-2.43	-6.9%	-2.93	-8.2%
ST4. Reduce cow weight by 10%	32.45	-0.35	-1.1%	-3.28	-9.2%
ST5. Reduce age at slaughter (18 months)	28.41	-4.04	-12.5%	-7.32	-20.5%
ST6. Improved grassland management	26.15	-2.26	-7.9%	-9.58	-26.8%
ST7. Methane inhibitor (3NOP)	24.90	-1.25	-4.8%	-10.83	-30.3%
ST8. Improved nutrient management	23.92	-0.98	-3.9%	-11.81	-33.0%
ST9. Nitrification inhibitors	22.44	-1.48	-6.2%	-13.28	-37.2%
ST10. Reduce age at slaughter (16 months)	22.76	0.32	1.4%	-12.96	-36.3%
ST11. Finish as bull beef (13 months)	22.31	-0.45	-2.0%	-13.42	-37.6%

NB. The figures are for illustration only and the order and magnitude of carbon savings from different measures will vary widely from farm to farm.

(v) The order in which the measures are implemented will have an impact of their relative impact with those at the beginning having a relatively greater effect.

(vi) The range of improvement measures modelled is not exhaustive and not all measures will be applicable in every case.

(vii) The intention of the study is to show the potential for different measures to reduce carbon emissions in beef production.

(viii) The study is focused on improvements in technical performance and related impact on carbon emissions and for this reason carbon sequestration has not been included. Agrecalc is also able to estimate carbon sequestration from grasslands, crops and soils through a soil carbon module.

(ix) The feasibility of individual measures will vary widely and will be influenced by farm specific factors including:

- Soils Type
- Climate and Geographical Location,
- Farming System,
- Business Resources and Infrastructure,
- The Technical and Management Ability of the Business Manager and his/her staff,
- The Fiscal Cost/Benefit to the business, and the
- Degree of Support and Training available locally.

(x) In practice, it is not feasible for every farm to adopt every potential technical and mitigation measures. Therefore, in practice, it is expected that farmers would select the measures most appropriate for their business. Equally, it is likely that farmers will choose to adopt these measures over a period of time, and therefore, the resultant reduction in carbon emissions will be phased over a number of years, especially given the fact that system changes take time to plan and fully take effect; for example changing the age at first calving from 3 years down to 2 years and introducing a programme of reseeding.

Glossary and Abbreviations

Agrecalc	- Agricultural Resource use Efficiency Calculator (SRUC)
ME	- Metabolisable Energy
Carbon dioxide equivalent	- Where all gas emissions are expressed in terms of their relative GWP relative to carbon dioxide
CP	- Crude Protein
DD	- Digestibility
Direct emissions	- carbon equivalent emissions produced on the farm during the production process
Embedded emissions	- carbon equivalent emissions produced off the farm in the growing, production, processing and transport of products, inputs or livestock brought into the farming system
DDGS	- Distillers Dark Grains and Solubles
DLWG	- Daily Live Weight Gain
DWT	- Deadweight
Feed Print	- Dutch feed LCA database
GHG	- Green House Gas
GWP	- Global Warming Potential
Indirect emissions	- carbon equivalent emissions produced outside the farm from production of inputs such as feed (see embedded emissions)
IPCC	- International Panel on Climate Change
LCA	- Life Cycle Analysis
LUC	- Land Use Change (associated with crop production)
LWT	- Liveweight
PAS2050	- British Standards Institute standard for Life Cycle Analysis
SAC	- SAC Consulting – a Division of SRUC
SRUC	- Scotland’s Rural College
Tier 1	- LCA method using standard static emissions values per livestock unit
Tier 2	- LCA method using dynamic calculation of livestock emissions based on feed energy demand, feed intake, growth rate and related factors.

Methodology

Objectives

This study, conducted by SRUC, supports the work of the Scottish Government suckler beef climate group by assessing the potential for carbon emissions reductions on ‘average’ suckler beef farms from adoption of a range of technical improvement and carbon mitigation measures.

Overview

In the first round of analysis work has been focused on the Breeder-Finisher unit as these encompass the complete beef production chain. Other beef systems such as Breeder-Store and Finishers will be assessed at a later stage. Details of all assumptions and data sources and references are included in the report and attached spreadsheet tables; “Carbon results–breeder finisher1.xls”.

Agrecalc

All the carbon emissions were generated using SRUC’s farm carbon life cycle tool; Agrecalc (Agricultural Resource use Efficiency Calculator). Agrecalc generates cradle to gate carbon assessments and represents a partial product life cycle from resource extraction (cradle) to the gate (i.e. the farm gate). Further details in Appendix 1.

SAC Beef Farm Model

To generate the input and output data for each scenario needed to conduct the carbon footprint in Agrecalc SAC has built a detailed SAC Beef Farm Model encapsulating:

- all physical inputs (feed, crops, grass, fertiliser, lime, fuel, breeding stock),
- performance data for crops and livestock (yields of cereals and straw, calving %, rearing %, age at first calving, sale weights, and age at sale), and
- output (livestock sales).

The model models purely the beef enterprise and the required area of grazing, silage ground and barley needed to meet the needs of the beef herd. As the feed requirement of the beef herd changes in each scenario, the area of grass and barley flexes in response.

In this case study a straw based manure system is used. Manure is applied to crops and grassland within their nutrient requirements with additional fertiliser applications as needed. It is assumed that 75% of the nutrient value of the manures will be fully utilised in the base scenario with better practices in subsequent scenarios increasing this level.

The model has been designed to allow modelling of ‘standard’ beef farming systems, and to assess how changes in performance or management practices affect physical inputs, technical performance, and farm output. The data generated has then been inputted into the Agrecalc carbon calculator to generate carbon emissions estimates on a whole farm, enterprise and per unit of output (kg deadweight of carcase weight) basis.

Utilising detailed analysis of the Cattle Tracing System (CTS), supplemented where necessary from the QMS Beef and Sheep Costings, the SAC Farm Management Handbook data and other SAC expert knowledge/Industry data sources/Research; a Baseline scenario for each beef farming system has been created to represent, as closely as possible, the national average for beef herd performance.

Using the Baseline scenario, it has been possible to evaluate the potential impact on carbon emissions of changing individual key technical aspects relevant to a particular beef system. Equally, through sequentially ‘stacking’ individual scenarios, with net changes from individual measures being compared to the preceding measure, while cumulative changes are compared to the baseline. In this way it has been possible to build up a picture of the potential impact on total carbon emissions. This allows an understanding of the net effect if all these measures where applied on the one farm.

Farm input data and carbon results data have been prepared by SAC farm business economists Julian Bell and Christine Beaton with technical assistance from other SAC staff. All beef rations have been derived from SAC Feedbyte with the input of SAC livestock nutritionist, Mary Young.

Rearer Finisher Systems

For the purposes of this report, utilising detailed analysis of the Cattle Tracing System (CTS), the Baseline for a Rearer Finisher system has been taken to be:

- Spring Calving.
- CTS data - Calving % 86%, Rearing % 80%.
- Homebred Replacement Heifers, calving for the 1st time at 3 years of age.
- Progeny not required for breeding slaughtered at 21 months of age, weighing 650 kg liveweight.
- Silage based winter diets and pastures > 10 years old.
- No current use of methane or nitrification inhibitors.

In addition to the Baseline scenario (ST1) noted above, the following scenarios were considered:

Scenario	**Description**
ST1	**Baseline**
ST 2	+ Increase No. of Calves Reared by 5%
ST 3	+ Reduce Age at First Calving to 2 years
ST 4	+ Reduce Cow Weight by 10%
ST 5	+ Reduce Age at Slaughter to 18 months
ST 6	+ Improve Grassland Management
ST 7	+ Improve Manure and Nutrient Management
ST 8	+ Use Methane Inhibitor (3NOP)
ST 9	+ Use Nitrification Inhibitors
ST 10	+ Reduce Age at Slaughter to 16 months
ST 11	+ Finish Bulls at 13 months

The results and implications of these scenarios are summarised in the accompanying set of briefs and excel tables. The briefs outline:

- A description of the Scenario and its relevance to overall carbon emissions.
- The assumption on which the scenario is based.
- The effect this scenario could have on carbon emissions.
- Factors affecting uptake and feasibility.
- Areas where specialist help/grant aid would be beneficial.

Each of the scenarios are stacked sequentially, meaning that the carbon results will reflect the new performance or management practice.

Assumptions Used in Carbon Emissions Calculations

Category	Scenario	Assumptions Used
Suckler Beef System	All	Rearer Finishers
Terminal Sires	All	Continental Terminal Sires
Calving Period	All	Spring Calving
Calving %	Baseline	86% - CTS 'Average' Data for Rearer Finishers
Calving %	Increased Calves Reared (then continued through all subsequent scenarios)	90% - 5% increase over CTS 'Average'
Calf Mortality	All Scenarios	8% - CTS 'Average' data
Rearing %	Baseline	80% - CTS 'Average' Data for Rearer Finishers
Rearing %	Increased Calf Reared (then continued through all subsequent scenarios)	84% - 5% increase over CTS 'Average'
Age at 1st Calving	Baseline Increased Calves Reared	3 years
Age at 1st Calving	Reduce Age at 1st Calving (then continued through all subsequent scenarios)	2 years
Mature Cow Weight	Baseline Increased Calf Numbers Reduce Age at 1st Calving	700kg
Mature Cow Weight	10% reduction in cow weight	630kg (90% of 700 kg)
Age at Slaughter	Baseline Increased Calf Numbers Reduce Age at 1st Calving Reduce Cow Weight by 10%	21 months
Age at Slaughter	Reduce Age at Slaughter to 18 months (then continued through all subsequent scenarios until age reduced to 16 months, then 13 months)	18 months
Age at Slaughter – Bull Beef	Finish as Bull Beef	13 months
Slaughter Weight	All	650 kg liveweight, 364 kg deadweight
Cow & Stock Bull Diets*	Baseline Increased Calf Numbers Reduce Cow Weight by 10% Reduce Age at 1st Calving Reduce Age at Slaughter to 18 months	Silage based diets – Average Quality – 10.5 ME, 11% CP Balanced with Barley, Rapeseed Meal and Vitamins & Minerals
Cow & Stock Bull Diets*	Improved Grassland Management (then continued through all subsequent scenarios)	Silage based diets – Good Quality – 11.2 ME, 14% CP Balanced with Vitamins & Minerals

Category	Scenario	Assumptions Used
Calf Diets*	All except 13-month Bulls	100 kg Creep fed prior to weaning
Calf Diets*	13-month Bulls	150 kg creep fed prior to weaning
Youngstock Diets*	Baseline Increased Calf Numbers Reduce Cow Weight by 10% Reduce Age at 1st Calving Reduce Age at Slaughter to 18 months	Silage based diets – Average Quality – 10.5 ME, 11% CP Balanced with Barley, Rapeseed Meal and Vitamins & Minerals
Youngstock Diets*	Improved Grassland Management (then continued through all subsequent scenarios except for Bull Finishing Diet)	Silage based diets – Good Quality – 11.2 ME, 14% CP Balanced with Vitamins & Minerals
Finishing Bull Diets*	13-month Finishing	Straw based diet Balance with Barley, Wheat Dark Grains, Molasses and Vitamins & Minerals
Improved Grassland Management	Improved Grassland Management (then continued through all subsequent scenarios)	Silage quality changes from 'Average' to 'Good' as qualified above. Grazing changes from set stocking to Rotational Grazing Improved grassland due to regular reseeding policy.
Liming	All	"Carbon results – breeder finisher1.xls"
Fertiliser – N	All	" "
Fertiliser - P	All	" "
Fertiliser - K	All	" "
Slurry	All	" "
Farmyard Manure	All	" "
Barley Grain in diets	All	All home grown. Hectares grown based on an average yield of 5.5 to 6.5 t/ha
Straw – Feeding & Bedding	All	All home-grown straw retained. Yield 2.9 to 3.4t/ha
Silage	All	All homegrown. Hectares grown based on 2 cuts – 32t/ha
Grazing Land Required	All	Based on a dry matter feed requirement of livestock
Total Land Area	All	Based on required areas of silage, grazings and barley.

Category	Scenario	Assumptions Used
% Utilisable Grass Dry matter	Baseline Increased Calf Numbers Reduce Cow Weight by 10% Reduce Age at 1st Calving Reduce Age at Slaughter to 18 months	50% rising to 65% in the improved grassland scenario
Methane Inhibitor	Methane Inhibitor (then continued through all subsequent scenarios)	3NOP – 20% reduction in Enteric methane emissions of housed animals
Electricity and fuel	All	Calculated using standard SAC values based on the number of livestock and the area of gras and crops

Scenario S1 – Baseline CTS Scenario

The Scottish beef industry is an amalgam of Weaned Calf producers, Yearling producers, Forward Store producers, Store and Forward Store Finishers (grassland and cereal based) and Rearer Finishers.

As Rearer Finishers combine all the key stages of the production process from breeding through to finishing, they have been used to show the potential effect on carbon emissions that key changes within the breeding and finishing periods could have on the total emissions from one farm.

While it is acknowledged that farming systems vary throughout Scotland as a function of geography, geology, history, logistics, weather, and individual farmer choices; in seeking to determine the current industry 'Average', the Cattle Tracing System (CTS) metrics were analysed to provide the Baseline scenario which the impact of key changes within the breeding and finishing periods could be evaluated.

The Baseline for a Rearer Finisher system has been taken to be a Spring calving herd selling finished cattle at an average of 21 months of age. Replacements are home bred.

The table below details the other assumptions made based on CTS metrics.

Assumptions for Scenario 1 Baseline - Using CTS Average Data

	Baseline
Calving Period	Spring
Calving %	86
Rearing %	80
Heifer Replacement Rate (%)	15
Age at First Calving (years)	3
Improved Manure & Nutrition Mgmt.	No
Nitrification Inhibitors	No
Cow Weight kg lw	700
Silage Quality (10.5 ME, 11% CP DM)	Average
Grazing System	Set Stocking
Calf Sale Weight kg lw	650
Age at Slaughter months	21
Methane Inhibitors (3NOP)	No
Alternative Feeds	No

Sources of data – CTS Average Data - Rearer Finishers

Carbon results for the Baseline

SRUC Agrecalc - Stacked	S1. Baseline CTS Average
Table C1 - total beef carbon emissions	
Units	(kg CO2e)
Year	
Energy use	0
Fertiliser production	40,335
Lime	165,278
Feed production	76,054
Bedding	14,996
Pesticides	28,314
Disposal carcases	53
Methane - feed digestion	877
Methane - manure	418,204
Nitrous oxide - fertiliser & manures	11,042
Total beef enterprise	**755,153**
Output (kg dwt beef)	1,027,372
Table C3 - per kg dwt beef carbon emissions by activity	**S1. Baseline CTS Average**
Unit	(kg CO2e/kg dwt)
Energy use	1.40
Fertiliser production	5.75
Lime	2.64
Feed production	0.52
Bedding	0.98
Pesticides	0.00
Disposal carcases	0.03
Methane - feed digestion	14.54
Methane - manure	0.38
Nitrous oxide - fertiliser & manures	9.47
Total Emissions (kg CO2e/ kg dwt beef)	**35.73**

Explanation for changes – see excel - “Carbon results – breeder finisher1.xls”

Scenario ST2 – Increase Number of Calves Reared

Background

For a breeding herd, the rearing percentage is the number of calves sold/kept for breeding per 100 cows mated. The rearing percentage is influenced by the calving percentage (number of calves born per 100 cows mated) and the calf mortality rates post-partum.

While the 2019 QMS Cattle and Sheep Enterprise Profitability report documents the 'Top Third' of recorded producers as having an 'average' calving % of 96%, and a rearing % of 91%; analysis of CTS metrics for all Scottish Rearer Finishers shows the Scottish 'average' calving percentage to be 86%, and the rearing % to be just 80%. While CTS analysis shows the range of rearing percentages on some holdings to be as low as 56%, and as high as 100%, care must be taken interpreting this data as corresponding percentages % will vary depending on herd size.

Research undertaken by Tim Geraghty, SRUC (2018) involving 1,500 suckler cows with an average rearing % of 82% identified that, of the 18% losses, 8% of losses were due to fertility issues, 0.9% due to cow mortality, 3% and 2% due to abortions and still births respectively, 1.6%, with unspecified neonatal accounting for 1.6% and older mortality 1.4%.

Importance

Calf losses from conception through to point of potential sale means that carbon emissions are occurring without the production of saleable meat.

To improve the reproductive output of the herd, provide a greater choice of replacement heifers and reduce non-productive emissions, there are a multitude of approaches to improve fertility and reduce calf losses available to all herds. These include:

- Improved nutrition and cow body condition management to improve fertility and colostrum quality for calves,
- Disease control (health plan) including vaccination programmes to reduce abortion and calf mortality,
- Calving period management including hygiene and colostrum to reduce mortality,
- Improved genetic selection for maternal characteristics, and
- Bull management to improve fertility and conception including use of Estimated Breeding Values (EBV) for Calving ease and using scrotal size as an indication of fertility.

Assumptions for Increasing the Number of Calves Reared

While a proportion of rearer finishers are achieving calving and rearing percentages in the high 90s, this scenario is aimed at 'Average' producers increasing calving and rearing % by 5% to 90% and 84% respectively.

	Baseline	Scenario 2
Calving Period	Spring	Spring
Calving %	86	**90**
Rearing %	80	**84**
Heifer Replacement Rate (%)	15	15
Age at First Calving (years)	3	3
Improved Manure & Nutrition Mgmt.	No	No
Nitrification Inhibitors	No	No
Cow Weight kg lw	700	700
Silage Quality (10.5 ME, 11% CP DM)	Average	Average
Grazing System	Set Stocking	Set Stocking
Calf Sale Weight kg lw	650	650
Age at Slaughter months	21	21
Methane Inhibitors (3NOP)	No	No
Alternative Feeds	No	No

Sources of data – CTS Average Data - Rearer Finishers

Wider Farm and Industry Implications

While improving industry 'average' calving and rearing percentages could increase the quantity of saleable meat from the suckler beef sector; it also provides scope to:

- Reduce total carbon emissions per kg of saleable meat.
- Reduce the total number of breeding cows.
- Reduce total feed, fertiliser, and lime use.
- Reduce intensity of production.
- Improve the genetic merit within each individual herd.
- Save on labour costs.
- Boost the profitability of Rearer Finishers.

Areas Where Specialist Help/Training/Grant Aid Would Be Beneficial

- Breeding management advice.
- Nutritional management advice including forage/feed analysis and rationing.
- Grassland management advice.
- Health Planning to minimise disease risks.
- Buildings advice to reduce injury and disease risk e.g. pneumonia
- Calving and Calf Management Workshops.

Carbon results for Increasing the Number of Calves Reared

SRUC Agrecalc - Stacked

Table C1 - total beef carbon emissions

	S1. Baseline CTS Average	ST2. Increase calves reared	Difference	
Units	(kg CO2e)	(kg CO2e)	(kg CO2e)	(%)
Year				
Energy use	40,335	41,446	1,111	2.8%
Fertiliser production	165,278	170,120	4,842	2.9%
Lime	76,054	77,782	1,728	2.3%
Feed production	14,996	15,479	483	3.2%
Bedding	28,314	27,830	-484	-1.7%
Pesticides	53	56	3	5.7%
Disposal carcases	877	675	-202	-23.0%
Methane - feed digestion	418,204	427,160	8,956	2.1%
Methane - manure	11,042	11,252	210	1.9%
Nitrous oxide - fertiliser & manures	272,219	278,773	6,554	2.4%
Total beef enterprise	**1,027,372**	**1,050,573**	**23,201**	2.3%
Output (kg dwt beef)	28,756	29,820	1,064	3.7%

Table C3- per kg dwt beef carbon emissions by activity

	S1. Baseline CTS Average	ST2. Increase calves reared	Difference	
Unit	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(%)
Energy use	1.40	1.39	-0.01	-0.9%
Fertiliser production	5.75	5.70	-0.04	-0.7%
Lime	2.64	2.61	-0.04	-1.4%
Feed production	0.52	0.52	-0.00	-0.5%
Bedding	0.98	0.93	-0.05	-5.2%
Pesticides	0.00	0.00	0.00	1.9%
Disposal carcases	0.03	0.02	-0.01	-25.8%
Methane - feed digestion	14.54	14.32	-0.22	-1.5%
Methane - manure	0.38	0.38	-0.01	-1.7%
Nitrous oxide - fertiliser & manures	9.47	9.35	-0.12	-1.2%
Total Emissions (kg CO2e/ kg dwt beef)	**35.73**	**35.23**	**-0.50**	-1.4%

Scenario ST3 – Reduce Age at 1st Calving to 2 years

Background

Cattle in Scotland are typically calved for the first time between 2 and 3 years of age.

- In the past, many farms calved both in the spring and the autumn which allows heifer calves from one herd to be used as replacement heifers for the other herd, calving down at 2.5 years of age.
- Due to reduced margins and labour availability, most suckler beef businesses opt to calve either in the spring or in the autumn, which means that they must choose between calving heifers at 2 or 3 years of age.

Importance

Calving at 2 years compared to 3 years significantly reduces the resources required to feed and manage a cow to first calving, reduces the number of unproductive livestock on farm, and increases the number of calves a cow will have in her lifetime.

Other key benefits to calving maiden heifers at 2 years of age include:

- Quicker genetic progress,
- A 24% lower energy requirement from weaning through to calving,
- Barren heifers have a higher cull value as they will be slaughtered before 30 months,
- Earlier maturing heifers have a shorter interval between calving and onset of first heat after calving, and
- A reduction in mature cow weight.

Each of these measures reduces the associated emissions per unit of output.

There is one caveat; while many breeds and systems are well suited to calving at 2 years of age; it is not an option for every business. It is a decision that has to be taken by each individual farmer as all herd compositions are different in terms of breed, and farms differ in terms of environment, climate, land type, resources including labour availability, and how each suckler herd is managed.

Assumptions for Reducing Age at 1st calving to 2 years

	Baseline	Scenario 3
Calving Period	Spring	Spring
Calving %	86	**90**
Rearing %	80	**84**
Heifer Replacement Rate (%)	15	15
Age at First Calving (years)	3	**2**
Improved Manure & Nutrition Mgmt.	No	No
Nitrification Inhibitors	No	No
Cow Weight kg lw	700	700
Silage Quality (10.5 ME, 11% CP DM)	Average	Average
Grazing System	Set Stocking	Set Stocking
Calf Sale Weight kg lw	650	650
Age at Slaughter months	21	21
Methane Inhibitors (3NOP)	No	No
Alternative Feeds	No	No

Sources of data – CTS Average Data - Rearer Finishers

Reducing the Age at First Calving From 3 To 2 Years of Age will:

- Reduce the total carbon emissions per kg of saleable meat from the suckler beef sector.
- Reduce the number of breeding stock carried on each farm.
- Reduce total feed, fertiliser, and lime use.
- Reduce slurry and farmyard manure production, and storage requirements.
- Reduce total housing requirements.
- Reduce intensity of production.
- Improve the genetic merit within each individual herd.
- Boost the profitability of Rearer Finishers.

Despite the potential financial and carbon emissions benefit; changing from calving at 3 to 2 years of age cannot be achieved overnight, it takes two years of careful planning starting when the potential replacement heifer calf is born. Heifers that are to calve down at 2 years of age need to:

- Be born early in the calving season to allow them to be heavier at bulling.
- Achieve a daily liveweight gain of 1.1-1.3 kg/hd/day up to weaning to reach puberty earlier.
- Reach 65% of the mature weight prior to bulling.
- Be bred to a high reliability easy calving sire with a short gestation length and low calf birth weight EBVs.
- Be fed and managed as a separate group from the cows, ideally up until their 3rd calving as the heifers are still growing during this period, otherwise they may fail to get back in calf.

Areas where Specialist Help/Training/Grant Aid would be beneficial

- Breeding management advice.
- Nutritional management advice including forage/feed analysis and rationing.
- Grassland and grazing management advice.
- Health planning to minimise disease risks.
- Calving management workshops.

Carbon results for Reducing Age at 1st Calving to 2 Years

SRUC Agrecalc - Stacked

Table C1 - total beef carbon emissions	ST2. Increase calves reared	ST3. Reduce age at 1st calving to 2 years	Difference	
Units	(kg CO2e)	(kg CO2e)	(kg CO2e)	(%)
Year				
Energy use	41,446	39,131	-2,315	-5.6%
Fertiliser production	170,120	158,193	-11,927	-7.0%
Lime	77,782	72,562	-5,220	-6.7%
Feed production	15,479	15,557	78	0.5%
Bedding	27,830	25,410	-2,420	-8.7%
Pesticides	56	54	-2	-3.6%
Disposal carcases	675	675	0	0.0%
Methane - feed digestion	427,160	407,068	-20,092	-4.7%
Methane - manure	11,252	10,696	-556	-4.9%
Nitrous oxide - fertiliser & manures	278,773	260,638	-18,135	-6.5%
Total beef enterprise	**1,050,573**	**989,984**	**-60,589**	-5.8%
Output (kg dwt beef)	29,820	30,184	364	1.2%

Table C3 - per kg dwt beef carbon emissions by activity	ST2. Increase calves reared	ST3. Reduce age at 1st calving to 2 years	Difference	
Unit	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(%)
Energy use	1.39	1.30	-0.09	-6.7%
Fertiliser production	5.70	5.24	-0.46	-8.1%
Lime	2.61	2.40	-0.20	-7.8%
Feed production	0.52	0.52	-0.00	-0.7%
Bedding	0.93	0.84	-0.09	-9.8%
Pesticides	0.00	0.00	-0.00	-4.7%
Disposal carcases	0.02	0.02	-0.00	-1.2%
Methane - feed digestion	14.32	13.49	-0.84	-5.9%
Methane - manure	0.38	0.35	-0.02	-6.1%
Nitrous oxide - fertiliser & manures	9.35	8.63	-0.71	-7.6%
Total Emissions (kg CO2e/ kg dwt beef)	**35.23**	**32.80**	**-2.43**	-6.9%

Explanation for changes – see Excel - “Carbon results – breeder finisher1.xls”

Scenario ST4 – Reduce Cow Weight by 10%

Background

In Scotland, cow size and weight vary considerably depending on breed and farm type. Mature cow size ranges from 500kg for traditional hill breeds to 1000kg for large continental breeds, with an average mature cow weight of ~ 700 kg liveweight.

There is a growing interest in using more maternal type cows crossed with Continental sires to maximise cow efficiency in terms of calf weaning weight and genetic capability of the calf post weaning.

Importance

The view that 'larger cows produce larger calves and so are more profitable' is widespread within the industry. However, the market no longer wants large cattle and hence why some processors have implemented over-400 kg carcass payment penalties.

Larger cows are less efficient from a production perspective as they have higher daily maintenance requirements and require more space when housed.

Based on a 200-day winter, a 600 kg cow requiring 75 MJ ME/day will require 2,000 MJ ME less than a 750 kg cow which requires 85 MJ ME/day. This equates to a saving of £19,000 for a herd of 100 suckler cows based on 760 kg less silage per cow (10.5 ME, 25% dry matter) @ £25/tonne.

The 200-day weight of a calf in relation to its' dam's mature weight expressed as a percentage provides a guide to cow efficiency. A 600 kg cow producing a 300 kg calf at weaning would have an efficiency rating of 50%, while an 800 kg cow weaning the same weight of calf, would only have an efficiency rating of 37.5%. To ensure efficiency of production, cows should have a minimum efficiency rating of 40%.

As cow beef is now regarded as a valued product, many herds have increased their replacement rate to improve the genetic merit of the herd with the added advantage that cows are being sold at a higher value as they are younger and in good condition.

Assumptions for Reducing Cow Weight by 10%

While the average mature cow weight is currently in the region of 700 kg liveweight, this scenario looks at the impact of reducing mature cow size by 10%.

	Baseline	Scenario 4
Calving Period	Spring	Spring
Calving %	86	**90**
Rearing %	80	**84**
Heifer Replacement Rate (%)	15	15
Age at First Calving (years)	3	**2**
Improved Manure & Nutrition Mgmt.	No	No
Nitrification Inhibitors	No	No
Cow Weight kg lw	700	**630**
Silage Quality (10.5 ME, 11% CP DM)	Average	Average
Grazing System	Set Stocking	Set Stocking
Calf Sale Weight kg lw	650	650
Age at Slaughter months	21	21
Methane Inhibitors (3NOP)	No	No
Alternative Feeds	No	No

Sources of data – CTS Average Data - Rearer Finishers

Wider Farm and Industry Implications

While changing breed or cross breeding can rapidly reduce mature weight; changes can be implemented within an existing herd through selecting bulls based with lower Mature Weight EBVs and select heifer replacements from moderate weight cows that have shown high productivity percentages (kg calf at 200 days compared to own weight). Equally, calving maiden heifers at 2 years can bring down mature size.

While reducing cow mature weight is linked to genetics and selection within the herd, reducing mature cow size weight is a longer-term goal, the overall benefits to the industry will be:

- A reduction in carbon emissions per kg of saleable meat.
- A reduction in maintenance costs leading to a reduction in total feed, fertiliser and lime usage.
- Improved genetic merit.
- Improved farm profitability.

Areas where Specialist Help/Training/Grant Aid would be beneficial

- Breeding management advice.
- Nutritional management advice including forage/feed analysis and rationing.
- Health Planning to minimise disease risks.
- Bull selection and herd management workshops.
- Grant aid for weigh crushes, weigh cells, automatic tag readers and livestock management software.

Carbon Results for Reducing Cow Weight By 10%

SRUC Agrecalc - Stacked	S1. Baseline CTS Average	ST4. Reduce cow weight by 10%	Difference	
Table C1 - total beef carbon emissions				
Units	(kg CO2e)	(kg CO2e)	(kg CO2e)	(%)
Year				
Energy use	40,335	38,661	-1,674	-4.2%
Fertiliser production	165,278	151,330	-13,948	-8.4%
Lime	76,054	69,715	-6,339	-8.3%
Feed production	14,996	16,941	1,945	13.0%
Bedding	28,314	25,168	-3,146	-11.1%
Pesticides	53	55	2	3.8%
Disposal carcases	877	643	-234	-26.7%
Methane - feed digestion	418,204	397,812	-20,392	-4.9%
Methane - manure	11,042	10,411	-631	-5.7%
Nitrous oxide - fertiliser & manures	272,219	253,437	-18,782	-6.9%
Total beef enterprise	**1,027,372**	**964,173**	**-63,199**	-6.2%
Output (kg dwt beef)	28,756	29,714	958	3.3%

Table C3 - per kg dwt beef carbon emissions by activity	S1. Baseline CTS Average	ST4. Reduce cow weight by 10%	Difference	
Unit	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(%)
Energy use	1.30	1.30	0.00	0.4%
Fertiliser production	5.24	5.09	-0.15	-2.8%
Lime	2.40	2.35	-0.06	-2.4%
Feed production	0.52	0.57	0.05	10.6%
Bedding	0.84	0.85	0.01	0.6%
Pesticides	0.00	0.00	0.00	3.5%
Disposal carcases	0.02	0.02	-0.00	-3.2%
Methane - feed digestion	13.49	13.39	-0.10	-0.7%
Methane - manure	0.35	0.35	-0.00	-1.1%
Nitrous oxide - fertiliser & manures	8.63	8.53	-0.11	-1.2%
Total Emissions (kg CO2e/ kg dwt beef)	**32.80**	**32.45**	**-0.35**	-1.1%

Explanation for changes – see excel - “Carbon results – breeder finisher1.xls”

Scenario ST5 – Reduce Age at Slaughter (18 months)

Background

Many farmers take pride in producing larger cattle and/or 'Topping the Market' when selling cattle locally, and historically, producing bigger cattle meant more income per head. However, the recent implementation by some processors of only paying full rates up to 400 kg deadweight (700 kg liveweight) has meant that these larger cattle producers have been hit with price penalties, not only on the kilos produced over 700 kg liveweight but on each, and every kilo produced.

Largely prompted by changes in the market place, since 2017, there has been a noticeable shift in the age at slaughter from 24-28 months of age down to 20-23 months of age[i] ; with 2019 CTS metrics showing the average age at slaughter for steers was 22 months and 21-22 months for heifers. However, the age at slaughter ranges for steers and heifers from 18 months up to 30 months of age.

The main reasons for extended finishing periods are:

- Linked to breed, as some, mainly native/traditional breeds are slower to finish.
- Organic production methods.
- Low input grazing systems.
- Niche/high value markets.
- Heifers selected for breeding but did not conceive.
- Cattle purchased as older forward stores that need time to achieve the correct degree of finish.
- Low quality grass.

Importance

Finishing cattle quicker reduces total emissions by the simple fact that if they are culled quicker, they stop producing emissions quicker. It would also enable faster turnover of finished cattle and therefore more output for reduced emissions (only when measured per unit output, not in terms of emissions per hectare).

Reducing finishing periods, reduces the number of days that cattle need to be maintained. Logically, maintenance requirements increase as cattle increase in size/weight and the heavier an animal gets, the higher the proportion of the diet is needed for maintenance, thereby reducing overall efficiency of production.

As a general rule of thumb, for cattle to maintain their weight, diets should be formulated on an energy basis of 10% of body weight in MJ ME + 10 MJ ME. For cattle to gain 1 kg per head per day, they need 10% of body weight in MJ ME + 45 MJ ME per head per day. A 200 kg animal needs 30MJ ME per head per day compared to a 700 kg animal which needs 80 MJ ME per head per day.

With regards Daily Liveweight Gain (DLG), at lower rates of gain e.g. 0.5 kg/hd/day, three quarters of the diet is used solely to maintain the animal and only a quarter is used for growth, compared to a higher rate of gain, of say 1.4 kg/hd/day, where only half the diet is used for maintenance and half is used for growth.

Reducing the age at slaughter from the current average of 22 months to 18 months of age is readily achievable for the majority of breeds through:

- Diet manipulation.
- Improved grassland management (including reseeding and making better quality silage (which reduces the need for supplementary feeds).
- Use of EBVs for bull selection such as 400-day weight and fat EBV traits.

However, advocating a quicker time to slaughter cannot be viewed by producers as a carte blanche to increase cow numbers to fill the production void, whether it be in the field or in winter housing.

Equally, while finishing cattle quicker reduces total emissions; it should be noted that there are environmental and health benefits from finishing cattle off high quality pastures with little, if any, concentrates are needed.

Assumptions for Reducing Age at Slaughter to 18 months

	Baseline	Scenario 5
Calving Period	Spring	Spring
Calving %	86	**90**
Rearing %	80	**84**
Heifer Replacement Rate (%)	15	**15**
Age at First Calving (years)	3	**2**
Improved Manure & Nutrition Mgmt.	No	No
Nitrification Inhibitors	No	No
Cow Weight kg lw	700	**630**
Silage Quality (10.5 ME, 11% CP DM)	Average	Average
Grazing System	Set Stocking	Set Stocking
Calf Sale Weight kg lw	650	650
Age at Slaughter months	21	**18**
Methane Inhibitors (3NOP)	No	No
Alternative Feeds	No	No

Sources of data – CTS Average Data - Rearer Finishers

Wider Farm and Industry Implications

In seeking to finish cattle earlier, subject to the different carcass specifications within the processing sector, many of the Continental type cattle producers have the capability to either adapt their management systems to sell finished cattle at the same target weight earlier or to sell finished cattle at lighter weights, especially given that Markets/Processors are looking at lower slaughter weights.

In addition to seeking to finish cattle at lighter weights in line with processors requirements, other reasons for finishing cattle quicker are:

- Less time on farm, so lower total carbon emissions.

- More efficient to finish continental cattle quicker (linked to daily maintenance requirements).
- Higher rates of daily liveweight gain is more efficient as a higher percentage of the ration is used or growth.
- Better use of resources – land, buildings and labour.
- Reduced costs of production.

To reflect the variations in land quality and climatic conditions, reducing the finishing age to 18 months at slaughter can be achieved by:

- Adapting grassland management practices and/or
- Reviewing the types and quantities of supplementary feeds used.

While reducing the average age of slaughter down to 18 months may not be possible on some farms where slow maturing breeds are kept, grazing quality is poor, or an all forage system is employed with no use of concentrate feeding; there is still scope to make improvements within the system especially through employing improved grassland management practices, producing better quality silage, reviewing livestock rations, setting daily liveweight gain targets and regular weighing/monitoring cattle performance.

Cattle destined for premium markets may require longer finishing to develop marbling or due to traditional breeds being used. Using more maternal type breeds can help with fat cover at finishing to ensure target markets are met.

To meet the processors demand for smaller higher quality carcasses, it is not all about large breeds versus small breeds but choosing types within breeds that will produce the right calves to meet buyers' requirements.

Areas where Specialist Help/Training/Grant Aid would be beneficial

- Breeding management advice.
- Nutritional management advice including forage/feed analysis and rationing.
- Grassland, grazing and forage management advice.
- Health planning to reduce disease risks.
- Buildings advice to reduce disease risk e.g. pneumonia.
- Alternative Feed Workshops.
- Grant aid for weigh crates, weigh cells, automatic tag readers and livestock management programs.

Carbon Results for Finishing Cattle at 18 Months of Age

SRUC Agrecalc - Stacked

Table C1 - total beef carbon emissions	ST4. Reduce cow weight by 10%	ST5. Reduce age at slaughter (18 months)	Difference	
Units	(kg CO2e)	(kg CO2e)	(kg CO2e)	(%)
Year				
Energy use	38,661	31,358	-7,303	-18.9%
Fertiliser production	151,330	111,207	-40,123	-26.5%
Lime	69,715	56,532	-13,183	-18.9%
Feed production	16,941	15,603	-1,338	-7.9%
Bedding	25,168	29,040	3,872	15.4%
Pesticides	55	41	-14	-25.5%
Disposal carcases	643	657	14	2.2%
Methane - feed digestion	397,812	377,405	-20,407	-5.1%
Methane - manure	10,411	10,041	-370	-3.6%
Nitrous oxide - fertiliser & manures	253,437	212,222	-41,215	-16.3%
Total beef enterprise	**964,173**	**844,106**	**-120,067**	-12.5%
Output (kg dwt beef)	29,714	29,714	0	0.0%

Table C3 - per kg dwt beef carbon emissions by activity	ST4. Reduce cow weight by 10%	ST5. Reduce age at slaughter (18 months)	Difference	
Unit	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(%)
Energy use	1.30	1.06	-0.25	-18.9%
Fertiliser production	5.09	3.74	-1.35	-26.5%
Lime	2.35	1.90	-0.44	-18.9%
Feed production	0.57	0.53	-0.05	-7.9%
Bedding	0.85	0.98	0.13	15.4%
Pesticides	0.00	0.00	-0.00	-25.5%
Disposal carcases	0.02	0.02	0.00	2.2%
Methane - feed digestion	13.39	12.70	-0.69	-5.1%
Methane - manure	0.35	0.34	-0.01	-3.6%
Nitrous oxide - fertiliser & manures	8.53	7.14	-1.39	-16.3%
Total Emissions (kg CO2e/ kg dwt beef)	**32.45**	**28.41**	**-4.04**	-12.5%

Explanation for changes – see excel - “Carbon results – breeder finisher1.xls”

[i] QMS 2017

Scenario ST6 – Improved Grassland Management

Background

Grass is an important crop on livestock farms and can provide 85-95 per cent of the energy requirements of beef farms. However, while grazed grass is the cheapest source of feed on farm and has the potential to be a high-quality, natural ruminant feed; it rarely commands the respect that it deserves, and often half of what is grown is wasted (AHDB 2019[i]).

Grassland management is not simply a case of balancing supply and demand/utilisation but by understanding and monitoring the phases of grass growth, it allows farmers to graze/cut grass at the optimum development stages, enabling greater productivity and output from grass. When managed well, grassland has the potential to significantly reduce input costs and in particular, bought-in feed costs; with some farms able to finish cattle purely off pasture and conserved forages.

Importance

If swards are not well managed, the proportion of poorer quality grass species and weeds increases. The combined effect of lower value species and poor grazing practice can significantly reduce yield, quality, and efficient use of nutrients.

A key aspect of good grassland management is understanding how grass grows. By measuring how much is available in the fields and how fast it is growing, it is then possible to make informed decisions on stocking levels and balancing feed supply with demand. It also allows farmers to better use and make the most of the peak growing period during the spring and summer months (e.g. through heavier stocking rates and/or making hay/silage).

Changing from set stocking to rotational grazing or paddock grazing improves grass utilization as cattle have less opportunity to waste grass and therefore more of the grass is converted into meat. However, this requires investment in additional fencing and water troughs, and the availability of labour to move stock or electric fencing on a regular basis.

Reseeding unproductive swards improves both the quantity and quality of grass produced, which in turn, improves grassland and forage intakes due to greater palatability. By monitoring grass growth and assessing the percentage of unproductive species within a sward, farmers can assess when fields should be reseeded. However, since the agricultural grant schemes moved away from offering grants for liming, reseeding and pasture regeneration in the early 1990's, many farmers have either simply not had the funds available to invest in reseeding or have not regarded reseeding as an investment priority, and as a result overall grassland productivity has fallen both in terms of quality and quantity. Whilst maintaining an old/poor ley can save on input costs in the short term, as the yield drops, the cost per tonne of forage increases and the nutritional value of the forage declines.

While reseeding pastures necessitates the use of lime and additional fertilisers in order to successfully establish and maintain a new grass sward will temporarily increase carbon emissions; this will be more than offset by the fact that the improvement in grass and forage quantity and quality will reduce the need for supplementary feed, boost daily liveweight gains and hence reduce finishing periods thereby reducing the total emissions per kilo of saleable meat produced. In addition to which, good grassland management can also improve forage digestibility, resulting in a decrease in enteric methane emission intensity (Hristov et al. 2013).

Perennial ryegrass, the UK's most commonly sown species, only ever has three live leaves on each individual plant (tiller). As the fourth leaf starts to grow, the first and the oldest leaf dies. When grass growth is at its highest, usually in May, a new leaf is produced every four to five days. At peak growth, all three leaves can be replaced within two to three weeks, but in mid-winter, when grass growth is at its slowest, it can take 30 days to produce one new leaf (AHBD Better Returns Programme 2019). Rotational grazing strategies are based on managing utilisation to optimize grass quality, and so animal performance, and to provide a rest for the plant to grow new leaf and build root reserves.

Regular soil analysis will allow the farmer to make informed decisions as to fertiliser and lime requirements to maximise the productivity of the sward. Phosphate and potash are essential for grass and clover growth. Phosphate is important for root development and energy transfer within plants, while potash has a key role in water regulation and Nutrient Use Efficiency (NUE).

Assumptions for Improving Grassland Management

	Baseline	Scenario 6
Calving Period	Spring	Spring
Calving %	86	**90**
Rearing %	80	**84**
Heifer Replacement Rate (%)	15	**14**
Age at First Calving (years)	3	**2**
Improved Manure & Nutrition Mgmt.	No	No
Nitrification Inhibitors	No	No
Cow Weight kg lw	700	**630**
Silage Quality (11.2 ME, 14% CP DM)	Average	**Good**
Grazing System	Set Stocking	**Rotational**
Calf Sale Weight kg lw	650	650
Age at Slaughter months	21	**18**
Methane Inhibitors (3NOP)	No	No
Alternative Feeds	No	No

Sources of data – CTS Average Data - Rearer Finishers

Wider Farm and Industry Implications

In seeking to improve grassland management, and in particular, grass production both in terms of quality and quantity and utilisation and reducing carbon emissions, it important for farmers to seek advice with regards:

- Soil health and nutrient management including routine soil and slurry/farm yard manure sampling.
- Improving grass utilisation of existing swards including forage conservation.
- Reseeding unproductive swards with productive grass and clover seed mixtures.
- Monitoring and managing grass growth to achieve target daily liveweight gains.

The overall benefits to improving grassland management for the suckler beef industry as a whole, will be:

- A reduction in carbon emissions per kg of saleable meat.
- A reduction in maintenance costs leading to a reduction in total feed, fertiliser and lime usage.
- Improved daily liveweight gains.
- Reduced finishing periods for livestock.
- Improved fertility due to better cow and heifer body condition prior to bulling.
- Improved farm profitability.

Areas where Specialist Help/Training/Grant Aid would be beneficial

- Grassland, grazing and forage management advice.
- Grazing management workshops.
- Reseeding Workshops including advice on reseeding grass/clover mixes.
- Nutritional management advice including soil, forage & /feed analysis and rationing.
- Health planning to reduce disease risks e.g. liver fluke.
- Grant aid for liming, reseeding, pasture regeneration, grass growth monitoring.
- Grant aid for weigh crates, weigh cells, automatic tag readers and livestock management programs.
- Grant aid for paddock fencing, electric fencing (for rotational grazing), access gates, water troughs and cattle tracks.

Carbon Results for Improved Grassland

SRUC Agrecalc - Stacked	ST5. Reduce age at slaughter (18 months)	ST6. Improved grassland management	Difference	
Table C1 - total beef carbon emissions				
Units	(kg CO2e)	(kg CO2e)	(kg CO2e)	(%)
Year				
Energy use	31,358	26,417	-4,941	-16%
Fertiliser production	111,207	79,771	-31,436	-28%
Lime	56,532	43,271	-13,261	-23%
Feed production	15,603	16,402	799	5%
Bedding	29,040	31,218	2,178	8%
Pesticides	41	28	-13	-32%
Disposal carcases	657	657	0	0%
Methane - feed digestion	377,405	372,022	-5,383	-1%
Methane - manure	10,041	9,688	-353	-4%
Nitrous oxide - fertiliser & manures	212,222	197,564	-14,658	-7%
Total beef enterprise	**844,106**	**777,038**	**-67,068**	-8%
Output (kg dwt beef)	29,714	29,714	0	0%

Table C3 - per kg dwt beef carbon emissions by activity

	ST5. Reduce age at slaughter (18 months)	ST6. Improved grassland management	Difference	
Unit	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(%)
Energy use	1.06	0.89	-0.17	-16%
Fertiliser production	3.74	2.68	-1.06	-28%
Lime	1.90	1.46	-0.45	-23%
Feed production	0.53	0.55	0.03	5%
Bedding	0.98	1.05	0.07	7%
Pesticides	0.00	0.00	-0.00	-32%
Disposal carcases	0.02	0.02	0.00	0%
Methane - feed digestion	12.70	12.52	-0.18	-1%
Methane - manure	0.34	0.33	-0.01	-4%
Nitrous oxide - fertiliser & manures	7.14	6.65	-0.49	-7%
Total Emissions (kg CO2e/ kg dwt beef)	**28.41**	**26.15**	**-2.26**	-8%

Explanation for changes – see excel - “Carbon results – breeder finisher1.xls”

Scenario ST7 – Methane Inhibitor (3NOP)

Background

3NOP (3-nitrooxypropanol) is a feed additive that can be used in beef cattle diets to reduce enteric emissions of methane without compromising productive performance. While there are many feed additives that claim to do this, 3NOP is one of the few/the only one to have verified scientific evidence to support this.

Importance

Adding 3NOP (3-nitrooxypropanol) at 2-3g 3NOP/animal/day to cattle diets reduces enteric emissions of methane without compromising productive performance. Reduced enteric methane emissions by 20% possible but 10% assumed feasible. (refs)

There is a 20% reduction in methane emissions when housed so around 50% over all i.e. 10% reduction in methane emissions.

Assumptions

	Baseline	Scenario 8
Calving Period	Spring	Spring
Calving %	86	**90**
Rearing %	80	**84**
Heifer Replacement Rate (%)	15	**14**
Age at First Calving (years)	3	**2**
Improved Manure & Nutrition Mgmt.	No	**Yes**
Nitrification Inhibitors	No	No
Cow Weight kg lw	700	**630**
Silage Quality (11.2 ME, 14% CP DM)	Average	**Good**
Grazing System	Set Stocking	**Rotational**
Calf Sale Weight kg lw	650	650
Age at Slaughter months	21	**18**
Methane Inhibitors (3NOP)	No	**Yes**
Alternative Feeds	No	No

Sources of data – CTS Average Data - Rearer Finishers

Wider Farm and Industry Implications

- So far little tested in commercial application, and so the variation in effectiveness for different systems has not been qualified.
- Expensive option for entire industry.

- 3NOP has a large net cost.
- Some potential for productivity gains in livestock production are possible but unproven in commercial application.

Areas where Specialist Help/Training/Grant Aid would be beneficial

- Nutritional management advice including rationing.
- Alternative Feed Workshops.
- Grant aid for weigh crates, weigh cells, automatic tag readers and livestock management programs to monitor cattle performance against targets set.

Carbon results improved methane inhibitors

SRUC Agrecalc - Stacked

Table C1 - total beef carbon emissions	ST6. Improved grassland management	ST7. Methane inhibitor (3NOP)	Difference	
Units	(kg CO2e)	(kg CO2e)	(kg CO2e)	(%)
Year				
Energy use	26,417	26,417	0	0%
Fertiliser production	79,771	79,771	0	0%
Lime	43,271	43,271	0	0%
Feed production	16,402	16,402	0	0%
Bedding	31,218	31,218	0	0%
Pesticides	28	28	0	0%
Disposal carcases	657	657	0	0%
Methane - feed digestion	372,022	334,820	-37,202	-10%
Methane - manure	9,688	9,688	0	0%
Nitrous oxide - fertiliser & manures	197,564	197,564	0	0%
Total beef enterprise	**777,038**	**739,836**	**-37,202**	-5%
Output (kg dwt beef)	29,714	29,714	0	0%

Table C3- per kg dwt beef carbon emissions by activity	ST6. Improved grassland management	ST7. Methane inhibitor (3NOP)	Difference	
Unit	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(%)
Energy use	0.89	0.89	0.00	0%
Fertiliser production	2.68	2.68	0.00	0%
Lime	1.46	1.46	0.00	0%
Feed production	0.55	0.55	0.00	0%
Bedding	1.05	1.05	0.00	0%
Pesticides	0.00	0.00	0.00	0%
Disposal carcases	0.02	0.02	0.00	0%
Methane - feed digestion	12.52	11.27	-1.25	-10%
Methane - manure	0.33	0.33	0.00	0%
Nitrous oxide - fertiliser & manures	6.65	6.65	0.00	0%
Total Emissions (kg CO2e/ kg dwt beef)	**26.15**	**24.90**	**-1.25**	-5%

Explanation for changes – see Excel - “Carbon results – breeder finisher1.xls”

Scenario ST8 – Improved Manure & Nutrient Management

Background

While driving feed efficiency is crucial in all beef growing and finishing systems, cattle diets impact on the manure that they produce, which in turn, impacts on the emissions that they produce.

Monitoring the manure cattle produce is a useful indicator of how well the rumen is functioning and how well the animal is digesting its diet. If the animal's rumen is working well, there should be:

- Little recognisable feed in the manure; and
- 80% of the cattle not eating, drinking, or sleeping should be ruminating.

Rumen fermentation and hence the organic manure produced is influenced by:

- The protein content of the diet and its degree of solubility,
- The amount of fibre and in particular long fibre in the diet,
- What format the diet is fed – cattle have the ability to select out what they like to eat and avoid what they don't which affects their overall intake but in terms of quantity and quality,
- The quality of the feed (spoiled or mouldy feed must not be fed to cattle,
- Water intakes – insufficient water troughs or warm weather can impact on water intakes.

While ensuring that cattle diets are correctly formulated and only good quality feeds are fed to cattle will help to reduce the overall carbon emission from grazing livestock; the emissions from disposing of organic manures produced over the winter when cattle are housed are influenced by the means in which the manure is stored and how it is later disposed of on the farm.

While a simple and obvious solution to emission produced when slurry and farmyard manure are being stored prior to disposal is to cover the manure; there is a significant cost associated with this, coupled with health and safety issues with regards safely covering slurry.

With regards the application of manure from cattle over the winter period, the Review and Update the UK Agriculture Marginal Abatement Cost Curve to assess the greenhouse gas abatement potential report (2015) found that "Improving the machinery operations with regards spreading organic manure (Low emission manure spreading), could provide higher abatement (0.07 Mt CO2e y-1), due to a combination of medium-level abatement rate (0.11tCO2e ha-1 y-1), and high potential additional uptake.

These techniques are widely used in some European countries (e.g. the Netherlands, Denmark), but have not been commonly adopted in the UK, partly due to the necessary capital investment in machinery or the higher cost of using contractors."

In addition to the method in which the organic manure, and in particular slurry is disposed of on land (splash plate or injected), the time of year when the manure is disposed of has an impact on the level of emissions. As well as this, as noted in the section below, switching from applying manure in the autumn to applying it in the spring has a significant bearing on the amount of synthetic nitrogen required for the next crop.

Importance

Farm profitability relies on efficient nutrient use for crop growth. A tanker load of slurry can contain an NPK value that equates to ~£46 of purchased artificial fertiliser.

Factors such as soil pH, matching nutrient applications to crop growth requirements and working to an accurate farm nutrient budget all help ensure nutrient use efficiency.

Regular soil tests for pH and nutrient values provide important details for the farm nutrient budget, as does taking into account previous cropping rotations. Equally important is nutrient testing to know the NPK value of home-produced slurry and farmyard manures, or of imported organic fertilisers e.g. digestates or composts.

Whilst applying nutrients to match crop requirements helps to improve uptake, consideration to application methods should also be made. It has been estimated that by moving from a splash plate application to using a trailing shoe or dribble bar could reduce ammonia losses that equate to 3 units of N per 1,000 gallons of slurry.

The table below highlights the impact that organic manure disposal method and timing, and the impact that improved planning and use of synthetic N can have on the amount of synthetic nitrogen required by a business:

Action	Reference	Synthetic Nitrogen saving (kg N/ha)
N1. Improved synthetic N use	Veory et al (2016)[1], p47	10
N2. Improved planning of organic N use	Veory et al (2016), p52	10
N3. Switching to low emissions spreading	Veory et al (2016), p52	10
*N4. Switching autumn manure application to spring	Veory et al (2016), p52	50

*not modelled

Assumptions

	Baseline	Scenario 11
Calving Period	Spring	Spring
Calving %	86	**90**
Rearing %	80	**84**
Heifer Replacement Rate (%)	15	**14**
Age at First Calving (years)	3	**2**
Improved Manure & Nutrition Mgmt.	No	**Yes**
Nitrification Inhibitors	No	No
Cow Weight kg lw	700	**630**
Silage Quality (10.5 ME, 11% CP DM)	Average	**Good**
Grazing System	Set Stocking	**Rotational**
Calf Sale Weight kg lw	650	650
Age at Slaughter months	21	**13**
Methane Inhibitors (3NOP)	No	No
Alternative Feeds	No	No

Sources of data – CTS Average Data - Rearer Finishers

Areas where Specialist Help/Training/Grant Aid would be beneficial

- Soil management advice including soil sampling and fertiliser/liming plans.
- Nutritional management advice including forage/feed analysis and rationing.
- Advice on Feeding systems and reducing food spoilage.
- Health planning to reduce disease risks.
- Waste Management Storage advice.
- Slurry and Farmyard Manure disposal demonstration days.
- Grant aid for slurry storages (to facilitate manures being applied in the spring rather than the autumn.
- Grant aid for covers for slurry towers and lagoons.
- Grant aid for more carbon efficient methods of slurry spreading e.g. by injection into the soil.
- Health and Safety training with regards working with slurry.

Carbon Results for Manure and Nutrient Management

SRUC Agrecalc - Stacked	ST7. Methane inhibitor (3NOP)	ST8. Improved nutrient management	Difference	
Table C1 - total beef carbon emissions				
Units	(kg CO2e)	(kg CO2e)	(kg CO2e)	(%)
Year				
Energy use	26,417	26,603	186	1%
Fertiliser production	79,771	64,473	-15,298	-19%
Lime	43,271	43,514	243	1%
Feed production	16,402	15,328	-1,074	-7%
Bedding	31,218	31,218	0	0%
Pesticides	28	26	-2	-7%
Disposal carcases	657	657	0	0%
Methane - feed digestion	334,820	334,820	0	0%
Methane - manure	9,688	9,688	0	0%
Nitrous oxide - fertiliser & manures	197,564	184,495	-13,069	-7%
Total beef enterprise	**739,836**	**710,822**	**-29,014**	-4%
Output (kg dwt beef)	29,714	29,714	0	0%

Table C3 - per kg dwt beef carbon emissions by activity	ST7. Methane inhibitor (3NOP)	ST8. Improved nutrient management	Difference	
Unit	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(%)
Energy use	0.89	0.90	0.01	1%
Fertiliser production	2.68	2.17	-0.51	-19%
Lime	1.46	1.46	0.01	1%
Feed production	0.55	0.52	-0.04	-7%
Bedding	1.05	1.05	0.00	0%
Pesticides	0.00	0.00	-0.00	-7%
Disposal carcases	0.02	0.02	0.00	0%
Methane - feed digestion	11.27	11.27	0.00	0%
Methane - manure	0.33	0.33	0.00	0%
Nitrous oxide - fertiliser & manures	6.65	6.21	-0.44	-7%
Total Emissions (kg CO2e/ kg dwt beef)	**24.90**	**23.92**	**-0.98**	-4%

Explanation for changes – see excel - “Carbon results – breeder finisher1.xls”

References

Eory, V., MacLeod, M., Topp, C.F.E., Rees, R.M., Webb, J., McVittie, A., Wall, E.,

Borthwick, F., Watson, C., Waterhouse, A., Wiltshire, J., Bell, H., Moran, D.,

Dewhurst, R., (2016). Review and update the UK Agriculture Marginal Abatement Cost Curve to assess the greenhouse gas abatement potential for the 5th carbon budget period and to 2050, Final report submitted to DEFRA.

Scenario ST9 – Nitrification Inhibitors in Artificial N Application

Background

Nitrification inhibitors (NIs) inhibit the oxidation of ammonium ions to nitrate with the aim of providing better synchrony between nitrate supply and crop uptake.

Use of nitrification inhibitors on grassland within beef systems would have no direct impact on the productivity of the beef system itself, but in reducing nitrous oxide (N_2O) emissions from soil following artificial N application to grassland would reduce overall emissions per unit of output for the whole system.

Importance

Nitrification inhibitors (DCD -dicyandiamide) would be applied with all artificial Nitrogen fertilisers. Application reduces the likelihood of nitrate being available in soils when they are wet and the denitrification potential and, consequently, N_2O emissions are high.

Potential to reduce nitrous oxide emissions by 50% from N fertiliser application.

Beyond reducing direct N_2O emissions, Nitrogen inhibitors Is can potentially lower emissions and improve emission intensity also by reducing nitrate leaching and subsequent indirect N2O emissions and increasing grass/crops yield (MacLeod et al. 2015a).

Nitrification inhibitors work on all types of fertilised land, regardless the origin of the N (synthetic N, manure spread or N originating from excretion via grazing). It is assumed that this would provide a 50% reduction in nitrous oxide emissions from soil application (MacLeod et al, 2010, Moran et al, 2008). MacLeod et al.2010c, Moran et al.2010.

Assumptions for Nitrogen Inhibitors in Artificial N Application

	Baseline	Scenario 9
Calving Period	Spring	Spring
Calving %	86	90
Rearing %	80	84
Heifer Replacement Rate (%)	15	14
Age at First Calving (years)	3	2
Improved Manure & Nutrition Mgmt.	No	Yes
Nitrification Inhibitors	No	Yes
Cow Weight kg lw	700	630
Silage Quality (10.5 ME, 11% CP DM)	Average	Good
Grazing System	Set Stocking	Rotational
Calf Sale Weight kg lw	650	650
Age at Slaughter months	21	18
Methane Inhibitors (3NOP)	No	Yes
Alternative Feeds	No	No

Sources of data – CTS Average Data - Rearer Finishers

Wider Farm and Industry Implications

- Nitrification inhibitors are expensive, and as they work to reduce nitrous oxide emissions from the soil after application rather than reduce fertiliser use significantly,
- Savings on fertiliser would be insignificant and there is no effect on grass yield.
- Uptake would be optimal if done in conjunction with other nutrient management options, such as nutrient budgeting and optimal application timing and methods.

Areas where Specialist Help/Training/Grant Aid would be beneficial

- Soil management advice including and rationing.
- Nitrification Application and Nutrient Budgeting Workshops and demonstration days.

Carbon results

SRUC Agrecalc - Stacked

Table C1 - total beef carbon emissions	ST8. Improved nutrient management	ST9. Nitrification inhibitors	Difference	
Units	(kg CO2e)	(kg CO2e)	(kg CO2e)	(%)
Year				
Energy use	26,603	26,603	0	0%
Fertiliser production	64,473	64,473	0	0%
Lime	43,514	43,514	0	0%
Feed production	15,328	15,328	0	0%
Bedding	31,218	31,218	0	0%
Pesticides	26	26	0	0%
Disposal carcases	657	657	0	0%
Methane - feed digestion	334,820	334,820	0	0%
Methane - manure	9,688	9,688	0	0%
Nitrous oxide - fertiliser & manures	184,495	140,568	-43,928	-24%
Total beef enterprise	**710,822**	**666,894**	**-43,928**	-6%
Output (kg dwt beef)	29,714	29,714	0	0%

Table C3 - per kg dwt beef carbon emissions by activity

	ST8. Improved nutrient management	ST9. Nitrification inhibitors	Difference	
Unit	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(%)
Energy use	0.90	0.90	0.00	0%
Fertiliser production	2.17	2.17	0.00	0%
Lime	1.46	1.46	0.00	0%
Feed production	0.52	0.52	0.00	0%
Bedding	1.05	1.05	0.00	0%
Pesticides	0.00	0.00	0.00	0%
Disposal carcases	0.02	0.02	0.00	0%
Methane - feed digestion	11.27	11.27	0.00	0%
Methane - manure	0.33	0.33	0.00	0%
Nitrous oxide - fertiliser & manures	6.21	4.73	-1.48	-24%
Total Emissions (kg CO2e/ kg dwt beef)	**23.92**	**22.44**	**-1.48**	-6%

Explanation for changes – see Excel - "Carbon results – breeder finisher1.xls"

References

MacLeod, M., Moran, D., McVittie, A., Rees, R., Jones, G., Harris, D., Antony, S., Wall, E., Eory, V., Barnes, A., Topp, C. F. E., Ball, B., Hoad, S. and Eory, L. (2010c) Review and update of UK marginal abatement cost curves for agriculture, Report No Report to CCC

Moran, D., MacLeod, M., Wall, E., Eory, V., Pajot, G., Matthews, R., McVittie, A., Barnes, A., Rees, R., Moxey, A., Williams, A. and Smith, P. (2008) UK marginal abatement cost curves for the agriculture and land use, land-use change and forestry sectors out to 2022, with qualitative analysis of options to 2050, Report No RMP4950, Committee on Climate Change, SAC.

Scenario ST10 – Reduce Age at Slaughter (16 months)

Background

In seeking to take advantage of the fact that feed efficiency is greater in younger cattle, coupled with processors seeking to reduce carcass weights so that they can reduce trimming waste and create smaller more affordable cuts of prime cuts of meat, some producers are seeking to finishing cattle at 16 months of age.

While finishing spring calving cattle at 18 months generally involves a period of grazing from age 12-18 months; cattle finished at 16 months do not.

Importance

Many abattoirs now require smaller and lighter carcasses, driven mainly by changes in consumer preferences. The average number of people per household is decreasing and the requirement for meals that take less time to cook is increasing, therefore consumers are showing a preference towards smaller cuts. Retailers also require carcasses to be a particular size and weight for portion control so that cuts can be packaged and displayed consistently.

As with finishing cattle at 18 months of age, finishing cattle at 16 months of age reduces total emissions by the simple fact that if they are culled quicker, they stop producing emissions quicker.

Reducing finishing periods, reduces the number of days that cattle need to be maintained. Logically, maintenance requirements increase as cattle increase in size/weight and the heavier an animal gets, the higher the proportion of the diet is needed for maintenance, thereby reducing overall efficiency of production.

As a general rule of thumb, for cattle to maintain their weight, diets should be formulated on an energy basis of 10% of body weight in MJ ME + 10 MJ ME, therefore reducing the finishing period from 18 months down to 16 months of age will save ~ 4,000MJ ME for the two month period, which equates to a reduction in forage requirement of 1.533 tonnes of average quality silage (10.25 ME, 25% Dry matter). For a 100-cow herd, with an average rearing % of 84%, this equates to a total forage saving of 129 tonnes of silage, which if costed at £25 per tonne, corresponds to a financial saving of £3,225 per annum.

Reducing the age at slaughter from 18 months to 16 months of age is readily achievable for the majority of non-traditional breeds through:

- Diet manipulation.
- Improved grassland management (including reseeding and making better quality silage (which reduces the need for supplementary feeds).
- Use of EBVs for bull selection such as 400-day weight and fat EBV traits.

However, advocating a quicker time to slaughter cannot be viewed by producers as a carte blanche to increase cow numbers to fill the production void, whether it be in the field or in winter housing.

Equally, while finishing cattle quicker reduces total emissions; it should be noted that there are environmental and health benefits from finishing cattle off high quality pastures with little, if any, concentrates needed.

Assumptions

	Baseline	Scenario 10
Calving Period	Spring	Spring
Calving %	86	90
Rearing %	80	84
Heifer Replacement Rate (%)	15	14
Age at First Calving (years)	3	2
Improved Manure & Nutrition Mgmt.	No	No
Nitrification Inhibitors	No	No
Cow Weight kg lw	700	630
Silage Quality (10.5 ME, 11% CP DM)	Average	Good
Grazing System	Set Stocking	Rotational
Calf Sale Weight kg lw	650	650
Age at Slaughter months	21	16
Methane Inhibitors (3NOP)	No	No
Alternative Feeds	No	No

Sources of data – CTS Average Data - Rearer Finishers

Wider Farm and Industry Implications

Finishing cattle at 16 months will not suit every system as its success is dependent on breed type, land quality and the type of system employed. Achieving high levels of animal performance through to finishing is paramount, requiring high quality feed and cattle with the genetic growth rate potential to utilize it.

The profitability of reducing the finishing period down to 16 months will be dependent on the costs of inputs and ensuring that heifer of certain breeds do not put on too much fat if pushed.

The other benefits of reducing the age at slaughter to 16 months are:

- Less time on farm, so lower total carbon emissions.
- More efficient to finish continental cattle quicker (linked to daily maintenance requirements).
- Higher rates of daily liveweight gain are more efficient as a higher percentage of the ration is used or growth.
- Better use of resources – land, buildings and labour as cattle not housed for a second winter.
- Potentially, reduced costs of production.

Areas where Specialist Help/Training/Grant Aid would be beneficial

- Breeding management advice.
- Nutritional management advice including forage/feed analysis and rationing.
- Grassland, grazing and forage management advice.
- Health planning to reduce disease risks.
- Buildings advice to reduce disease risk e.g. pneumonia.
- Alternative Feed Workshops.
- Grant aid for weigh crates, weigh cells, automatic tag readers and livestock management programs.

Carbon Results for Reducing the Age at Slaughter to 16 months

SRUC Agrecalc - Stacked	ST9. Nitrification inhibitors	ST10. Reduce age at slaughter (16 months)	Difference	
Table C1 - total beef carbon emissions				
Units	(kg CO2e)	(kg CO2e)	(kg CO2e)	(%)
Year				
Energy use	26,603	36,092	9,489	36%
Fertiliser production	64,473	84,818	20,345	32%
Lime	43,514	51,264	7,750	18%
Feed production	15,328	15,291	-37	0%
Bedding	31,218	19,118	-12,100	-39%
Pesticides	26	71	45	173%
Disposal carcases	657	558	-99	-15%
Methane - feed digestion	334,820	320,904	-13,916	-4%
Methane - manure	9,688	9,078	-610	-6%
Nitrous oxide - fertiliser & manures	140,568	147,493	6,925	5%
Total beef enterprise	**666,894**	**684,687**	**17,792**	3%
Output (kg dwt beef)	29,714	30,078	364	1%

Table C3 - per kg dwt beef carbon emissions by activity	ST9. Nitrification inhibitors	ST10. Reduce age at slaughter (16 months)	Difference	
Unit	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(%)
Energy use	0.90	1.20	0.30	34%
Fertiliser production	2.17	2.82	0.65	30%
Lime	1.46	1.70	0.24	16%
Feed production	0.52	0.51	-0.01	-1%
Bedding	1.05	0.64	-0.42	-40%
Pesticides	0.00	0.00	0.00	170%
Disposal carcases	0.02	0.02	-0.00	-16%
Methane - feed digestion	11.27	10.67	-0.60	-5%
Methane - manure	0.33	0.30	-0.02	-7%
Nitrous oxide - fertiliser & manures	4.73	4.90	0.17	4%
Total Emissions (kg CO2e/ kg dwt beef)	**22.44**	**22.76**	**0.32**	1%

Explanation for changes – see Excel - "Carbon results – breeder finisher1.xls"

Scenario ST11 – Finishing as Bull Beef (13 months)

Background

Feed is a major cost in all beef production systems and taking steps to improve feed-use efficiency will improve margins, with nutritional, genetic and management factors all influencing feed-use efficiency.

In general, bull beef production systems can be highly feed-efficient achieving faster rates of growth, with greater lean tissue deposition than steers and heifers.

Importance

Keeping bull calves entire allows for faster growth rates and shorter finishing periods compared to uncastrated steers and thereby, is more efficient from a carbon emissions perspective as the bulls are slaughtered at a younger age. Other positives include:

- High daily liveweight gains is more efficient as a higher percentage of the ration is used for growth.
- Reduced carbon emissions per kg of meat produced.
- Quick turnover of cattle, with less time on farm.
- Reduces grazing pressure on grassland farms as the system is housing based.
- Suitable for arable units given that cattle are finished on a cereal based diet.
- Reduction in feed and bedding costs.
- Better use of resources – land, buildings and labour.
- Potential to achieve top grades in terms of carcase quality.
- Improved sustainability.
- Potential for higher profit levels.

In short, this type of finishing system is more efficient and cost effective from both a carbon emission and a financial perspective.

Assumptions

	Baseline	Scenario 11
Calving Period	Spring	Spring
Calving %	86	**90**
Rearing %	80	**84**
Heifer Replacement Rate (%)	15	**14**
Age at First Calving (years)	3	**2**
Improved Manure & Nutrition Mgmt.	No	No
Nitrification Inhibitors	No	No
Cow Weight kg lw	700	**630**
Silage Quality (10.5 ME, 11% CP DM)	Average	**Good**
Grazing System	Set Stocking	**Rotational**
Calf Sale Weight kg lw	650	650
Age at Slaughter months	21	**13**
Methane Inhibitors (3NOP)	No	No
Alternative Feeds	No	No

Sources of data – CTS Average Data - Rearer Finishers

Wider Farm and Industry Implications

Like other more specialist finishing systems, a bull beef enterprise is not a practical option for every rearer finisher unit for the following reasons:

- Health and safety. Bull group sizes need to be kept small – no more than 20. Batches should not be mixed as this leads to fighting and riding which can adversely affect carcase quality. Bulls must be housed away from other stock, particularly breeding stock to minimise normal breeding behaviours and stress.
- The cost and availability of suitable housing.
- Waste management – from 3 -13 months, a group of 50 bulls will produce a total of 400m^3 of slurry; and while an 18-month finished steer, will produce a similar quantity of slurry in the same time period, a greater proportion of its' life is spent outdoors, and therefore the required slurry capacity and investment therein, is less.
- The cost of the cereal based diet, given that the bulls will eat ~2 tonnes of concentrates per head at a cost of ~ £140 per tonne. For a group of 50 bulls, this equates to a monthly feed bill of £2,300 for the 6-month finishing period.
- Currently, if bulls reach the target slaughter weight before 12 months of age, they are slaughtered as 'Veal' which has a limited market. Going forward, the Beef Industry would benefit from the veal classification being lowered to 10 months of age to allow very efficient cattle to be finished under 12 months of age.
- Some slower finishing/more traditional breeds are not suited genetically to this type of rapid finishing system.
- Due to the ability for higher daily liveweight gains, if larger framed bulls are kept to 12 months of age, some are already over the deadweight limits before they reach the required degree of finish which results in price penalties and potential losses.
- Providing continuity of supplies for processors – if every spring calving rearer finisher opted to finish all their male progeny as 13-month bull beef, there would be a glut of carcasses in late spring early summer, and potential shortages of supply out with this period.

Areas where Specialist Help/Training/Grant Aid would be beneficial

- Breeding management advice.
- Nutritional management advice including forage/feed analysis and rationing.
- Health planning to reduce disease risks.
- Buildings advice to reduce disease risk e.g. pneumonia.
- Alternative Feed Workshops.
- Grant aid for weigh crates, weigh cells, automatic tag readers and livestock management programs.
- Grant aid for slurry storage including covers for slurry towers and lagoons.
- Grant aid for more carbon efficient methods of slurry spreading e.g.by injection into the soil.
- Grant aid for good quality handling systems to reduce stress levels especially prior to slaughters as this results in darker meat which has a lower shelf life and reduces the value of the carcase.
- Health and Safety training.

Carbon Results for Finishing Bull Beef at 13 months of Age

SRUC Agrecalc - Stacked

Table C1 - total beef carbon emissions	ST10. Reduce age at slaughter (16 months)	ST11. Finish as bull beef (13 months)	Difference	
Units	(kg CO2e)	(kg CO2e)	(kg CO2e)	(%)
Year				
Energy use	36,092	34,033	-2,059	-6%
Fertiliser production	84,818	66,680	-18,138	-21%
Lime	51,264	45,473	-5,791	-11%
Feed production	15,291	44,799	29,508	193%
Bedding	19,118	17,424	-1,694	-9%
Pesticides	71	62	-9	-13%
Disposal carcases	558	569	11	2%
Methane - feed digestion	320,904	316,166	-4,738	-1%
Methane - manure	9,078	9,402	324	4%
Nitrous oxide - fertiliser & manures	147,493	136,472	-11,021	-7%
Total beef enterprise	**684,687**	**671,080**	**-13,607**	-2%
Output (kg dwt beef)	30,078	30,078	0	0%

Table C3 per kg dwt beef carbon emissions by activity

	ST10. Reduce age at slaughter (16 months)	ST11. Finish as bull beef (13 months)	Difference	
Unit	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(kg CO2e/kg dwt)	(%)
Energy use	1.20	1.13	-0.07	-6%
Fertiliser production	2.82	2.22	-0.60	-21%
Lime	1.70	1.51	-0.19	-11%
Feed production	0.51	1.49	0.98	193%
Bedding	0.64	0.58	-0.06	-9%
Pesticides	0.00	0.00	-0.00	-13%
Disposal carcases	0.02	0.02	0.00	2%
Methane - feed digestion	10.67	10.51	-0.16	-1%
Methane - manure	0.30	0.31	0.01	4%
Nitrous oxide - fertiliser & manures	4.90	4.54	-0.37	-7%
Total Emissions (kg CO2e/ kg dwt beef)	**22.76**	**22.31**	**-0.45**	-2%

Explanation for changes – see Excel - "Carbon results – breeder finisher1.xls"

Agrecalc introduction

Agrecalc is the UK's leading agricultural resource efficiency and greenhouse gas emissions calculator. It has over 3,500 users in all sectors of agriculture across the UK and this number is growing rapidly as governments, retailers, commercial farm businesses and other farming industry stakeholders seek to measure and mitigate agricultural emissions.

Agrecalc methodology

Agrecalc is a farm carbon footprint tool designed to identify and measure the main sources of carbon emissions, as well as benchmark key performance indicators and is well matched to meet the requirements of this tender.

- IPCC and PAS2050 compliant
- Encompasses all UK farm enterprises in the one tool with effective resource transfers between them
- Presents carbon emissions at – Whole Farm, Enterprise, and Product level
- Includes soil carbon sequestration module – first one for UK that is IPCC compliant
- Available free at the individual farm level enabling FEP participants to access their farm data within and beyond the AHDB carbon auditing project.

Agrecalc estimates the type, source, and extent of farm greenhouse gas emissions for all the main greenhouse gases related with agriculture. The three main greenhouse gases produced from agriculture include carbon dioxide, produced by burning fossil fuels; methane, produced as a natural by-product of animal digestion and nitrous oxide which is released from soils following the application of nitrogen fertiliser (manufactured and organic) and soil disturbance. Making more efficient use of resources strongly correlates with reduced production costs per kg of output, improving profitability of the farm business.

Agrecalc has been employed in various situations and under diverse contexts in the recent years. The tool was employed in research-related context leading to publication in peer-reviewed journals for modelling alternative management scenarios of economic and environmental sustainability of beef finishing systems in Scotland (Kamilaris et al., 2020), estimating carbon footprints from dairy farms (March et al., 2019), studying and understanding uncertainty in the carbon footprint of beef production (Sykes et al., 2019).

Agrecalc was also employed in in policy-related context from Scottish Government supporting the Beef Efficiency Scheme, which is a five-year climate change scheme that aims to help beef breeders improve their efficiency, sustainability, and quality of their beef herd, by helping increase their genetic value from 2016 and reduce greenhouse gas emissions (BES, 2018). Plus, it is employed in industry-related context from Quality Meat Scotland to produce estimates of the GHG emissions associated with enterprises surveyed for the annual 'Cattle and Sheep Enterprise Profitability' report (Quality Meat Scotland, 2019, 2018).

Agrecalc is unique in UK agriculture in the extent to which one tool combines resources from SRUC's Education, Research and Consultancy. SAC Consulting has drawn on support from

SRUC's research in the development of its carbon management services and tools. SRUC has a proven track record of research and advice covering a wide range of carbon issues in soil, crop and livestock production. This strong science base ensures our consultants provide up to the minute comprehensive advice on carbon management which they then roll out to their farmer clients in practical terms.

Furthermore, a peer reviewed paper (Sykes et al., 2017) and an independent study by Ricardo on behalf of ClimateXChange (Wiltshire et al, 2019) conclude that Agrecalc, is the most accurate tool on the market. Agrecalc is constantly backed by SRUC researchers leading to updating versions and developing new modules according to the latest valid scientific methodologies (IPCC, 2019), while linking with all the latest research on climate change and mitigation strategies for agriculture, for example developing greenhouse gas marginal abatement cost curves for agricultural emissions from crops and soils in the UK (Eory et al., 2015; MacLeod et al., 2010; Moran et al., 2011).

Agrecalc's key features include the fact that emissions are calculated for the whole farm, per enterprise and per unit of saleable product, all mainstream agricultural enterprises are included (e.g. beef, sheep, dairy, pigs, poultry, cereals, oilseeds, potatoes, vegetables, and fruits, etc.), it generates year on year comparisons, benchmarks and key performance indicators. Also, it is based on a PAS2050 compliant tool providing assurance that the greenhouse gas emissions being reported are calculated in a consistent way across the industry, while the latest IPCC Tier I and Tier II calculations are used. In a nutshell, Agrecalc:

- Combines SRUC world-class research with practical on-farm expertise from SAC Consulting.
- Conforms to IPCC Tier II calculations for all livestock types & PAS 2050:11 supply chain standards.
- Calculates whole farm, enterprise & product emissions, and carbon sequestration.
- Covers all mainstream agricultural systems and food sectors.
- Constructs "What if?" scenarios for carbon mitigation solutions and tailored group Portals.
- Developed from SRUC's science base with practical consultancy experience
- Successfully delivered over 5,600 farm audit reports on over 2,950 farms across all UK agricultural sectors for a variety of farm, government, and commercial projects

Agrecalc produces accurate carbon footprint reports for all farm enterprises. Its reports identify practical management changes to lower farm emissions, while offering the ability to benchmark a business to peers within the group or at industry level. Reducing emissions boosts farm enterprise productivity and efficiency and the tool is built specifically to monitor performance and the impact of the changes implemented. This is an easy-to-use and evidence-based tool that assesses productivity, provides data-driven benchmarking, and suggests cost-effective solutions designed to empower farmers to understand the environmental aspects of agriculture and implement practical and cost-effective solutions leading to net-zero emissions from farming.

Agrecalc's specific terms and conditions can be found on the website here. Agrecalc has a straightforward policy regarding its use, services provided, data usage and privacy notice.

Agrecalc's Full Version with all features available will be employed in this project. After the completion of this project, the farms involved can keep all of their recorded data, carbon reports produced and accounts intact, by using the free pass for the Complimentary version of the tool that will allow them one carbon report per year, or by licencing the Full version for unlimited carbon reports and all additional features available.

Agrecalc Methodology Summary

Agrecalc Farm Carbon Reporting Methodology	
IPCC Methodology compliant	IPCC (2006) Tier I and II methodology
Publicly Available Specification (PAS) 2050	PAS2050 certified (BSI, 2020)
Livestock and Manure Management	IPCC (2006) Tier II methodology
Fertiliser Applications and Crop Residues	IPCC (2006) Tier I methodology
Embedded Emissions Production of Fertilisers	Emission Factors (EFs) Kool et al. (2012)
Emissions Imported Feed and Bedding	Vellinga et al. (2013)
Emissions Electricity and Fossil Fuels	DEFRA/DECC (2013) Conversion Factors for Company Reporting
Additional sources	Sykes et al. (2017), Kamilaris et al. (2020)
Soil Carbon Sequestration Module Methodology	
Calculating Soil Carbon Stocks	IPCC (2019) refinement to the 2006 Guidelines on National Greenhouse Gas Reporting
UK Climate Type	SoilGrids250m data repository Hengl et al. (2017)
Stock Change Factors	SAC Consultants and SRUC researchers Sykes (2018)
Biochar	IPCC (2019) and Hammond et al. (2011)

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