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Evidence Project Final Report

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Project identification

1. Defra Project code: IF0207
2. Project title: Developing options to deliver a substantial environmental and economic sustainability impact through breeding for feed efficiency of feed use in UK beef cattle
3. Contractor organisation(s): Bioscience Network Limited
   The Roslin Institute
   Easter Bush
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4. Total Defra project costs (agreed fixed price): £ 44,865
5. Project: start date 03/01/2012
   end date X/X/2012

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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

Livestock production is one of the major contributors to global GHG production, accounting for an estimated 18% (in CO_2 equivalents) of total anthropogenic emissions and around 7% of total emissions in the UK. The majority of the emissions are of methane, nitrous oxide and ammonia, and livestock production accounts for an estimated 37%, 65% and 64% respectively of the total global anthropogenic emissions of each. A large proportion of these emissions, particularly of methane are accounted for by production of ruminants. For example, in the UK the production of beef cattle alone account for around 20% of the total emissions of methane from agriculture. The result of previous studies have suggested that genetic improvement of beef cattle, that included the improvement of feed use efficiency, could make a substantial contribution to improving the economic and environmental impact of beef cattle production in the UK.

The main goals of this study were (i) To establish the relative benefits and costs of a series of possible options for projects focused on delivering large numbers of beef cattle with EBVs for measures of feed use efficiency, and (ii) To help develop a platform for launching a project that would act as a catalyst for the delivery of a significant impact at an industry level in terms of improving environmental and economic sustainability of UK beef production systems. A series of parallel activities were undertaken to achieve the goals: a) a brief review of literature, b) consultations with research and industry representatives in Australia, Canada, USA and Ireland to ensure that experience and lessons learnt from similar projects that have been run in other countries were taken into account, c) desk based modelling, d) individual consultations and a group meeting with key stakeholders to evaluate the level of support from key industrial and potential funding stakeholders for the different options.

The approach used for the modelling work was based on two parts. Part one was focused on investigating the likely selection response in a hypothetical beef breed when selection was done using a range of alternative indices. In each case it was assumed that recording of feed intake was focused on bulls and done only on a small proportion of those available. Part two was focused on estimating the likely impact both in terms of increased profit and reduced GHG. In order to make the results more relevant to the UK scenario, the population parameters used for the purebreds was based on data for the Limousin breed and number of animals in commercial herds based on FAPRI-UK 2010 predictions.

The result of the modelling work suggested that 10 years of selection using the currently available selection tools for UK beef cattle, when considered over a 20 year time horizon, would be expected to results in an increase in profit at the commercial farm level of around £31M along with an associated

reduction in GHG emissions of 725kt with an estimated shadow carbon value of around £26M. Recording and including a measure of feed efficiency such as residual feed intake in the breeding goal would be expected to increase projected responses by around 39% and 22% respectively. Also directly recording carcass traits would be expected to increase the total return to current approaches by around 73 and 75%, increasing the projected total cumulative return in farm profit to £54M and in GHG emissions reduction to 1,255kt with an estimate shadow price value of around £45M. Increasing the level of use of recorded bulls from the current estimated level of 50% to 90% would be expected to more than double the total cumulative economic response (profit and shadow carbon value) that was predicted both by using of the existing tools and of responses expected when a measure of feed efficiency and carcass traits where also included in the breeding goal.

The results of this study show that:

- Selection of purebred beef cattle using the currently available selection index tools will deliver a substantial positive impact on the economic and environmental sustainability of beef cattle production in the UK. At current rate of use of recorded bulls, 10 years of selection when considered over a 20 year time horizon, would be expected to result in a cumulative increase in profit at the commercial farm level in the UK of around £31M, whilst also reducing GHG reduction by around 726,000 tonnes – which is a win-win scenario
- Recording feed intake in order to include a measure of feed efficiency into selection indices in addition to current traits would be expected to increase the realised benefits in farm level profit by around 39% and in GHG reduction by around 22%
- Also recording carcass traits at the abattoir would increase the total benefits over current practice by around 73% and 75% respectively
- The establishment of agreed industry standards for recording of feed intake (that reflect current management practice) and for the measure of feed efficiency to be included in selection indices, would be an important step in minimising confusion and simplifying knowledge transfer
- Recording of feed intake on the crossbred progeny of high merit sires would likely be the most suitable approach to use for the main beef breeds in the UK, and would likely be the approach that would also gain the strongest industry support
- To provide a strong platform for on-going selection in any breed it would likely be necessary to provide access to facilities for record in the order of 1500-2000 animals that are the progeny of at least 100 sires to allow good genetic parameters to be estimated, and to ensure that access to recording facilities is still available thereafter to allow the continued testing of progeny from a number of high merit young bulls on an annual basis
- A further more detailed modelling study focused on two stage selection would be needed to determine the optimum number of bulls to test annually to maintain good selection responses as part of such a recording programme
- 10 years of selection using current approaches would be expected to result in a reduction or around 3% in GHG emissions per unit of beef produced. Also recording feed intake and carcass traits on the progeny of a proportion of the bulls available would result in a reduction of around 6%, whilst recording both and increasing the rate of uptake of recorded bulls to 90% would be expected to result in a 10% decrease. These reductions would be expected to be even larger if selection was conducted for longer periods
- Recording feed intake and carcass traits and collecting DNA or recorded animals and their sires as part of a well structured programme would provide a valuable resource that would allow the development and validation of genomic marker panels that could help further increase the rates genetic improvement and overall impact
- Establishing incentive schemes focused on increasing the level of recorded bull use in commercial herds from 50 to 90% could have a dramatic effect on the realised benefits from genetic improvement. Greater uptake of bulls selected using the current selection tools could result in the impact increasing to over twice what is currently predicted, and up to around five times if records for feed efficiency and carcass traits were also included

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:

- the objectives as set out in the contract;
- the extent to which the objectives set out in the contract have been met;
- details of methods used and the results obtained, including statistical analysis (if appropriate);
- a discussion of the results and their reliability;
- the main implications of the findings;
- possible future work; and
- any action resulting from the research (e.g. IP, Knowledge Exchange).

1. Introduction

1.1 Background

Livestock production is one of the major contributors to global GHG production, accounting for an estimated 18% (in CO_2 equivalents) of total global anthropogenic emissions and around 7% of total emissions in the UK. The majority of the emissions are of methane, nitrous oxide and ammonia, and livestock production accounts for an estimated 37%, 65% and 64% respectively of the total global anthropogenic emissions of each (Steinfeld *et al,.* 2006). A large proportion of these emissions, particularly of methane are accounted for by production of ruminants. For example, in the UK the production of beef cattle alone account for around 20% of the total emissions of methane from agriculture (FAPRI-UK, 2010).

Reductions in emissions could be achieved simply by reducing the total livestock numbers, however this is not a desirable medium or long-term solution given that global demand for livestock products is increasing year on year. A more appropriate goal would be to improve both the environmental and economic stability of livestock production. Changes in management, feeding and genetics could all potentially play a role in achieving this goal.

Results from a previous Defra funded study (AC0204) have shown that genetic improvement can play a major role in improving both the environmental and economic sustainability of livestock production. Current approaches primarily aimed at improving economic efficiency have also helped to deliver reductions per unit product of around 15-25% over 20 years in pigs and poultry species. The report also showed however that historic impact in the UK beef industry had been low, partly due to the low uptake of genetic improvement approaches but also due to the lack of recording and selection for measures of feed use efficiency, which had played an important part in the impacts being delivered it the other livestock species. Whilst not currently practiced in the UK, research conducted in a number of other countries has shown that genetic improvement in measures of feed efficiency in beef cattle is possible, and can help deliver real impacts in terms of improving economic and environmental sustainability.

1.2 Objectives

This project had two overall goals: (i) To establish the relative benefits and costs of a series of possible options for projects focused on delivering large numbers of bulls with estimates of their genetic breeding value (EBVs) for measures of feed use efficiency, and (ii) To help develop a platform for launching a project that would act as a catalyst for the delivery of a significant impact at an industry level in terms of improving environmental and economic sustainability of UK beef production systems. These overall goals were addressed through four specific objectives:

1. To identify and evaluate the relative merits (primarily in terms of likely impact, support, set-up and running costs) of a series of options for establishing a project that could deliver a strong platform from which to improve feed use efficiency in the UK beef cattle population.
2. To evaluate the level of support from key industrial and potential funding stakeholders for the different options and to ensure that feedback from key stakeholders is taken account of in refining possible options.
3. To ensure that experience and lessons learnt from similar projects that have been run in other countries are taken into account when developing the different options.
4. To identify the likely level of financial support that would be required from Defra to develop each of the options identified.

2. Materials and Methods

2.1 Project structure and collection of information

A series of parallel activities were undertaken to achieve the objectives: a) initial review of literature (obj. 1), b) consultations with International groups working in relevant areas (obj. 3), c) desk based modelling, d) individual consultations with key stakeholders, and e) stakeholder meeting and follow up discussions.

Initial investigations confirmed that breed societies have a strong influence on the strategy and activity in the UK beef breeding supply chain, and that a high proportion of the genes in the UK beef slaughter animal population were accounted for by the five main breeds (see section 3.1). As a result of this finding and the need to limit the number of stakeholders in the first instance, initial consultations were limited mainly to representatives from these five breed Societies and representatives from red meat levy boards in Great Britain.

The consultations were initially conducted through individual meetings (aimed at ensuring that good input was received from all the stakeholders involved), followed by a small stakeholder workshop in which the main comments raised in the individual meetings were discussed, along with the preliminary results from the literature review, international consultations and modelling work. Comments made at the workshop were then used to refine the modelling work done.

Although initially planned, a second stakeholder workshop to discuss the final results could not be arranged within the time frame of the project due largely to the latter part of the short scoping study coinciding with the start of the show season. Follow-up correspondence and consultations with the stakeholders after the first workshop were therefore done largely through email and phone calls.

As part of initial discussions, two examples of successfully run industry led commercial units in the UK that could provide potential options for recording feed intake were identified. The first was a specialist unit recently built and run to record feed intake in animals from the Stabiliser breed; the other a commercial finishing/progeny testing unit that was recently established by Adam Quinney and Arrow Valley Feeders. An overview of both systems was provided as part of the stakeholder workshop and further details on both systems are provided in this report. Representatives from both initiatives were also included in the initial consultations.

In contrast to the UK, a number of other countries have undertaken a considerable amount of research in relation to recording feed intake in beef cattle and selecting on measures of feed use efficiency. A series of consultations with international groups working in relevant areas were conducted to meet objective 3. Although the results from published research were used as a starting point, the main emphasis was placed on getting a good overview of the current and on-going activity and on finding out more about the level of industry participation and uptake that had been achieved, together with any lessons that had been learned along the way. Discussions were held with a number of people (researchers and industry members) that were closely associated with the activity in Australia, Canada (Alberta), North America, and Ireland.

2.2 Modelling the potential impacts

This part of the study had two main objectives, 1) To quantify the likely impact in terms of improving farm level profitability and reducing GHG emissions by including selection on a measure of feed efficiency into current breeding goals and performance recording, 2) To estimate the likely numbers of animals that would need to be recorded to help deliver a good industry level impact. The results in relation to both these objectives were key components needed to help meet objective 1 in the main study.

The developing the approach three expectations were considered, namely

1) If selection to improve some measure of feed use efficiency was to be done in the UK, it would most likely be done by incorporating a chosen measure in current breeding programmes with selection alongside current economically important traits, rather than selection in isolation. Given the practical difficulties and high costs associated with recording individual feed intake, it would only likely be done on a proportion of the animals available for selection.
2) Previous studies focused on the UK have shown that current methods of genetic improvement not only increase farm profitability (Amer *et al*. 2007) but also contribute to greenhouse gas (GHG) mitigation (Moran *et al*. 2008, final report AC0204). Although a large part of the breeding goal for the currently used selection indices for beef cattle, carcass traits are currently not directly recorded in the UK, with selection being based on correlated live weights, ultrasound measures of fat and muscle depth and visual assessment of muscling. Directly measuring carcass traits could potentially improve the rate of genetic improvement through selection.
3) The UK beef breeding industry can be described as having a pyramid like structure, where all genetic improvement (and the supporting performance recording) is undertaken in purebred populations which is then disseminated through to the rest of the industry through the purchase of the improved stock by commercial producers.

In view of these expectations, the approach used for the modelling work was based on two parts. Part one was focused on investigating the likely selection response in a hypothetical beef breed when selection was done using a range of alternative indices. In each case it was assumed that recording of feed intake was focused on bulls and done only on a small proportion of those available. In order to make the results more relevant to the UK scenario, the genetic parameters and population parameters assumed were based on data available for the UK population of the Limousin breed. Although, the parameterisation was done using Limousin data, we would expect the overall structure to also be similar in other UK beef breeds. Part two was focused on estimating the likely impact both in terms of increased profit and reduced GHG, of the genetic improvement achieved being disseminated through to the commercial herd level.

As part of that overall approach, the effect of a series of variations was investigated, namely: i) Including records for feed use efficiency and carcass traits directly in the selection index, ii) Taking account of genetic improvement achieved through selection pressure on dams as well as sires, iii) Changing breeding goals to focus more on GHG reduction, iv) Increasing the level of recorded/improved bull used in commercial herds.

Changes in selection responses in the purebred population

The potential impact of including records for feed use efficiency and carcass traits was investigated by estimating the likely change in selection response by adding in these as new traits directly in the selection index. Results for all alternative indices were compared relative to expected improvement rates and impact from selection using a base (current) index. The base index was constructed to mimic the terminal sire index that is used by some UK breeds, such as the Limousin, namely the Beef Value index. Given that there is still uncertainty over which measured of feed efficiency should be used, it was necessary to chose and exemplar measure as a focus for this modelling study. The exemplar measure of feed use efficiency used was Residual Feed Intake (see section 3.2 for a definition) measured post weaning adjusted for ultrasound fat depth at the end of test ($RFI_{pw\text{-}fat}$) as suggested in Basarab *et al.* (2011). The trait included in the breeding goal was $RFI_{pw\text{-}fat}$ in commercial cattle.

Changing economic weights

The estimates of economic weights used in the base (Beef Value) index were aimed at maximising profit at the commercial farm level (Amer *et al*., 1998). An economic value for $RFI_{pw\text{-}fat}$ was calculated using a similar approach, and estimated as £0.069 per kg DMI improvement (Peter Amer, Abacus, 2009). The effects of using three alternative sets of index weights more heavily focused on reducing GHG emissions were also investigated. Weight used for two of the indices were derived as part of a previous Defra funded study (FG0808), and were based on one of two units of interest, CO_2 eq./kg saleable meat and eq./breeding cow. Weights for the third index were based on the expected impact of response to selection on GHG emissions from a beef system and multiplied by the prevailing shadow price of carbon (SPC, CO_2 eq.) when disseminating genetic improvement to the wider population (economics + SPC).

Impact in the commercial population

Given the typical pyramid structure of performance recording and genetic improvement dissemination in the UK beef industry we can assume that genetic improvement that occurs at the pinnacle of the breeding structure will disseminate through the purchase of the improved stock by commercial producers. Based on the analysis of national data (Amer *et al*., 2007, Todd *et al*, 2012, and recent analysis of BCMS data) it can be deduced that currently approximately 50% of cows that produce progeny destined for slaughter in the UK are mated to bulls that flow from recorded pedigree populations undergoing genetic improvement. Economic return at the whole industry level from adoption of different selection approaches in the purebred population were therefore calculated assuming that only 50% of animals slaughtered each year were the progeny of recorded animals. More details on the modelling assumptions made are described in Amer *et al*., (2007).

The cumulative marginal net discounted return from 10 years of selection (at a steady state) in the purebred population with benefits considered over a 20-year horizon were calculated, including farmer profitability and societal economic benefit from reduction in GHG emissions using the prevailing shadow price of carbon at the projected time point (Price *et al*., 2007). It should be noted that the SPC is projected to rise with time, indicative of the cumulative damage cost over time of additional GHG emissions. A time horizon of 10-years beyond the selection period was used to allow time for the genetic improvement made in the elite purebred herds to be fully disseminated to the commercial level.

The assumed numbers of bulls used and cows mated each year in commercial herd were based on the information presented by Amer *et al.* (2007) and those detailed in the FAPRI-UK animal number projections. It was also assumed that each breeding male would mate approximately 150 cows over their lifetime and this was the main penetration route of genetic improvement into the commercial population. The FAPRI-UK agricultural projections (FAPRI-UK 2010 Baseline Projections, August 2010) were also used in this study to model the impact of genetic improvement as it would be expected to penetrate into the commercial population of beef cows – the dams of the commercial slaughter population.

Added benefits through selection on dams

In the base scenario, it was assumed that genetic improvement was effected only through selection pressure being applied to bulls. The effect of including an additional selection intensity of 0.8 on females was also investigated. The generation interval assumed for females was 6.25 years which was calculated as being typical for the Limousin breed.

Changes in level of use off recorded bulls in commercial herds

In all initial investigations it was assumed that only 50% of cows that produce progeny destined for slaughter in the UK are mated to bulls that flow from recorded pedigree populations undergoing genetic improvement, which is typical of the current industry norm. The effect of increasing the percentage of cows mated from 50% to 90% was also investigated.

2.3 Numbers of recorded animals needed

In order to set up a breeding programme that can deliver a good industry impact, sufficient records are needed to first estimate breed specific genetic parameters, followed by the continued collection of a sufficient number of records thereafter to ensure that EBVs with good accuracy can be generated on enough bulls to allow differentiation and selection to be possible. The number of records needed for a given breed at both stages was investigated using standard genetic methodology, with answers refined using literature estimates of heritability for the trait of interest and correlations with other traits.

The optimum numbers of animal to record at both stages will depend on a wide number of factors e.g. measure of feed efficiency used, number of sites and timescales of recording, capacity of the recording facilities, structure of the breeding programme used, number of animals in the pedigree population etc. To develop detailed recommendations would therefore require a large simulation study to be conducted, which was beyond the resources available for this study. However it was possible to also investigate the likely impact on selection responses of changing the numbers and type of animals recorded, to help further inform the assessment of the relative merits of the different recording options under consideration. The impact of recording purebred vs crossbred animals when the genetic correlation between RFI_{pw} measured in purebred and crossbred animals was assumed to be 0.7 was investigated, along with the effects of changing the number of bulls tested and of changing the number of crossbred progeny tested per bull.

3. Results

3.1 Industry structure (GB) and genetic evaluations

The UK beef industry is generally characterised by a large number of small herds which results in an overall average herd size of 28 cows. Around 48% of herds have between 1 and 50 cows, only 3% of herds have more than 500 cows (Defra 2008 and Todd *et al*., 2011). Although pure-bred beef and beef cross beef animals account for the largest proportion of the slaughter beef animals produced, beef from dairy cross-beef animals also plays an important role, with dairy breeds accounting for around 36% of the total genes of the slaughtered beef animals (Todd *et al*., 2011).

Beef production is done through a wide range of management systems (upland and lowland conditions), but are predominantly grass fed, out-doors during spring, summer and early autumn and indoor, with largely silage and concentrate based feeding, during late autumn and winter months (*Mary Vickers, EBLEX pers. comm.*). The main calving period tends to be in spring (around April) but some births also occur in other parts of the year particularly in early autumn. Beef cross diary calves tend to be mostly born in autumn (Defra, 2008). The majority of prime slaughter cattle produced are steers and heifers, with the proportion of young bulls slaughtered as prime beef being relatively small. In 2011 the proportion of slaughter cattle accounted for by steers, heifers and young bulls was 54%, 33% and 13% respectively, which was similar to the proportions seen in each of the previous 10 years (*Kim Matthews, EBLEX, pers comm.)*. Young bulls tend to be slaughtered at around 12-14 months of age, whereas steers and heifers are more commonly slaughtered between the ages of 22 and 29 months, with the median age tending to be around 24 months, however the majority of animals are slaughtered before 30 months of age (BCMS, 2012).

Table 1: Genetic contribution of the main breeds (>5% total) to the UK prime slaughter beef cattle in 2008*

Type	Breed	% of Sires	% of Maternal Grand Sires	%Total genetic contribution
Beef	Limousin	31.0	18.4	21.8
	Charolais	18.6	5.2	11.1
	Simmental	10.4	10.4	8.8
	Aberdeen Angus	8.8	7.6	7.0
	Belgian Blue	9.0	4.0	5.9
	Five breeds total	**77.8**	**45.6**	**54.6**
Dairy	Holstein/Friesian	9.0	38.8	32.6

**from Todd et al., 2011*

Breeds

Five pure-bred beef breeds account for more than half of the total genetic contribution to the beef slaughter animals (Table 1). Collectively these account for 77.8% of sires of slaughtered animals and 54.6% of the total genetics, with a large proportion of the remainder being accounted for by dairy breeds, predominantly Holstein/Friesian. As well as accounting for a high proportion of the terminal sires used, these five breeds also have a strong influence of the commercial breeding females, accounting for 45.6% of the sires of females retained for breeding. Pedigree pure-bred cattle continue to play a very important role in the UK beef breeding sector accounting for nearly all of the sires used. As a result, Breed Societies have a strong influence on the overall strategy and activity within the breeding supply chain.

Genetic evaluations of UK beef cattle

Genetic evaluations for beef cattle in the UK are conducted through two main providers, Signet and BreedPlan. Signet is part of EBLEX (the red meat levy board for England) but also receives financial support from HCC and QMS, the other two red meat levy boards (Wales and Scotland, respectively) in Great Britain. As part of the Signet service, data analysis is provided by Edinburgh Genetic Evaluations (EGENES), which is part of SAC. Signet provides the genetic evaluation service for only one of the five main breeds, Limousin. BreedPlan is a division of the Agricultural Business Research Institute (ABRI) in Australia. They deliver genetic evaluations service for the other four main breeds, i.e. Aberdeen Angus, Charolais, Simmental and Belgian Blue.

Technical support to breeders and commercial producers in relation to interpreting the results of genetic evaluations and what they need to record to get good EBVs of their animals is mainly provided through the respective breed societies, Signet, Breed Plan, and the levy boards. The support is provided primarily in the form of information on websites, technical booklets and presentations at group meetings. The number of on-the-ground technically trained support staff is low.

3.2 Literature review

A typical beef production system essentially consists of three main production phases:

1) Rearing of replacement heifers
2) Cow maintenance and calf production
3) Growing and finishing of progeny destined for slaughter

A number of animal characteristics affect the overall production efficiency within each of these phases. For example, in phase 1, heifer growth rate, fertility and age at first mating/calving play an important role; in phase 2, cow fertility, calving ease, cow size and calf survival all have a big effect; and in phase 3, birth weight, growth rate and carcass composition are important along with maintaining or improving meat quality to ensure that the final product can be sold.

Variation in all these characteristics has been shown to be at least partly under genetic control (e.g. Simm, 1998) and improvements could be made through selection of the highest genetic merit animals parents of future generations. With the exception of calf survival and meat quality traits, estimates of genetic merit or breeding values (EBVs) for recorded purebred animals for many of these traits have been available for British beef breeds for some time, either directly or on correlated traits where direct measurements were not routinely possible (e.g. ultrasound scans of muscle and fat depths used as predictors of carcass traits). EBVs for traits of importance in phase 3, often referred to as ‘Terminal sire traits’ have been available for over 15 years (Crump *et al*., 1997) whereas EBVs for more ‘maternal traits’, affecting phase 1 and 2, have been available for just over 5 years (Roughsedge *et al*., 2005). Given the range of characteristics that need to be considered, selection decisions have been simplified through the aggregation of relevant EBVs into selection indices with the relative importance of each weighted by their relative contribution to overall profit at the farm level. Two indices have tended to be published for most breeds, one terminal (sire) index and one more focused at self replacing/maternal or dual purpose herds, which have been available for around 15 and 5 years respectively (Amer *et al*., 1998; Roughsedge *et al*., 2005). Although two evaluations systems are currently available in the UK, the records collected, EBVs calculated and indices presented tend to be similar. Differences although present between evaluations systems and breeds tend to be small.

In beef production approximately 60-75% of the total variable cost of production is accounted for by the cost of feed. The amount of feed produced and consumed also has a big effect on the level of overall emissions. Genetic improvement in many of the traits currently being considered would be expected to result in reductions in the amount of feed consumed per unit product. However, genetic variation in feed efficiency over and above that captured by differences in other measured traits has also been estimated in numerous species.

Measures of feed use efficiency

The improvement of feed use efficiency has been a goal in various animal species for a number of years (McKay *et al*., 2010, Preisinger & Flock, 2000, Archer *et al*., 1999, Clutter & Brascamp, 1998). How best to assess the variation between animals has received considerable attention. The focus has tended to be on measurements of Feed Efficiency (FE), Feed Conversion Efficiency (FCE), Feed Conversion Ratio (FCR) or Lean Tissue Feed Conversion (LTFC), which are the ratio of feed consumed to production, weight gain or lean tissue; Residual Gain (RG) which is gain adjusted for differences in feed intake; or Residual/Net Feed Intake/Net Feed Efficiency (RFI, NFI, NFE), which is the difference between actual intakes and the predicted feed requirements given the animal’s body weight maintenance and measured growth or production. In each case the assessments tend to be difficult and expensive, needing the accurate recording of feed intake and growth rate of individual animals when fed standard diets *ad libitum* (Clutter & Brascamp, 1998, Archer *et al*., 1999).

Heritability estimates for FE, FCR, LTFC and RFI across all livestock species have tended to be moderate (0.16 - 0.46) (Clutter and Brascamp, 1998, Archer *et al*., 1999; Crews *et al* 2003, Crowley *et al*., 2010). Despite the challenges of recording, genetic selection in pigs and poultry is relatively common at the commercial level with measures of feed efficiency such as FCR and FE being preferred. Good annual rates of genetic progress have been achieved of around -0.015, -0.025 and -0.024 kg/kg feed in broilers, layers and pigs respectively (McKay *et al*., 2000, Preisinger and Flock, 2000).

The most appropriate measure to quantify variation in feed use efficiency in ruminants has been and continues to be a source of considerable debate (see for example the reviews in Archer *et al*., 1999 and Berry *et al*., 2009). A number of measures, such as FCR and FE are strongly correlated with body size, proportion of maturity and production level. Selection solely for high FCR or FE in the growing phase can thus result in indirect selection for increased mature size. Consequently whilst feed use efficiency in the growing and finishing phase may be improved, where females are also retained for breeding, the overall efficiency of the production system may be little changed or even worsened due to increased feed requirements for maintenance of the breeding female. As a result of these concerns, research in Australia and Canada has tended to focus on using measures of RFI, which can also be referred to as NFI or NFE (we will hereafter use RFI for simplicity). The concept of RFI was first used Koch *et al*. (1963), and aims to quantify variation in feed use efficiency that is not accounted for by differences in size and production levels. Animals with negative RFI values are deemed to be more efficient.

In young growing animals RFI is generally calculated as: $Y_i = \beta_0 + \beta_1 ADG_i + \beta_2 MMWT_i + RFI_i$

Where Y_i is the daily feed intake for animal i, B_0 – is the regression intercept, B_1 and B_2 and partial regression coefficients on average daily gain (ADG) and metabolic mid weight (MMWT) respectively (where MMWT is the live weight mid way through the test period raised to the power of 0.75 or 0.73) and RFI is the residual error term (Crews, 2005).

By definition RFI is phenotypically independent of the production traits that are used to calculate expected feed intake and thus it allows comparisons between animals differing in levels of production during the measurement period. However, even the use of RFI does provide some challenges. Whilst phenotypically independent from the component traits and other production traits, it is not necessarily genetically independent from them, which raises concerns over the long term implications of responses to selection and has prompted alternative measures to be proposed; for example, Basarab *et al*., 2011 suggested that the common positive genetic correlation between RFI and fatness (so lower RFI animals are genetically leaner and at a lower stage of maturity) may at least partly account for a slight negative association between low RFI and heifer fertility. As a result, they suggested that RFI adjusted for fatness at the end of the test period would be a preferable measure to use.

Kennedy *et al.,* (1993) showed that the heritability of RFI, its genetic correlations with component traits and the direct and indirect response to selection on RFI is determined by the genetic and phenotypic parameters for the component traits. Genetic independence from other production traits could be ensured by calculating RFI based on the genotypic regression of feed intake on production traits (Kennedy *et al*., 1993), but this approach also raises more challenges in terms of explaining to producers how the measurements are derived.

The majority of research and discussions to date in relation to RFI has essentially focused on responses and correlated effects to selection or the interpretation of RFI as a stand-alone trait. In practice, selection of feed use efficiency is more likely to be done in tandem with selection for improvement in a series of other traits included in a selection index. Kennedy *et al*., (1993) suggested that improved feed use efficiency would likely be best achieved in practice by selection on a multi trait index which includes feed intake, production and body weight along with appropriate economic weightings for each. As we will discuss later, such an approach has already been adopted in some countries for promotion to industry and is also being considered in others. Although useful in an index, interpretation of a standalone EBV for feed intake is also not as straightforward as one would hope. Given high correlations with production traits and body weight, heavier and faster growing animals would be expected to consume more feed and as a result have a higher EBV for feed intake at a given age. A low EBV for feed intake may therefore not always indicate a more feed efficient animal.

It is important to realise that for most of the measures that have been considered and published in literature, the main component measurements are the same, namely accurate records of feed intake over a period of time, and at least a record of live weight at the start and end of that period, but ideally taken at more frequent intervals during the test period. This characteristic has the benefit that the choice of measurement to use need not be made before the recording begins and a series of measures can also be considered and tested as part of the genetic evaluations, prior to the final choice being made of which measure to include in an index and to publish.

In contrast to some other breeding industries, such as those for pigs and poultry, the UK beef breeding industry is characterised by a large number of independent breeders with relatively small herd sizes, who in turn are selling to producers with access only to a low level of technical support. Under these circumstances the overall selection impact realised in practice will likely depend as much, if not more, on the level of understanding and acceptance of the measures used than on using the approach that is considered most theoretically optimal. Given that there is still considerable debate internationally regarding the best approach to use, developing strong UK-wide industry support for one specific measure/approach at the outset and minimising changes and confusion thereafter is likely to be a vital step in achieving good and sustained UK industry level impact.

Correlations with other traits of interest

The majority of the research published for beef cattle has tended to focus on RFI. Correlations between measures of feed efficiency and other traits of interest have tended to be favourable, with low RFI animals tending to be leaner, with larger eye muscle areas (Arthur *et al*., 2001; Bouquet *et al*., 2010; Crowley *et al*., 2011b). A positive association between a reduction in RFI and methane production has also been reported in a number of studies, with low RFI animals having daily methane yields of as much as 24-28% less than medium and high RFI animals (Nkrumah *et al*., 2006; Hegarty *et al*., 2007; Jones *et al*., 2011)

However, there are two suggestions of unfavourable associations that are worthy of note. A small negative association between low RFI and meat tenderness has been reported in some studies (McDonagh *et al*, 2001; Ahola *et al*., 2007), but the conclusion is not supported in others (Baker *et al*., 2006). Similarly an association between low RFI and a delay in the onset of puberty has also been reported, which may in turn have negative consequences on heifer fertility (Crowley *et al*., 2011a; Donoghue *et al*. 2011; Shaffer *et al*. 2011). However Basarab *et al*., (2011) has suggested that any potential negative association with fertility could be avoided by adjusting RFI for ultrasound fatness at the end of the test period.

Test ages/diets and correlations with feed efficiency at other ages and on other feeds

Ideally the efficiency with which an animal uses feed throughout its life could be measured to ascertain the variation between animals in overall efficiency. However, given the difficulty in achieving this, assessments in most species (including beef cattle) have tended to be done for a limited period of time post weaning, where the rate of weight gain and the composition of that gain would be expected to be fairly consistent if animals are on a non-restrictive diet. Due to the difficulties associated with recording intakes at pasture, recording in ruminants has tended to focus on animals fed concentrate and silage based diets in feed lot systems, with the age at start of test around 7-10 months.

In using this approach it is hoped that differences between animals in efficiency measured post-weaning is strongly associated with difference at older ages and that correlations between them are high. Whilst not extensively researched, some work had been done in Australia using RFI as the measure of feed efficiency and the results published have tended to support this expectation. Archer *et al*., (2002) reported phenotypic and genetic correlations of 0.40 and 0.98 respectively, between RFI measured post weaning and in the mature cow. Although based on a small data set, Herd *et al*., (2011) also reported a positive correlation between RFI measured post weaning on heifers and in mature cows fed pellet rations (0.38) and on pasture (0.28), although the correlation was low when cows were fed a restricted diet (0.02). Jeyaruban *et al.* (2009) also reported a high genetic correlation (0.65) between RFI measured post-weaning (around 10 months) in cattle fed a growing ration, and RFI measured in older cattle (around 18 months of age) fed a finishing ration in feedlots.

Test duration

During early research work in beef there were no accepted standard test conditions for recording post weaning feed intake and live weights of beef cattle for the purpose of deriving measures for feed use efficiency. More recently the recommendations made by Archer *et al*. (1997) for use with automatic feed intake measurement systems have tended to be adopted. They recommended that animals be first allowed to adjust to the automatic feeders and diets over a period of at least 21 days and then tested over a further period of 70 days, with live weights measures at least every two weeks. They concluded as part of the study that such a test period would result in little or no loss in accuracy compared to a longer test length of 119 days. In fact a test length of 35 days was sufficient to test feed intake, with the longer test period of 70 days only required to get good estimates of growth rate and thus RFI or FCR.

Variations on this protocol have been suggested in recent years, for example Wang *et al.,* (2006) have suggested that the test duration could be shortened to 63 days when feed intake animals were weighed weekly and Kearney *et al.,* (2004) further suggested by using automated weight systems, the duration of test could be further reduced to 56 days. Where the number of feed bins was a limiting factor, Donoghue *et al.,* (2009) also suggested that using a week on/week off testing system could be used successfully to test a higher number of animals. In practice in the UK, where building space is also likely to be a limiting factor, the benefit from considering either variation is likely to be small.

Indirect measures and use of genomic markers

Due to the difficulties associated with recording individual intakes for ruminants, considerable interest has been expressed in finding and using indirect measures of RFI or FCR. However despite considerable effort little success has been achieved so far.

One candidate that has received considerable attention for use in beef cattle has been the concentration of Insulin-like Growth Factor 1 (IGF1) in plasma. Although found to have a moderate heritability and a number of papers have reported positive associations (Johnston *et al.*, 2002; Moore *et al*. 2005, Davis and Simmen, 2006), the association reported in others has been minimal or zero (Lancaster *et al*., 2008; Kelly *et al*., 2010). Jeyaruban *et al*., 2009 also reported that the direction of the association with NFI may also change with age and feeding regime. They reported that whilst IGF-I level was lowly positively associated with RFI measured post weaning, the direction of the correlation although still low was reversed with RFI in older animals (around 18 month of age) fed in a feed lot. As a result, interest in using variations in IGF-I level as proxy measure has greatly reduced.

The potential to predict an animal’s genetic merit for measures of feed use efficiency using genomic marker panels has also received considerable attention in recent years. Although early results were encouraging, no major genes for feed use efficiency have been found (Moore *et al*., 2009). More recent results have described various levels of success, with the genomic panels developed on the whole tending to account for less than 25% of the genetic variation in the trait of interest and only in the breed and population that was used to derive the panel (Mujibi *et al*., 2011; Snelling *et al*., 2011; Bolormaa *et al*., 2011). A dramatic reduction has been seen in recent years in the cost associated with genotyping and whole genome sequencing and this has offered the opportunity to use high density marker chips and whole genome sequencing in on-going research projects. The results from these studies may lead to better results, however it is unlikely to result in genomic panels that will replace or dramatically reduce the need for feed intake recording.

It’s very likely that genomics will provide a very useful tool to genetic improvement programmes for many traits of interest in beef cattle, including feed efficiency measures. They will most likely be used as part of marker-assisted or genomic selection programmes resulting in genomic EBVs being produced that are based on the optimal use of both genomic information and records collected on selection candidates and their relatives. In the context of feed efficacy measures in beef cattle, the most likely benefits will be increasing the accuracy of selection of both high merit animals on which to record feed intake, and also of their relatives, both of which could play an important role in increasing the rate of genetic improvement. However, for any genomic panels to be used in the UK, it will be necessary to validate or train the panels within the populations of interest. That will only be possible if records on the traits of interest and DNA on the recorded animals have been collected as part of a well-structured recording programme.

3.3 <u>Experience and lessons from activity in other countries</u>

A short summary of the results from the international consultation with research and industry groups in Australia, Canada (Alberta), USA and Ireland are shown below. More detailed overviews for each country are included in Appendix 2.

Australia

- A large amount of research related to feed efficiency has been done as part of the large Beef CRC research and extension programmes that ran from 1994-2012
- Industry standards for recording were published in 2001
- The main focus has been on recording RFI and two RFI EBVs, one for post weaning and the other for feed lot finishing cattle, are now published for the Angus breed
- Despite the large amount of research, the level of industry-led recording is low – Angus Australia are the only breed society that are currently active in recording, which is primarily done through a jointly funded (with the Australian red meat levy board, Meat and Livestock Australia) Sire Bench-marking project
- As part of the current project, recording is more focused on purebred steers that are around 12 months of age as opposed to immediately post weaning. This change has been done to better fit with typical management practices in commercial herds
- There is a growing interest in generating an EBV for feed intake as opposed to RFI and to include it in the selection index
- There is also a growing interest from private farms in setting up recording facilities but mostly only from breeders of Aberdeen Angus cattle

Canada (Alberta)

- Research has been on-going since 2002, mostly led by academic groups but in collaboration with industry groups (breed associations or private breeding companies)
- Industry standards for recording were first published in 2004
- The main focus of recording to date has been on young bulls (post weaning) with data used to generate breeding values for RFI with the exception of one breed that are publishing values for residual gain
- Most of the main breed associations are now involved in projects that are part public funded with substantial industry in-kind or cash contributions. The main focus of these projects is on generating breeding values for bulls and investigating relationships with carcass traits
- Most on-going research projects are intended as pilot projects to help kick-start industry led activity. With this in mind, much of the recording is being done in commercial feed lots that would be available for the industry to use after the research projects have been completed
- Feed intake facilities (GrowSafe units) are currently set up in four research centres and five commercial feed-lot units
- In 2012 breeding for low RFI was approved as a recognised method for reducing GHG as part of the national carbon trading programme

USA

- The interest in recording feed intake is growing, but the activity is mostly driven through private initiatives and there has been little or no coordinated activity until recently
- 29 private testing stations and a number of research organisations have been fitted with GrowSafe recording equipment in recent years, providing a test capacity for over 30,000 young bulls a year.
- Industry standard recommendations for recording and generating estimated progeny differences (EPDs, which is half the EBV) were published in 2010 by the Beef Improvement Federation. The main focus of the recommendations is on testing young bulls post weaning and recommending that EPDs for feed intake be generated and included in selection indices
- A large $5M research project is currently underway with a heavy focus on developing more of a national programme for improving feed efficiency in beef cattle. The programme has a heavy focus on genomics but also has a high level of industry participation in a demonstration project

Ireland

- Feed intake recording on young purebred bulls has been done at a central test facility for around 35 years for the purpose of generating EBVs for feed intake which are then included in a selection index
- Although the level of industry engagement has been good, the overall industry impact of the programme has been relatively low
- 2012 has seen the start of a new programme which has a new focus on collecting feed intake and carcass records on crossbred progeny (most likely young bulls) from high index bulls
- The crossbred animals will be sourced through a structured programme with commercial herds that are participating in the G€N€ Ireland programme. These herds are offered semen form high merit bulls at a discounted rate provided a minimum number of inseminations are done and records collected on the progeny
- The programme is coordinated by the Irish Cattle Breeding Federation (ICBF) which receives public funding.

As can be seen from the short overviews, very different approaches have been used in each of the countries consulted. Despite these differences, there were a number of key lessons that emerged from the review, which included:

- Establishment of agreed industry standards for recording and presentation of results was important. This would help to minimise confusion and allow best use to be made of recording resources and the data collected. It was particularly important where the aim was to promote industry led recording (potentially through more than one provider) and where genetic evaluations were being delivered by different providers
- Ensuring that the agreed protocols reflected common industry management practices was important to increase the ease with which recording could be done
- Involving key industry groups early in the planning and ensuring participation in any activity was important
- In most countries breed associations played a key role in helping to develop momentum and drive uptake within industry
- There was no clear agreement on which measurement of feed use efficiency should be used, and variations occurred between countries and between breed associations and groups within countries. Where research programmes had played a strong part in helping to drive activity, use of RFI or NFI tended to be most common (Australia and Canada). However, generating EBVs for feed intake and incorporating them into a selection index was becoming a more popular approach, especially amongst industry representatives, and was the approach taken in Ireland and most commonly used in the USA
- Using commercial recording facilities during any set up phase (that would be available for industry to use thereafter) was seen as being important to get industry buy-in and to help facilitate continued recording
- Demonstration of the value of selection and genetic improvement in the trait of interest to commercial producers and breeders was important to get industry buy-in

3.4 UK Industry consultations

The industry consultations raised a number of important considerations relating to developing recording programmes that could be feasible in the UK and would likely gain strong industry support. The main points are shown below in three main categories: general comments, those relating to recording and industry uptake:

General

- There was strong support and agreement that achieving genetic improvement in feed efficiency in UK cattle beef cattle was important – especially in view of increasing feed costs
- It would be important to have a clear definition of an appropriate measure of feed efficiency and how to record it to minimise confusion (some confusion at present)
- The levy bodies would be in favour of an initiative that would involve recording animals from more than one breed. Providing technical and financial support would be difficult to justify if benefits were only delivered to one breed
- Breed societies would be keen to work together provided breed specific information/data remained confidential to the breed
- Although there is a strong interest from the breed societies in participating in recording; large scale recording

would be unlikely to be established in the UK unless non-industry funding was available, at least to help start any initiative

- Contract finishing enterprises were not common in the UK but one had been recently established by Adam Quinney and Arrow Valley Farmers which was linked to ABP and ASDA. The unit is currently focused on mostly finishing young bulls over a four month period. Animals are housed in groups of 20 with feed intake recorded for each group. The total capacity for the unit is around 340 animals per batch (a more detailed overview is shown in Appendix 2)
- Only one industry-led, individual feed intake recording facility is currently operating in the UK. The unit was established in 2012 and is run by BIG, solely focussing on recording feed intake in the Stabiliser breed, mostly testing young bulls (a more detailed overview is shown in Appendix 2)

Recording

- Ensuring high bio-security would be vital if pure-bred animals were being recorded
- Removing young bulls from the pedigree herd would not generally be popular as it could be disrupting to the current management systems used by breeders
- Recording pure-bred animals not destined for breeding may be a good option, but sourcing high numbers may be a challenge
- Recording feed intake on crossbreds would be one way of getting more cattle
- Adapting commercial finishing units was seen as a good way of reducing costs of recording
- Ensuring good balance of families/sires/herds in each recording batch was likely to be a challenge – good coordination and strong buy-in from breeders and producers would be vital
- Developing more structured programmes such as that used by ICBF as part of the G€N€ IR€LAND programme could have a big effect on ensuring a good supply of cattle and data structure but would likely add to the overall cost

Industry uptake

- Reducing GHG emissions was considered strategically important by industry leaders, but it was not seen as high priority by individual breeders and producers as it was currently not a commercial driver
- It would be important to demonstrate the economic value of in terms of reducing feed costs and of using high genetic merit bulls to help encourage uptake and increase overall impact
- Having a demonstration unit that producers could visit would be very helpful to support Knowledge Transfer and promote uptake
- A strong and coordinated Knowledge Transfer initiative would be needed to help promote the value of any new measures to breeders and producers

3.5 Modelling the potential impacts

The results of the modelling are described in full in Appendix 3.

The likely impacts over a 20 year time horizon at a UK beef industry level of selecting for 10 years purebred animals based on the Beef Value index and four alternative indices are shown in Table 2. Impacts are quantified in terms of overall GHG reduction, the economic value of that GHG reduction, the expected increase in profit at the farm level and the cumulative economic benefit.

The results suggest that selecting animals solely based on the value for the current Beef Value index, could result in an increase in profit at the industry level of nearly £31M, with an additional benefit in terms of GHG reduction of CO_2 equivalent of 725.620 k tonnes which, given the projected shadow price of carbon, would have an economic value of around £25M, proving a cumulative total return of around £56.8M.

In deriving these numbers it was assumed that a selection intensity of 0.1 was applied, but even at a lower selection intensity of 0.2, predicted returns were still £24.6M and £20.6M respectively, with a cumulative value of around £45.2M. Including $RFI_{pw\text{-}fat}$ solely a trait in the breeding goal (with selection pressure being applied through correlations with other recorded traits) had only a small effect on the projected cumulative returns. Substantially larger increases were predicted when $RFI_{pw\text{-}fat}$ was also recorded, increasing farm level profit by 39% and GHG reductions by 22%, with a cumulative value of between £14.2M and £17.8M. Also recording carcass traits provided a dramatic increase in overall returns by around 74% relative to the base level in both profit and GHG reduction, with a cumulative value of between £33M and £42M depending on the selection intensity applied.

Changing the economic values and index weights to focus more heavily on GHG reduction, provided only a small benefit in terms of reducing emissions (1-2%) and was achieved at the expense of a small reduction in farm level profit (~3%). This suggest that most of the potential benefits in reducing GHG can be achieved through genetic improvement can be gained by having a primary focus on improving farm level profit when a measure of feed efficiency is included in the breeding goal. Given the economic loss at the farm level of adopting these alternative index weights, it would likely require financial incentives to stimulate industry uptake and use. As only small additional benefits in GHG reduction were predicted, any such approach if solely focused on simply stimulating the use of any of these alternative indices would not be cost effective.

Added benefits through selection on dams

For the earlier index scenarios we assumed that genetic improvement was only effected through a selection intensity being applied to bulls. In practice it is reasonable to assume that some use of index values will also be made in selecting breeding females as replacements in the pure-bred herds. By adding only a small selection intensity on the females of 0.8, the overall impact at the farm level profit and in reducing emissions was increased by around 15% (Table 3).

Table 2: The expected industry level impact of selecting breeding bulls based on the current Beef Value index and the likely benefits of including RFI in the selection goal, recording RFI and recording carcass traits

	Index scenario				
	1 (Current)	**2**	**3**	**4**	**5**
Recorded					
Standard BV traits *	✓	✓	✓	✓	✓
RFI_{pw-fat}			✓	✓	✓
Carcass Weight					✓
Carcass Fat Score					✓
Carcass Conformation Score					✓
Traits in the breeding goal					
Carcass Weight	✓	✓	✓	✓	✓
Carcass Fat Score	✓	✓	✓	✓	✓
Carcass Conformation Score	✓	✓	✓	✓	✓
Gestation Length (direct)	✓	✓	✓	✓	✓
Calving Difficulty (direct)	✓	✓	✓	✓	✓
RFI_{pw-fat}		✓		✓	✓
Selection intensity 0.1					
GHG reduction (kt CO_2 eq.)	725.62	733.07	798.49	884.02	1,254.86
Industry (£ M CO_2 eq. at SPC)	25.88	+0.27	+2.56	+5.65	+18.88
Industry (Farm Profit £ M)	30.92	+1.44	+7.32	+12.15	+23.09
Cumulative benefit (£ M)	**56.80**	**+1.71**	**+9.88**	**+17.80**	**+41.97**
Selection intensity 0.2					
GHG reduction (kt CO_2 eq.)	578.24	584.18	636.30	704.47	999.98
Industry (£ M CO_2 eq. at SPC)	20.62	+0.21	+2.07	+4.50	+15.04
Industry (Farm Profit £ M)	24.64	+1.15	+5.84	+9.69	+18.40
Cumulative benefit (£ M)	**45.26**	**+1.36**	**+7.91**	**+14.19**	**+33.44**
% improvement relative to current expected					
Industry (CO_2 eq. at SPC)		1%	10%	22%	73%
Industry (Farm Profit)		5%	24%	39%	75%

**Standard traits included in the Beef Value (index BV) are birth weight , weight at 200 and 400 days of age, muscle score, fat depth, muscle depth, gestation length and calving difficulty*

Table 3: The impact of the breeding programme with records on RFI and carcass traits when selection intensity applied to bulls is 0.1, plus the added benefit of a selection intensity of 0.8 in females, when 50% or 90% of bulls used at the commercial level are from recorded herds

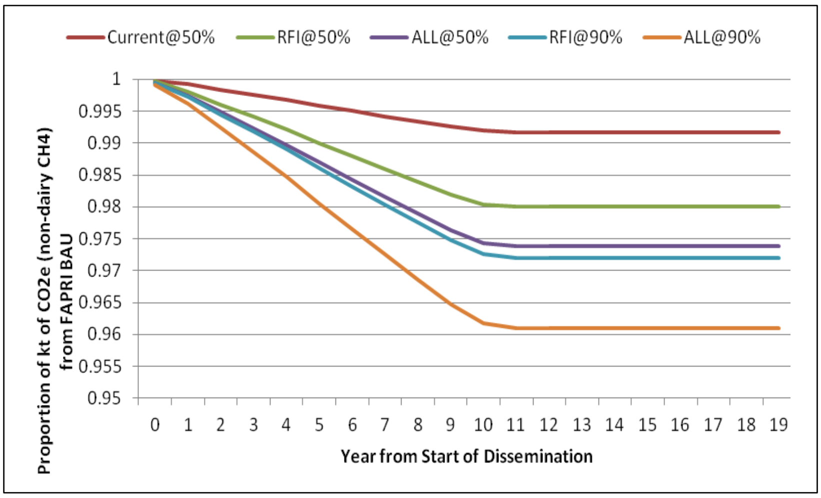
% use of recorded bulls	Benefit	Current + RFI	+Female genetic improvement	Current + RFI + Carcass	+Female genetic improvement
50%	Industry (£ M CO_2 eq. at SPC)	£31.53	£37.59	£44.76	£51.02
	Industry (Farm Profit £ M)	£43.06	£51.55	£54.01	£60.58
	Cumulative benefit (£ M)	£74.59	£89.14	£98.77	£111.60
90%	Industry (£ M CO_2 eq. at SPC)	£79.25	£94.37	£112.52	£128.07
	Industry (Farm Profit £ M)	£108.53	£127.83	£134.31	£150.21
	Cumulative benefit (£ M)	£187.78	£222.20	£246.83	£278.28

Changes in level of use of recorded bulls in commercial herds

Increasing the level of use of recorded bulls in commercial herds had a dramatic effect on industry level impacts (Table 3). Projected returns, both in terms of increased farm level profit and reduced GHG emissions more than doubled when the level of uptake was increased from 50-90%. It is acknowledged that it would take time to increase the number of herds recording to meet the demand for bulls if such a change were to be achieved. However, it does demonstrate the value and impact both in terms of increasing profit and reducing GHG emissions that increasing the level of recording and selection primarily on a selection index in purebred herds could have. Increasing the level of recording and use of above average indexed bulls in the commercial herd by even a small amount could deliver potentially large returns.

The expected impact on GHG emissions relative to the current FAPRI-model based line, of 10 years of selection using the current Beef Value index and that with RFI or RFI and carcass records included at a 50% and 90% uptake level are shown in Figures 1 and 2. The results are expressed at a population level in Figure 1 and relative to the total weight of beef produced in Figure 2.

Figure 1: The amount of GHG abated due to alternative beef genetic improvement strategies at a population level relative to the FAPRI baseline

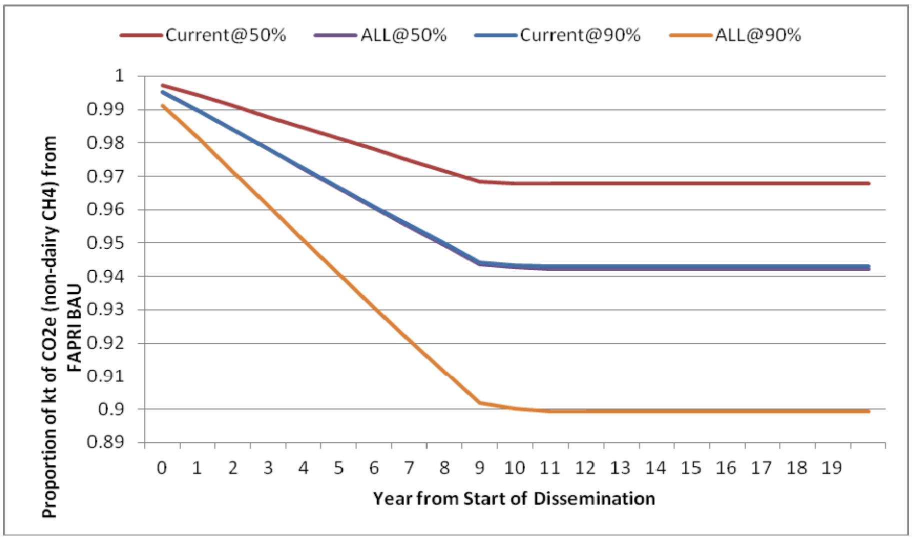


We can see from Figure 1 that in comparison to the baseline, genetic improvement – as currently performed – will reduce expected GHG emissions in future. This is not generally captured in the FAPRI-UK business as usual baseline as that assumes status quo in terms of management and performance and therefore does not include ongoing genetic improvement.

The Climate Change Act requires that greenhouse gas emissions are reduced by at least 80% below base year (2010 inventory) levels by 2050 (equivalent to 154.2 $MtCO_2$ eq. on the basis of the 2010 inventory). Over the entire economy and the different carbon budget periods this is made up of a 22% reduction by budget period 2008-12, 28% reduction by period 2013-17, 34% reduction by period 2018-22 and 49% reduction by 2023-27 – the fourth carbon budget period. Agriculture does not have set reductions targets in place, however, it is hoped that agriculture reductions will be achieved via voluntary measures through the uptake of the Agriculture Industry Plan (England) and Farming for a Better Climate (Scotland).

The best genetic improvement scenario in beef would reduce the total GHG emissions by 4%, which is 12% of the GHG reduction target for the third carbon budget period (2022). It is important to note that this is relative to inventory methodology based on animal numbers. Therefore, some of the reduction is due

Figure 2: The amount of GHG abated due to alternative beef genetic improvement strategies relative to the total amount of beef produced (including genetic improvement in carcass weight) at a population level relative to the FAPRI baseline, akin to reduction in emissions intensity*



**Projected values for all 50% and current 90% are very similar and do not appear as separate on this graph* to a simple projected fall in the numbers of animals (considered in the FRAPRI-UK baseline of comparison). However, many of the agricultural industry plans (and Scottish Govt) focus of improvements in efficiency of the systems of production rather than a simple reduction in agricultural activity. In this scenario, the reductions should be expressed per tonne of output from the different agricultural activities (Figure 2). In this scenario the potential emissions savings are much higher with a reduction in the emissions intensity compared to the FAPRI emissions intensity baseline of 10% - almost 30% of the reduction targets by the third carbon budget reporting period. However, capturing the value of this benefit would require a change to the reporting of GHG emissions from agriculture.

It is important to point out that in both figures the starting point is year 0 of dissemination, which effectively assumes that at that point recording of both RFI and carcass traits is at a steady state within the population, and in the case of changing the uptake level, there are sufficient numbers of herds recording to meet the demand. These graphs do not take account of the likely time lag associated with setting up recording of a new trait and generating a high number of records was not taken into account, nor increasing the number of herds recording. Expressing the results relative to a starting point for any new initiative would introduce a time lag into these impacts being seen.

Numbers of animals required to estimate genetic parameters

As a general rule of thumb, the minimum requirement for good genetic parameters is that the estimates are significantly different from 0 i.e. the standard error is less than twice the difference between the estimate and zero. Where a trait is to be included in a multi-trait breeding goal, good estimates of correlations with other traits as well as the heritability are also needed. The number of recorded animals required to derive 'good' genetic parameters is dependent on a number of factors, including:

1) The heritability of the trait being considered
2) The likely size of correlations with other traits of interest and the heritability of those traits
3) The structure of the data e.g. the number of different groups being recorded, the size of those groups, location, difference in management and feeding between them, genetic linkages between the recorded groups etc.
4) The numbers of sires that are represented in the recorded population

Based on the estimates published in literature, it is clear that depending on which measure of feed efficiency was chosen, the heritability and correlation with other traits of interest would vary. As a result it is difficult to deduce the exact numbers of records that would be required to generate good genetic parameters (at least without a detailed simulation study which was outside the scope of this project). However it is possible to make some approximations. If we assume (as for part one), that the main trait of interest is $RFI_{pw\text{-}fat}$, with a likely heritability of around 0.3, and all animals are recorded in one group and at one time, with very consistent recording protocols and very homogeneous background effects, then the minimum number of recorded animals needed to derive just a heritability estimate that is significantly different from zero would be around 500. If the number of sires represented in the data varied e.g. reduced from 100 to 50, the total number of animals needed is not reduced as the number of progeny required per sire would increase. Higher numbers would be needed to obtain good estimates of genetic correlations with other traits, particularly were those estimates were expected to be in the region of 0.1-0.2 as in the case of a measure such as $RFI_{pw\text{-}fat}$.

Given that genetic correlations with other recorded traits of interest would be expected to be low for a measure of $RFI_{pw\text{-}fat}$, and that recording would likely to be done in a number of batches, from animals born to dams of different ages, with different management backgrounds; the numbers of animals required in practice to get good genetic parameters is likely to be at least **1500-2000**.

It should be noted that these estimates of numbers are based on individuals being selected at random from the population for recording (progeny groups of representative sires in the wider population). These numbers would decrease slightly if prior information was used to select progeny from sires that were genetically diverse for the target trait(s).

Numbers required after the establishment phase

Once genetic parameters have been estimated, more records still need to be collected on an on-going basis in order to derive EBVs with good accuracy, especially for young bulls that are candidates for breeding.

The accuracy of an estimated breeding value is a function of the type of information that is being used to predict the genetic worth of an individual. This information can come from ancestors (pedigree index), its own record, records from siblings, progeny or more distant relatives/descendents – the more information you have the higher the accuracy. Obviously the higher the accuracy, the more confident we can be that the estimate is a true reflection of the animal's genetic merit. It follows that the lower the accuracy the more risk is being taken in using that bull as part of a breeding programme. Although there are no hard and fast rules, when a moderate amount of risk is considered acceptable, an accuracy of around 0.60 is generally considered a good threshold above which to select young bulls for use. If the trait in the breeding goal was $RFI_{pw\text{-}fat}$ in purebred animals, then such a target could be achieved if feed intake had been recorded on the animal itself and a small number of other relatives e.g. sire. However as we will discuss later, if the breeding goal is $RFI_{pw\text{-}fat}$ in crossbred progeny, then a genetic correlation of one between RFI measured in purebreds and crossbreds cannot be assumed. If the genetic correlation was less than one, the accuracy expected from the availability of such information would be reduced. Where records are directly recorded on crossbred progeny the trait of interest would be recorded directly. Where only progeny are recorded (akin to a progeny test scheme) around 15-20 progeny would be needed to achieve a target of around 0.6 if we assume little or no added information is being gained by having records on other correlated traits.

Recording purebred vs. crossbreds

When considering which animals to record individual feed intake on, one aspect to consider is the relative merit of recording purebred versus crossbred progeny. To help answer that question it is first important to define the measure of efficiency that is in the breeding objective. In the majority of beef breeding programmes the main objective is to improve performance (e.g. in terms of improving profit or reducing GHG emissions) of animals at the commercial farm level. Ideally the measures of feed efficiency chosen would be measured on animals that are typically used at the commercial level. Where purebred animals are used in commercial herds, as is common in some counties and for some breeds (e.g. Stabalisers), then measurements taken in purebred breeding can be assumed to have a genetic correlation of 1 with the same traits in the commercial herds, and a record on the animal itself will be equivalent to records on around 10-15 progeny. When the majority of commercial herds are crossbreds, as is most common in the UK, the most appropriate measure to include in the breeding objective would be feed efficacy in crossbred animals, and correlation of 1 with the same measurements taken on purebreds cannot be assumed.

Published estimates of the genetic correlation between purebred and crossbred performance are typically less than 0.7. In Table 4 we see that when the genetic correlation between purebred performance in 0.7 and the breeding goal includes $RFI_{pw\text{-}fat}$ measured in crossbred animals, only recording RFI in purebred animals would reduce the expected selection response by around 25%. Including records on five paternal half sibs has little impact. Where the number of feed intake recording places is limited, the recording of purebred animals may seem like an attractive option in so far that fewer animals would need to be recorded and records would be available for a bull at a younger age. However, these results help highlight two important considerations. The first is that recording feed intake only on selection candidates will result in a lower accuracy compared to recording a number of crossbred progeny. The other is that if only purebred animals were to be recorded, it would be important to collect records directly on selection candidates as the value of records from paternal half sibs is low. If only purebred animals were to be recorded and RFI in crossbred was in the breeding objectives, ideally data would need to be collected first to allow the correlation between purebred and crossbred records to be estimated. Obviously the ideal scenario would be that records were collected both on the selection candidates themselves and their crossbred progeny, but this option would likely be more expensive. The results in Table 4 only consider the effects when selection is done on an index of beef value traits and RFI. The difference between purebred and crossbred information would be expected to be even greater if records on carcass traits were also considered, especially given that it would be very difficult to collect carcass records on the purebred bulls.

Table 4: Expected impacts on index accuracy and selection responses in the purebred population from selecting on an index including beef value traits and RFI (selection intensity 0.1) and RFI is recorded on different animals, when the genetic correlation between RFI in purebred and crossbred animals is 0.7*

		Scenario		
		1	2	3
Recorded	Animal itself (purebred)		✓	✓
	5 parental purebred half sibs			✓
	10-15 crossbred progeny	✓		
Selection responses	Economic	2.95	2.15 (72%)*	2.19 (74%)
	Reducing GHG	23.42	17.64 (75%)	17.84 (76%)
	Index Accuracy	0.67	0.49 (73%)	0.49(73%)

**Values expressed as a % of that achieved with crossbred records is shown in brackets*

Number of bulls and progeny to test

Ideally feed intake records would be available for all selection candidates, either on themselves, their progeny or both. In reality, given the expense involved with recording, it will likely only be possible to collect records for a proportion of the bulls of interest. The optimum number of bulls to evaluate will depend on a wide number of factors, and as a result to develop detailed recommendations would therefore require a large simulation study to be conducted, which was beyond the resources available for this study. However it was possible to also investigate the likely impact on selection responses of changing the numbers and type of animals recorded, to help further inform the assessment of the relative merits of the different recording options under consideration.

Table 5: Proportional (%) change in selection responses in the pedigree population (relative to testing ~250*), when then the numbers of new bulls tested (for RFI) are varied

	No bulls tested per yr	N~50	N~150	N~250	N~400	N~600	N~800
	Selection Intensity	0.4	0.2	0.1	0.05	0.01	0.005
Selection response	Economic	-45.0	-20.3	0	17.7	52.7	66.0
	GHG reduction	-45.0	-20.3	0	17.7	52.7	66.0

**Testing around 250 bulls per year is similar to the selection intensity of 0.1 shown in Table 2*

Given a limited number of testing places, one consideration is the ratio of bulls to test *versus* number of progeny per bull, and it was possible to draw some conclusions about their relative merits in this study. The results in Table 5 show that reducing the number of bulls tested per year does have a fairly dramatic effect on the selection response, however in contrast the effect of reducing the number of progeny per bull is less (Table 6). However it is important to note that the results in Table 6 are based on the assumption that all progeny are tested in one batch along with the progeny of all other bulls. If the progeny are tested in different batches and at different times, the number of animals required would increase.

Table 6: Impact of increasing the number of crossbred progeny tested per sire

	% change relative to n=15					
Selection response	n=5	n=10	n=15	n=20	n=25	n=30
Economic	-7.7	-2.9	0	1.9	3.3	4.3
GHG reduction	-3.5	-1.3	0	0.9	1.6	2.1
Index Accuracy	-7.7	-2.9	0	1.9	3.3	4.3

3.6 Evaluation of feasible options for recording cattle

Following the outputs from the review of literature and stakeholder consultations a total of six different feasible options for recording feed intake in beef cattle in the UK were identified, namely:

- Academic led and managed recording of: a) purebred cattle or b) crossbred cattle
- Industry led and managed recording (own facilities) of: a) purebred cattle or b) crossbred cattle
- Industry led, subcontracted recording of: a) purebred cattle or b) crossbred cattle

The pros and cons related to each option were assessed, along with a similar assessment of recording young bulls versus steers/heifers. An assessment of the likely economic costs associated with each of the six main options was also conducted. Finally a summary was produced highlighting the relative advantages and disadvantages of each system.

Different options for recording:

Academic led and managed recording:

Pros
- Once established, would likely deliver a high standard of recording
- Could deliver added value information such as GHG emissions, product quality and behaviour/welfare traits and new recording tools to reduce future costs
- Independence from those that profit from the sales of the improved animals

Cons
- Establishment and running costs likely to be higher compared to other options
- Industry would not take ownership over the initiative and help drive it

Industry led and managed recording (via own facilities):

Pros
- Likely to achieve the greatest sense of industry ownership – especially if the main breed societies take a leading role in running this option
- Would potentially provide the largest legacy in so far that there would be a dedicated facility that would be available for use after any establishment phase would have been completed

Cons
- Initial establishment costs would likely be high if new facilities needed to be built
- Hard to get full across industry representation and could therefore lead to "them and us" culture

Industry led and subcontracted recording:

Pros
- Industry ownership delivered through the breed societies leading this option
- Establishment and running costs likely to be lower compared to other options

Cons
- Less control over recording done

Recording purebred vs. crossbred animals

Recording Purebred

Pros
- EBVs available at younger ages for pedigree animals
- Lower numbers required
- Useful information provided through dams to increase the accuracy of genetic evaluations

Cons
- High health status required - due to high value animals form different farms being brought together
- Limited carcass data on tested animals as slaughter may not be an option in most circumstances
- Not ideal as a demonstration model for many commercial producers
- Potential for some resistance from breeders to send in their high value bulls due to bio-security concerns
- Potential for some resistance from breeders to send in their high value bulls in case they get a low EBV
- Sourcing enough animals close to a recording facility may be difficult – higher transport cost

Recording Crossbreds

Pros
- Lower bio-security concerns
- Easier to collect carcass data on tested animals
- Would potentially allow recording and monitoring of meat quality traits to asses relationships with measures of Feed use efficiency
- Good demonstration model for the beef industry
- More suitable for recording as part of a commercial finishing system
- More scope to minimise pre-test variation in management and feeding
- Concerns of purebred breeds less on a potential barrier to maintaining good throughputs on recording sites
- Sourcing enough animals close to a facility may be easier

Cons
- Longer delay until EBVs available at younger ages for pedigree animals
- Little or no useful information provided through dams to increase the accuracy of genetic evaluations

Recording Bulls vs. Steers/Heifers

Bulls

Pros
- Would likely allow FI recording close to post weaning ages and then slaughtered at the end
- Best suited to commercial indoor finishing system

Cons
- More difficult to manage as they get older
- Potentially less useful as a demonstration model for UK industry compared to steers and heifers

Steers/Heifers

Pros
- Better demonstration model for the UK industry than young bulls
- Due to need to delay recording age if destined for slaughter, could potentially be useful to increase throughput through recording facilities
- Potentially more easy to source out-with a structured programme

Cons
- Would likely need feed intake recording at ages >12 months if animals were to be slaughtered at the end of test
- Longer delay to records becoming available
- Management of the overall programme potentially more difficult due to longer timescales
- Potentially more variation in slaughter end points

3.7 Economics of the different options

A detailed description of the estimated costs involved in the setup and running of a project of the scale and duration to deliver a real outcome is provided in Appendix 4 and summarised in Table 7. The costs are split into the capital and non-capital costs associated with setting up the facilities and recording 1800 animals (over 2 years), and then the ongoing costs of running the facilities and recording 900 animals per year thereafter. The total costs as well as the cost per animal are provided.

3.8 Summary

A summary of the relative advantages and disadvantages of the six systems considered in this report is shown in Table 8. Each system is given a mark again the different aspects considered and the total of all the marks provides an indication of the relative suitability of each system in terms of costs, benefits, feasibility and long term impact. A higher total score indicates a greater suitability for that system.

Table 7: Summary of costs for each option

Cost Heading	Cost Requirements per System						
	Academic led and recorded		Industry led - own recording facilities		Industry led - subcontracted recording		
	Pure-bred	Cross-bred	Pure-bred	Cross-bred	Pure-bred	Cross-bred	Cross-bred (producer owned cattle)
Setup costs to record 1800 animals over 2 years							
Capital cost (per facility)	£900,000	£900,000	£750,000	£750,000	£410,000	£410,000	£410,000
Non-capital cost (2 years)	£1,572,000	£915,000	£1,342,000	£685,000	£1,519,200	£889,200	£315,000
Total setup cost	£2,472,000	£1,815,000	£2,092,000	£1,435,000	£1,929,200	£1,299,200	£725,000
Setup cost/animal	**£1,373**	**£1,008**	**£1,162**	**£797**	**£1,072**	**£722**	**£403**
Ongoing costs to record 900 animals per year							
Ongoing cost (per year)	£746,250	£417,750	£631,250	£302,750	£719,850	£404,850	£117,750
Ongoing cost/animal	**£829**	**£464**	**£701**	**£336**	**£800**	**£450**	**£131**

Table 8: Evaluation of different options for recording cattle

Aspects to be considered	Academic led and recorded		Industry led – own recording facilities		Industry led – subcontracted recording		
	Pure-bred	Cross-bred	Pure-bred	Cross-bred	Pure-bred	Cross-bred	Cross-bred (producer owned cattle)
Quality of data recorded	3	3	2	2	2	2	2
Industry acceptance	2	3	2	3	2	3	3
Practicality	2	1	2	3	1	3	3
Demonstration value	1	2	2	3	2	3	3
Relative benefits (GHG red and profit) over 10 years	2	1	2	1	2	1	1
Relative benefits (GHG red and profit) over 20 years	1	3	1	3	1	3	3
Set up cost (Capital)	-3	-3	-2	-2	-1	-1	-1
Set up cost (Non capital)	-3	-2	-3	-2	-3	-2	-1
Relative annual running costs after set up (per animal tested)	-3	-2	-3	-2	-3	-2	-1
Legacy value	1	1	3	3	2	2	2
Total	**3**	**7**	**6**	**12**	**5**	**12**	**14**

Each option is ranked on a scale of 1-3, where 1=low, 2=medium and 3=high. Scores with a minus sign indicate a negative criterion e.g. costs. An overview of the assumptions made as part of this evaluation is shown in Appendix 4.

4. Discussion

Due to the difficulty and cost associated with recording individual feed intake, it highly unlikely that deriving feed efficiency records for a very high number of cattle would be cost effective in the UK. However, the results of this study show that testing only a relatively small proportion of the purebred bulls per year (either directly or on their crossbred progeny) could potentially deliver a big impact which would be increased even further if carcass records were also collected.

In reality the predicted impacts from improving feed efficiency reported here are likely to be an underestimate of the true value that could be gained as likely correlated improvements in feed efficiency of the breeding cow was not included. Although the magnitude of the correlation is unclear, there is strong evidence from literature that there is a positive relationship between RFI measured post weaning and in the mature cow. Given that terminal sire breeds in the UK account for a high proportion of the genes of replacement females as well as slaughter progeny, this positive association could confer a substantial additional benefit given that the maintenance of the cow accounts for a high proportion of the overall costs and environmental burden of beef production.

Measures of feed efficiency

The results of the literature review and the international consultations has helped to highlight that there is not yet a clear consensus regarding the best measure of feed efficiency to use in selection programmes for beef cattle. Consequently there is a high potential for confusion and a lack of industry understanding and uptake as a result. The establishment of agreed industry standards for both recording (that take account of typical management practices in the UK) and presentation of results would be a very important step if recording of feed intake was to be undertaken on a large scale in the UK. Developing agreed standards for presentation of results would help greatly reduce potential confusion amongst commercial producers and breeders, especially given that some breeders may be involved in the breeding of more than on breed of cattle. It would also greatly simplify knowledge transfer and promotion across all breeds, and allow the levy bodies to more easily take a role in knowledge transfer and promotion across all breeds. The development of industry standards would also facilitate the potential for collaborations between breeds with the aim of reducing overall recording costs.

Recording Crossbred vs pure-bred and the practicality of a two stage selection approach

The recording of feed intake on purebred animals is an attractive option in so far that in theory fewer animals would need to be tested and EBVs for feed efficiency would be available at a younger age. However, the results of this study suggest that for the five main breeds considered, it is unlikely that a high number of breeders will be willing to send their young bulls to a central test facility, which in turn may have a negative effect on the throughput and overall impact that could be achieved. By focusing only on recording purebred animals, it would also not be possible to directly record carcass traits, which was shown to deliver a large additional benefit. The recording of purebred half sibs destined for slaughter may be possible for some breeds, but this may be of little value if the breeding goal includes feed efficiency in crossbred progeny, which seems most appropriate for most of the breeds considered here. Given that the selection of which animals to retain or sell as breeding bulls and which to slaughter may be done only at weaning within a purebred herd, if pure bred animals were to be used, it may also be important to minimise any potential bias through preferential treatment of some animals prior to entering the feed intake testing e.g. through access to concentrates pre weaning, as this would further dilute the value of the data being collected. Potential bias due to preferential treatment of some animals prior to test would need to be a consideration in all the options considered. Although difficult to control when testing purebred sourced from a number of different farms, more control would be possible as part of a well managed structured programme focused on producing crossbred progeny from high merit sires for the purposes for testing.

Recording feed intake directly on crossbred progeny would overcome any concerns regarding potential genetic differences between feed efficiency in purebred and commercial animals. Adopting this approach would introduce a delay in EBVs with good accuracies being available for bulls and, given a fixed number of test places, would reduce the total number of bulls for which high accuracy EBVs could be generated. However, the additional benefit delivered through being able to directly record carcass traits as part of a structured programme would likely offset these negative aspects whilst also greatly simplifying the management of the recording process. The ability to slaughter tested animals could also potentially allow data on meat quality traits to be collected, thus allowing monitoring on potential negative effect or even generate data for a more in-depth research study. Although commercial producers do not currently receive direct payments for high meat quality in the UK, it is considered a very important characteristic of beef from UK cattle. Based on results published in literature, any negative effects of selection on measured of feed use efficiency on meat quality, even if present, are likely to be small. However, any uncertainty could have a negative effect on industry uptake and acceptance of selection for improved feed use efficiency. Such a project could play an important role in addressing any such concerns.

Recording feed intake on crossbred animals also provides a number of other important benefits. It would reduce the complexity involved with maintaining a very high health status within the units, be more useful as a demonstration facility for commercial producers and also makes it more feasible to consider sub-contracting of the recording, which as we will discuss later could provide a means of dramatically reducing the overall recording costs. From a demonstration viewpoint recording feed intake on steers and heifers would be better as they account for a substantially higher proportion of the slaughter animals in the UK compared to young bulls. However, the recording of young bulls would provide numerous practical advantages and allow accurate EBVs to be generated earlier for the sires. Given the important placed on demonstrating the benefit of selection to commercial producers in a relevant management systems as part of the industry consultation, it would be important to establish whether demonstration of sire differences when progeny are finished as young bulls would be accepted by the majority of producers are being relevant to their own production systems.

Two stage selection

Given the low genetic correlations with other recorded traits, use of feed efficiency measures such as RFI also provides an additional challenge with regards to dissemination, in that EBVs with reasonable accuracies would only be generated for recorded animals, their parents and a relatively small number of other close relatives. EBVs with higher accuracies on more relatives should be possible if the target trait was feed intake itself, due to its high genetic correlation with other measured traits, particularly related to growth traits. But even then, it would be difficult and expensive to generate good EBV with good accuracies for a large proportion of the bulls that would be offered for sale to commercial producers.

Once genetic parameters had been estimated, to deliver a high impact, feed intake recording would therefore likely need to be targeted at differentiating between high index bulls followed by encouraging the use of the highest ranking bulls within the elite purebred herds. As part of the previous index comparison work it was assumed that around 15 progeny for each of around 250 bulls were tested, equating to around 3750 animals being tested each year, but it was assumed that the bulls to test were not pre-selected on the Beef Value index. In practice the most appropriate method to use would likely be a two stage selection approach where bulls whose progeny are to be tested are pre-selected either on their own feed intake records or on their Beef Value index. If managed effectively, such an approach could be quite powerful, despite the relatively small number of bulls that were being tested. For example in the Limousin breed analysis of the pedigree for bull calves bulls born or registered in 2011 reveals that around 225 of the bulls used (15% of the total) are the sires of around 50% of the bull calves being produced each year. Assuming that index values play an important part choosing these sires then it offers a realistic opportunity to deliver real gains. Such an approach could be further strengthened through a coordinated marketing and promotion approach for high merit bulls evaluated for feed efficacy in addition to other traits, such as that currently being rolled out in Ireland. A further, more detailed investigation of the likely benefit of a two stage selection approach would be needed for this to be confirmed and to ascertain the number of bulls that would likely need to be tested to achieve the same selection response as shown in Table 5.

Options for recording

Given the desire to establish a recording platform that would deliver a large overall impact, have strong industry support and provide a strong platform for on-going activity, amongst the options considered, the recording of crossbred cattle as part of an industry led initiative, either through their own managed facilities or as part of subcontracted activity, were seen as likely to provide the best option for the UK industry. Its important to note the development of automated recording systems such as the GrowSafe units which require a lower labour and technical input, has allowed these options to be more feasible. In both cases it would seem important for the breed societies to play a strong sole in any initiative, but it would also be important to ensure that at least some level of scientific support would be provided through academic advisors with a good knowledge of the area.

The building of one or more dedicated facilities which were then managed by an industry group would likely provide the strongest platform for continued activity, especially if the industry groups involved had provided some level of financial support to its establishment. Given that contract finishing systems are not commonly operating in the UK, it may be difficult to find enough facilities wishing to undertake subcontracted recording. However, the results suggest that if possible, this would provide a lower cost option potentially both in terms of set-up and subsequent running costs. Under such a model we would envisage the subcontract would be issued by an industry steering group that involved one or more breed societies and other industry stakeholders and would be done under licence or as part of an approval scheme with recording being done as set out in the agreed industry standards. To reduce set up costs and risk for the subcontractor, the GrowSafe units could be purchased and owned by the industry steering group and leased to the unit for the duration of the subcontract. The sourcing of animals would be coordinated by the industry steering group and a minimum throughput guaranteed as part of the contract. Such an arrangement would provide clear benefits for the subcontractor in being able to maintain high throughputs, but would also have clear benefits for the industry stakeholders in reducing initial setup costs and potentially better prediction of on-going costs.

One variation also considered as part of this study was the option of the commercial producers retaining ownership of the crossbred animals and paying for the finishing costs, which is similar to the model currently used at the Arrow Valley farmers unit. This option would essentially involve a sharing of risk across more industry stakeholders and thus lower recording costs per animals for the industry steering group. As part of the costings derived in this study it was assumed that an incentive payment of £75 per animal was needed to ensure that producers participated in any scheme modelled on this option (which included a potential discount for semen from young bulls of interest). If this payment was not needed the obviously the cost associated with this option would be lower. Whilst this option would require more coordination activity it is worth noting that it does have similarities with the current integrated finishing model that is currently being successfully run by Blade Farming (see more details in Appendix 2). Whilst the costs assumed here may be far too simplistic, it would be worth investigating the feasibility of this option further.

Although potentially resulting in higher quality data being collected, the option of the academic run facilities would likely be less suitable in the long term due mainly to higher expected running costs. However it was assumed in deriving these costs that it would be necessary to build new facilities. In reality there are a number of recording facilities owned by academic institutions that could offer some recording capacity if not fully occupied as part of research projects. An overview of the facilities available is provided in Table 9. Whilst the on-going running costs may still be higher than for the industry led options considered, it would be worth investigating further if these facilities could be used to increase total capacity during any set up phase, thus allowing a reduction in the time needed to generate enough data to estimate genetic parameters, but without incurring the additional cost associated with building more recording facilities that may not be fully need once the set up phase was complete.

Added value for evaluating and validating genomic panels

Based on the results of the literature review, it appears that robust genomic panels that can be used to consistently predict a substantial proportion of the genetic variation across breed in one or more of the economically important traits beef cattle are not currently available. However, the use of genomic tools is still expected in time to provide a very useful tool to genetic improvement programmes for many traits of interest in beef cattle, including feed efficiency measures. These tools are likely to be of most value when used as part of genomic selection or marker assisted selection approaches in structured breeding programmes. It is important to point out that use of such genomic panels will only be possible in populations which have records on the traits of interest and DNA on the recorded animals have been collected as part of a well-structured recording programme, as data will be needed to either train the genomic panels used as part of genomic selection approaches, or to validate panels are part of a marker assisted approach. Providided DNA is collected on the crossbred animals tested and on their sires, the data collected as part of an initiative focused on recording feed intake and carcass traits could provide a valuable resource that may be used for this purpose. If well structured, it could provide that data that could potentially also be used to allow the UK to participate in international collaborative project that are focused on harnessing the value of genomics to maximise the impact in the national herds of each participating county.

Table 9: Recording facilities currently available in GB academic institutions

Organisation	*Main facilities*
IBERS, Aberystwyth	50 feed intake bins providing total capacity per batch of between 100-150 animals, housed in groups of 10
SAC, Edinburgh	44 HOKO feeders providing a total capacity per batch of around 100
University of Reading	Beef unit is fitted with Calan gates that provide the capacity to record feed intake for 48 animals per batch (6 groups of 8 in total)
University of Nottingham	Unit fitted with Calan gates that provide the capacity to record feed intake for 50 animals per batch (10 groups of five)

Increasing the uptake of recording bulls in commercial herds

The results of this study suggest that increasing the level of use of high merit recorded bulls in commercial herds from 50 to 90% could have a dramatic effect on the overall benefits from selection, more than doubling the impact currently predicted in both farm level profit and in GHG reduction from using existing selection tools and even more than doubling the increased impact expected when feed intake and carcass traits were also recorded. If a new initiative focused on recording feed intake and carcass traits were set up that also provided an excellent demonstration facility, it is possible that at least a small increase in industry uptake could be achieved, particularly if strongly supported by the key industry stakeholders and linked to a well structured Knowledge Transfer programme. However, to achieve a big increase it is likely that additional incentives would be needed to facilitate the process.

Financial incentive schemes have been used in the past with good success (e.g. Welsh Beef Quality Improvement project that was run by Hybu Cig Cymru) and these could also prove successful in other parts of the UK. Given the large environmental benefits predicted, it would also seems justified to consider including the use of high index bulls as an option in agri-environment schemes. Such an approach could prove to be a very powerful tool to help highlight the win-win scenario to commercial farmers whilst also achieving good environmental benefits.

5. Conclusions

The results of this study show that:

- Selection of purebred beef cattle using the currently available selection index tools will deliver a substantial positive impact on the economic and environmental sustainability of beef cattle production in the UK. At current rate of use of recorded bulls, 10 years of selection when considered over a 20 year time horizon, would be expected to result in a cumulative increase in profit at the commercial farm level in the UK of around £31M, whilst also reducing GHG reduction by around 726,000 tonnes – which is a win-win scenario
- Recording feed intake in order to include a measure of feed efficiency into selection indices in addition to current traits would be expected to increase the realised benefits in farm level profit by around 39% and in GHG reduction by around 22%
- Also recording carcass traits at the abattoir would increase the total benefits over current practice by around 73% and 75% respectively

- The establishment of agreed industry standards for recording of feed intake (that reflect current management practice) and for the measure of feed efficiency to be included in selection indices, would be an important step in minimising confusion and simplifying knowledge transfer
- Recording of feed intake on the crossbred progeny of high merit sires would likely be the most suitable approach to use for the main beef breeds in the UK, and would likely be the approach that would also gain the strongest industry support
- To provide a strong platform for on-going selection in any breed it would likely be necessary to provide access to facilities for record in the order of 1500-2000 animals that are the progeny of at least 100 sires to allow good genetic parameters to be estimated, and to ensure that access to recording facilities is still available thereafter to allow the continued testing of progeny from a number of high merit young bulls on an annual basis
- A further more detailed modelling study focused on two stage selection would be needed to determine the optimum number of bulls to test annually to maintain good selection responses as part of such a recording programme
- 10 years of selection using current approaches would be expected to result in a reduction or around 3% in GHG emissions per unit of beef produced. Also recording feed intake and carcass traits on the progeny of a proportion of the bulls available would result in a reduction of around 6%, whilst recording both and increasing the rate of uptake of recorded bulls to 90% would be expected to result in a 10% decrease. These reductions would be expected to be even larger if selection was conducted for longer periods
- Recording feed intake and carcass traits and collecting DNA or recorded animals and their sires as part of a well structured programme would provide a valuable resource that would allow the development and validation of genomic marker panels that could help further increase the rates genetic improvement and overall impact
- Establishing incentive schemes focused on increasing the level of recorded bull use in commercial herds from 50 to 90% could have a dramatic effect on the realised benefits from genetic improvement. Greater uptake of bulls selected using the current selection tools could result in the impact increasing to over twice what is currently predicted, and up to around five times if records for feed efficiency and carcass traits were also included.

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References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.