Developing options to deliver a substantial environmental and economic sustainability impact through breeding for feed efficiency of feed use in UK beef cattle

Defra project code: IF0207

Appendix 1: References

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Appendix 2: International activity and UK Industry led examples

International Activity

Following the short summaries of the international activity contained in the full report, more details of the activity in (1) Australia, (2) Canada, Alberta, (3) USA, and (4) Ireland are provided below.

1. <u>Australia</u>

Research into Net Feed Efficiency/Intake (NFE/NFI) has a long history in Australia, having started in 1993 with a project aimed at establishing divergent selection lines (high and low NFE), estimation of genetic parameters and correlations with other important traits such as growth, muscularity, meat quality, maternal ability and fertility; and establishing if there was a relationship between NFE measured post weaning in young cattle and NFE in mature cows. The work then continued as part of the three rounds of the Beef Cooperative Research Centre (Beef CRC; the first of which started in 1994) and was expanded to look at possible proxy measures and prediction of genetic merit for NFE/NFI using genomic markers.

The Beef CRC was a large multi-disciplinary research programme aimed at addressing the research and extension needs of the Australian beef industry. To achieve this goal, the overall activity was governed by a management committee that included representatives for a number of different industry sectors. The work done was funded by multiple participants including the Australian Government, state governments, MLA, industry partners as well as Australian and international research organisations. The Beef CRC came to an end in mid-2012.

As part of the early research activity, a series of workshops involving representatives from different sectors of the Australian beef industry were held to develop a Standards Manual for testing beef cattle for net feed efficiency. The purpose of the manual was to set out the agreed standards required for testing facilities wishing to gain accreditation by the Performance Beef Breeders Association (PBBA). Only testing facilities accredited by the PBBA were eligible to submit data to breed society databases for the purpose of generating BREEDPLAN Estimated Breeding Values (EBVs) for NFI, with BREEDPLAN being the only commercial provider of genetic evaluations for the Australian beef cattle industry. The manual was published in 2001. The main objective in developing the manual was to minimise the amount of non-genetic variation between tests with the aim of maximising the value of the data being collected.

As a result of the large amount of research that has been undertaken, the concept of NFI is well accepted in the Australian beef industry. However, the level of industry adoption so far has generally been low. Most of the feed intake (FI) recording to date has been done on research farms with very little having been done on private farms or feedlots.

FI data was collected and breed specific genetic parameters estimated for a number of breeds as part of the early research. Trial EBVs for NFI were first published for the Angus and Hereford breeds in 2002. However, only the Angus Society (Angus Australia) has chosen to continue with the work and continue to publish EBVs, but still only on a trial basis. Two Trial NFI EBVs are currently published by BREEDPLAN for the Angus breed – NFI for post weaning and NFI for feedlot finishing. The former is largely based on FI data collected over a 70 day period for young bulls and heifers around 300 days of age, fed on a diet containing an energy level of 10MJ/kg. The latter is generally based on data collected over a

70 day period for steers of around 560 days of age, fed on a diet containing an energy level of 12MJ/kg.

Little FI data was collected in the latter years of the Beef CRC research programme as it approached its completion in mid-2012, and little additional data was collected outside of the research activity. However, there is currently a renewed interest in FI recording within the Angus breed as part of a large progeny test programme, called the Angus Sire Benchmarking Program. As part of this project Angus Australia has collaborated with the University of New England (UNE) and Growsafe Systems Ltd to secure the installation 32 Growsafe FI recording nodes at the Tullimba research feedlot (near Armidale, NSW) which is managed and run by UNE. They have also installed two GrowSafe Beef weighing units over water points at the feedlot to monitor body weight change throughout the test period. Interest in the installation of FI recording equipment has also been expressed by a number of private breeders (Alison Sunstrum, *pers comm*.).

The Angus Sire Benchmarking Program is jointly funded by Angus Australia and Meat and Livestock Australia (as part of the Beef Information Nucleus project). As part of the programme, around 120 elite Angus sires will be tested over 3 cohorts (around 40 per year), with the aim of generating around 1,500 steer and 1,500 heifer progeny for evaluation. All matings will be done using synchronised breeding and artificial insemination across a small number (around 5) herds in each cohort, so as to minimize management and birth date variations amongst the progeny. The calving ease and growth of all progeny will be recorded. FI and carcass traits will be recorded on the steers, whilst the heifers will be taken through to mating and their fertility and subsequent calving performance recorded.

The FI recording will focus on steers that have been weaned and "backgrounded" (pasture fed) on breeder farms prior to entering the testing programme at Tullimba at around 12 months of age for a period of around 91 days (21 days adaptation and 70 days test period). The programme is currently only at an early stage with the first cohort of cattle (about 400 steers from 35 sires) due to start their feed testing in September 2012.

Following the FI test period the steers will be transferred to a nearby commercial feedlot where they will be fed for an additional 120 – 150 days prior to slaughter (without individual FI recording). The initial pasture feeding period followed by slaughter after a fixed number of days on feed lot feeding (220-250; total combined FI and non-FI recording periods) has been chosen as it is typical of the specifications required for the "long-fed" high-marbling export market to which many Angus cattle in Australia have traditionally being targeted. All the steers in the same batch will be slaughtered after the same number of days on feed, and the actual feed period for each batch from within the range of 220-250 days will be chosen based on market conditions, feed costs and time of year as is typically done under a commercial scenario. The need to better fit with current typical management practice is also the reason for the delay to the age at the start of FI recording compared to the post weaning start ages used in some earlier research programmes (12 months vs. 7-10 months). Following slaughter, comprehensive carcase and meat quality data will be recorded on all steers. Ultrasound measurements will also be used to estimate body composition components at different stages of the finishing programme.

The Angus Sire Benchmarking Program will generate NFI-Feedlot EBVs for all the sires being evaluated and their relatives. In addition, DNA will also be collected on all animals to enable the validation of future DNA markers and genotype tests.

In the first cohort of the programme (2010 joining) 35 sires were used, including bulls from Australia, New Zealand and the UK. In the second cohort (2011 joining), 47 bulls were used, including 37 from Australia, 8 bulls from NZ, 1 bull from USA and 1 bull from UK. To participate, the owners of each bull nominated supply of 100 doses of fertile/ viable semen at their own cost, along with a fee of $2,500 (plus tax) ($4,000 for international bulls). The fee is a small contribution towards the total cost per sire in the project. All bulls accepted must have tested negative for BVD and be double vaccinated for Campylobacter and Leptospirosis.

Although the focus to date has been on publishing EBVs for NFI, this approach is likely to be reviewed in the future. There is a view amongst some industry representatives that publishing FI EBVs and including these in a multi-trait selection index would be a preferable option (Peter Parnell, *pers comm.*). There is also a belief that breeders are more likely to invest in recording particular traits (e.g. FI) if they are provided EBVs that are directly related to the measurements taken. Publishing the individual EBVs is also seen as important as it assists breeders in understanding the differences between animals that may have similar index values (i.e. for different reasons).

The lack of industry adoption of FI measurement is thought to be largely due to the high cost involved with recording and the lack of clarity of the benefits from selection for this trait. It is also possible that the lack of realisation of the initial hype and expectation surrounding the use of IGF-1 and genomic markers (as accurate low cost predictors) may ultimately have stifled rather than stimulated industry recording of FI.

It is anticipated that the reduced labour requirement associated with using the GrowSafe system, and the demonstration of the value of improved feed efficiency by the Angus Sire Benchmarking Program, may help increase the level of industry interest and activity in recording this trait in the future.

2. Canada (Alberta)

In 1998 following a tour of the RFI research facilities in Australia, three Canada-based researchers (Dr John Basarab, Bob Kemp and Dr. Warren Snelling) approached Alberta-based GrowSafe Systems Ltd. about developing less costly and more efficient FI recording equipment that was available at that time. The result was a new standard in FI measurement equipment that could be produced at one-tenth of the cost of other equipment available at the time, and operated with less than one-tenth the labour. This collaboration essentially initiated the interest in FI recording in Alberta.

In 1999, two research projects were started to investigate the relationships between RFI and carcass composition. The first was led by Basarab and colleagues in cooperation with Beefbooster Inc.(Hybrid composite seed-stock producers), funded by Canada-Alberta Beef Industry Development Fund to investigate the relationship between RFI and body composition using a classical serial slaughter approach. The other (led by Dr. Bob Kemp and later Dr. Denny Crews) began measuring RFI in Charolais and Angus cattle at the Lethbridge Research Centre.

In 2002 a project lead by Basarab entitled “Commercialization of Net Feed Efficiency in Beef Cattle” was initiated with cattle breeders and Olds College. About 220 purebred Hereford, Aberdeen Angus, Red Angus, Limousin, Simmental and Charolais bulls were measured for RFI from autumn 2002 to spring 2005. This project helped to establish the ‘Animal Behavior and Feed Efficiency Network’, and early activity within the project led to the development of the recording standards document which was first published in 2004. The document sets standards in relation to the equipment used for recording (e.g. GrowSafe) for age at start of test, pre-conditioning period, test duration, diets, frequency of live weight recording, and measurement of body composition and measures of feed efficiency.

In 2005 the research consortium released the first North American Expected Progeny Differences (EPD) for NFE and incorporated them into a multi-trait economic index. The genetic parameters first used were generated using data from the pilot project but were later re-estimated as more data became available.

As part of the on-going activity, nine FI recording units with GrowSafe FI equipment have been established, four based at research centres and five that are run as commercial units. The total recording capacity across the nine units is around 3700-4000 animals per year, assuming 7 animals/node and two batches per year (Figure 1). New facilities are also planned at the Elora Research Centre in Ontario and at The Nova Scotia Agricultural College.

The commercial units are generally large feedlots that offer individual FI recording in groups as an optional service which incurs a daily charge over and above the usual feed lot finishing costs, which include a daily management (yardage) fee as well a cost for the feed consumed. The service is mostly offered for testing young bulls.

Figure 1: GrowSafe FI capacity in Canada

Location	Purpose	No. nodes	Capacity
Lacombe Research Centre, Alberta	Research	24	336
Kinsella Research Ranch, Alberta	Research	40	560
Lethbridge Research Centre, Alberta	Research	36	504
Lanagan Research Centre, Manitoba	Research	16	224
Cattleland Feedyards, Alberta	Commercial	40	560
Namaka Farms, Alberta	Commercial	56	784
Olds College, Alberta	Commercial	10	140
Morison Feedlot, Alberta	Commercial	29	406
Lakeland College, Alberta	Commercial	10	140
Total		261	3664

In May 2008 the Phenomic Gap project was approved for funding from the Alberta Funding Consortium and later the Alberta Livestock and Meat Agency (ALMA) for $1 million cash and about $3 million in contributions from industry and provincial/federal governments. The primary objectives were to phenotype large numbers of progeny for feed efficiency, RFI, live animal carcass merit, and carcass and meat quality and palatability, and to genotype most of these animals using the Illumina 50K bead chip. Over 3500 cattle (mostly first cross) have been characterized for RFI and growth traits, 2000 for carcass traits and over 1000 for meat quality traits as of July 2012. Approximately 2600 of these animals have been genotyped using the 50K SNP chip and these data will be used for the discovery and validation of existing and new genetic markers for economically important traits.

Starting in 2011 the focus of the research has changed to RFI and female fertility and productivity with a joint project among Alberta Agriculture and Rural Development, Agriculture and Agri-Food Canada-Lacombe, University of Alberta and University of Manitoba. This project will measure over 600 heifers for RFI and follow their subsequent FI, fertility and productivity as cows.

Presently, FI testing in Canada is driven mainly by research projects that are funded jointly by government and industry, that involve seed-stock producers such as Beefbooster Inc., Deseret Ranches of Alberta and the purebred associations. For example, Beefbooster has been testing about 50 young TX (terminal cross) bulls per year since 2003 and Deseret Ranches has been testing about 50 young bulls per year, increasing to 150 per year for 2010 and 2011. The Canadian Hereford Association will test 200, 300 and 400 young bulls for RFI in 2012, 2013 and 2014 respectively, and calculate EPDs for their breeders. The Canadian Charolais and Angus Associations test 150 steers and 100 heifers per year at Kinsella Ranch, University of Alberta in association with Agriculture and Agri-Food Canada. The Canadian Simmental Association has a large project to examine the relationship between RFI and carcass and meat quality traits on 1000 Simmental cattle over three years from 2012. DNA is collected on all animals tested. The Canadian Limousin Association is trying to start a project on FI and carcass traits but is yet to be successful. In all cases, the main focus is recording RFI on animals, post-weaning generally between 7-13 months of age.

Recording in many of these projects is being done through research facilities and commercial feedlots, the latter under contact to the research groups. Many projects include a significant in-kind contribution from industry partners, for example the owners of the cattle retain ownership, pay for the feed consumed by the animals whilst on test and yardage costs (at feed lots). The cost of FI recording and genotyping are generally covered by project grant funding, but in some cases the costs associated with FI recording are also partly paid by industry partners.

Most of these projects are intended as pilots to help kick-off more widespread recording within the respective breeds. Working closely with the respective breed associations, conducting much of the recording in commercial feedlots that can be used after the research projects, and a primary focus on recording FI in young bulls is partly done to help facilitate and encourage continued activity.

The data collected in the project so far has been mainly used to generate genetic parameters and EPD/EBVs for RFI within the respective breeds, with the exception of the Angus Association who have chosen to generate EPDs for residual gain.

In 2012 the Government of Alberta approved the 'Quantification protocol for selection for low residual FI in beef cattle', as part of the Specified Gas Emitters Regulation. The protocol details the testing criteria and minimum guidelines for recording to meet the needs of the scheme. To get a certified RFI EBV, FI needs to have been recorded in approved centres which have been fitted with GrowSafe equipment. The sole focus in the protocols is on RFI measured on post weaning animals 8-13 months of age. It is hoped that this initiative will help increase the amount of industry-led FI recording.

3. USA

Although some research activity had been conducted previously, the main interest and activity related to feed intake recording in beef cattle has been gradually increasing in the USA since around 2002. Initial activity was mostly focused around data collection at research institutes, but more recently a number of private test stations have also installed feed intake recording equipment. For example, 29 private test stations and a number of research organisations have now installed GrowSafe recording equipment in recent years which provides a test capacity of around 30,000 young bulls a year. If facilities with other types of recording equipment are also included the total capacity is likely to be higher

The main focus of activity so far has tended to be recording of purebred young bulls with the data being used to generate EPDs for FI, but variations do occur partly motivated by competition between breed associations and breeding groups and their desire to differentiate themselves.

Although gradually increasing over time, the activity has tended to be fragmented with little overall coordination. In part this could be due to the fact that the links between industry and academic groups are not very strong and genetic evaluations tend to be done by different academic groups or private companies for different breeds or breeding groups. In some cases genetic evaluations are also done in-house by the breed associations themselves.

Prior to 2010 there was no accepted industry standard for recording and doing genetic evaluations for FI and measures of feed efficacy. However in 2010 the Beef Improvement Federation (BIF) included recommendations for FI in their Guidelines for uniform Beef Improvement programmes. The BIF is an industry-led, membership based organisation that was established in 1961 and its main activity is focused around helping to standardise breeding programmes and methodologies, and to create greater awareness, acceptance and usage of beef cattle performance concepts. This is done primarily by publishing and updating guidelines related to recording and genetic evaluations, and running an annual convention primarily aimed at providing a knowledge exchange platform between the industry and researchers working on projects related to beef cattle. The BIF membership includes over 40 state and national beef cattle associations amongst a total membership of 73 organisations.

The sole focus of the recording guidelines is on recommendations for recording of post weaning FI and subsequent genetic evaluations. The main recommendations are:

Recording

- FI should only be recorded in animals when housed in groups
- The range in date of birth in a test group should be within 60 days
- Animals should be tested after weaning at around 260 days but not younger than 240 days, and completed before the animals are 390 days of age
- Adaptation period (to facilities and diet) of least 21 days should be used
- Actual testing period of at least 70 days with animals weighed at least twice at the start (on separate days) and twice at the end of test.
- Test diets best suited to local conditions can be used, but all animals on the same test should be fed the same diet
- The diet composition must be recorded and maintained throughout the test period and enough information must be collected to allow diets to be adjusted to a common nutritional base.

- Diets used for growing bulls should contain at least 2.4Mcal ME/(kg DM) and diets for finishing steers at least 2.9Mcal ME/(kg DM)

Genetic evaluations

- Genetic evaluations should be done using FI as the recorded trait with genetic prediction of efficiency measures (if needed) and selection indices calculated after the analysis.
- FI EPDs should be used in selection indices (as it is easier to derive economic values for FI) – but may not be most appropriate for expression of single trait EPD
- If an EPD for a measure of feed efficiency is desired, either an EPD for RFI or Residual Gain should be derived from genetic evaluation results. The use of ratios as a measurement of efficacy in not recommended.

April 2011 saw the start of the largest research project so far focused on improving feed efficiency in beef cattle. The $5M, five year research project called; the national program for genetic improvement of feed efficiency in beef cattle, is funded by the United States Department of Agriculture (USDA). Its main focus is to develop selection tools and better understanding of feed efficiency in beef production, including the development of a national across-breed Genomic Selection programme. The research consortium includes 20 researchers from 11 different institutes as well as a number of industry groups. The project will make use of FI records that have been collected on 8,000 cattle from 8 different breeds. Around 2,400 of these will be genotyped with the aim of developing a genomic selection programme. The main feed efficiency measure used will be RFI.

Around one-third of the total project costs are devoted to extension and outreach, delivered mostly through an industry demonstration project that involves 24 collaborating seed-stock producers and one commercial feedlot, who have been involved throughout the planning and development process for the activity. More information on the project can be found at www.beefefficiency.org.

4. Ireland

Recording of individual FI in beef cattle has been done for a number of years in Ireland. Most of the recording of has been on pure-bred young bulls at the National Bull performance test station at Tully which has been in operation for around 35 years. In 2000, the Irish Cattle Breeders Federation (ICBF) was formed as an independent body to oversee cattle breeding in Ireland. The national genetic evaluations for cattle in Ireland and the central performance test are now run by ICBF. Some feed intake recording of crossbred cattle has also been done at the 'Grange' research centre, but this has largely been as part of short term research projects.

Over 5000 bulls across 13 breeds have now been tested at the station since its establishment. In recent years around 180-200 bulls have been tested annually in two intakes (May and November). Although numbers varied between intakes, as a general rule around 60% of bulls were from the Limousin and Charolais breeds with around a further 30% from the Simmental, Angus and Hereford breeds.

Bull selection and testing protocols

Each year around 1500-2000 bulls (across breeds) were first identified for possible entry to the station through examination of the national genetic evaluation results. The owners of bulls that had values for two genetic indexes above set thresholds (five star rating for Suckler Beef Value and 3 star or more for Milk and Fertility) and that were within defined age ranges (generally 9-12 months old at the start of test) were invited to apply for entry.

All nominated bulls were inspected and scored by ICBF staff for a series of muscular, skeletal and functional traits. Owners of all bulls that pass the first inspection were requested to undertake on-farm health testing in collaboration with their own vet for: TB, Brucellosis, EBL, Johne's, BVD and IBR. Provided all tests were negative, the breeder was then invited to bring their bull to the pre-entry isolation centre. All breeders wishing to do so were asked to pay a €600 fee for each bull entered, which partly contributed towards the costs of testing.

All bulls put forward entered a pre-entry isolation centre for a 30 day TB, Brucellosis and IBR test. All bulls failing any health test during the pre- test isolation were returned to their breeders. The pre-test isolation period was also used as an acclimatisation period with all bulls fed concentrates.

Bulls passing all disease testing were then moved to the Tully test station where they continued their performance test for a further period of approximately 90 days, during which they were weighed five times.

The main objective of the Tully performance test station was to identify the best young bulls for potential progeny testing through the G€N€ IR€LAND programme, and from there into active AI. For the bulls tested but not selected for the programme, the breeders have the option to take them back or offer them for sale at the end of test at a specifically organised sale.

G€N€ IR€LAND

G€N€ IR€LAND is a progeny testing scheme that launched for beef in 2007 (with a similar programme for dairy launched in 2005), that is primarily aimed at testing high genetic merit young bulls in commercial herds. As part of the programme, ICBF encouraged AI companies to buy young bulls with €uro-Star Indexes, such as those that were tested at Tully.

Semen from the bulls purchased were made available at a subsidised rate to commercial herds that participated in the G€N€ IR€LAND programme through the AI companies, provided they used a minimum of 10 straws per year and records were sent back to ICBF. The target was to sell 700 straws of semen for each selected bull to participating herd owners. From there, key information was recorded on all male and female progeny including gestation length, calving difficulty, weaning weight, carcass data and maternal performance. During the early part of the programme, additional financial incentives were offered to herd-owners to get involved, including €20 for each recorded insemination to a test bull, which was paid once the requested data was received by ICBF. Around 400 herds participated in the spring 2009 programme. From 2007 to 2011, 56 bulls were made available as part of the programme, of which around 15 were bulls that were tested at Tully.

Feed use efficiency measures used

The approach used for publication to industry was to include feed intake directly into the index as a trait in its own right. Although a considerable amount of research has been conducted in recent years looking at the relative value of using different measures of feed use efficiency using data from the Tully centre (refs), it is unlikely that the approach used will be changed. FI is included as a trait in the beef carcass sub-index of the main suckler beef value index. Both the suckler beef value index and beef carcass sub-index were launched in 2007. All the data collected at Tully was included in the national genetic evaluations for the relevant breeds allowing FI EBVs with a higher accuracy to be generated for the tested bulls and all their relatives.

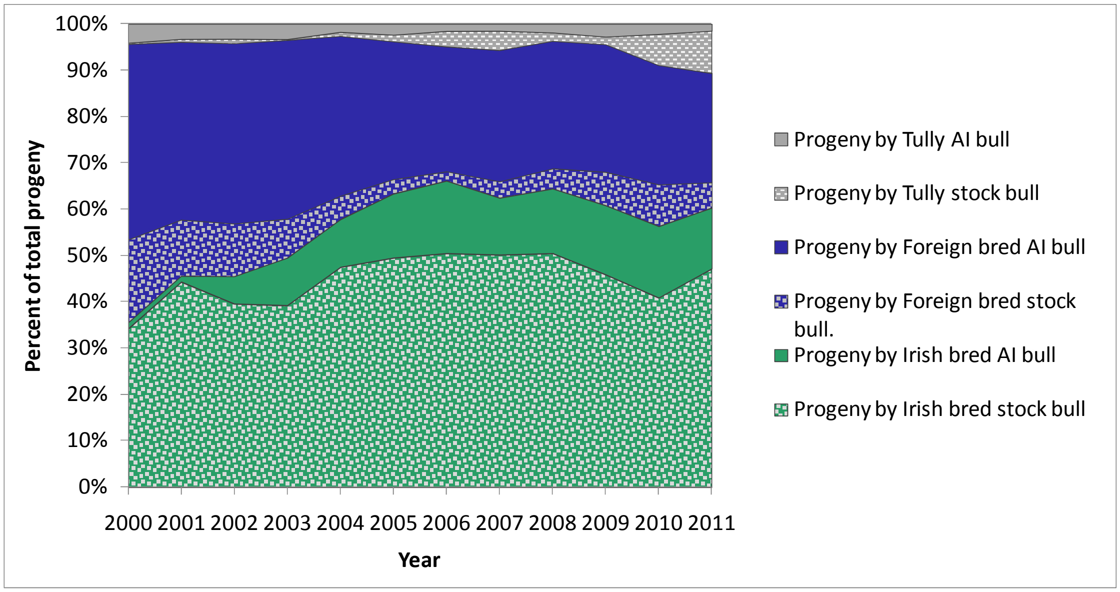
Level of industry engagement and uptake

Although not run at full capacity, the level of industry engagement to testing at Tully has generally been good. Demand for bulls at the end of test sale has been high, likely to be partly due to the greater amount of data available on these bulls, but also potentially more so due to their excellent health status.

The activity at the station has been overseen by a committee which included ICBF staff, other scientific advisors as well as a number of representatives from industry. There was also a strong drive to provide regular industry updates on the on-going activity.

Despite the high level of industry engagement, the level of use of bulls tested at Tully in the Irish pedigree beef industry has not been high, tending to be less than 5% per year, although the impact has increased in recent years through the use of sons of bulls that have been tested at the station (Figure 2).

Figure 2: Origin of beef sires in pedigree herds in Ireland



Source: ICBF

Changes underway

Although the industry buy-in to the current approach has been good, around 12 months ago ICBF conducted a review which suggested that better value for money and bigger benefits for the Irish beef industry could be gained by testing the crossbred progeny of elite bulls and also looking at novel traits such as meat eating quality and disease resistance etc. The change to the new format is currently underway and the last purebred bull sale was held in October 2011. As part of the new programme the aim in the first instance will be to test a similar numbers of animals (~180 per year) but ultimately with a view to increase the number tested to around 600 per annum. All the crossbred cattle tested will be bought-in form the Gene Ireland participating herds and their carcasses sold for consumption once the necessary measurements have been taken. In addition to providing a wider range of measurement, the new approach is expected to involve a much reduced Health scheme/testing programme.

The main focus of the testing will be young bulls that will be purchased at around 11-12 months of age and fed at the test station for 120 days (30 day acclimatisation and 90 days FI), then slaughtered. If more animals are needed to maintain good throughputs, steers and heifers will also be sourced, however these will be bought in at 18-20 and 14-16 months of age respectively, to allow the animals to be slaughtered at the end of the testing period. Due to the relatively small number of records expected for steers and heifers, it is likely that all data collected will be used to generate only one EBV for FI.

From 2012 onwards changes are also being made to the G€N€ IR€LAND programme. The programme will be active on two levels:

1) More structured engagement with purebred herds:

Breeders will be invited to become part of an accreditation scheme which allows their herds to put forward bulls for potential purchase as part of the G€N€ IR€LAND programme. They will be asked to pay a fee of €250 per year for a minimum of 4 years to join the scheme. The quality, quantity and timeliness of data recorded for nine traits/events will be assessed for the herd by ICBF and assigned a Herd Data Quality Index (HDQI). Accreditation will be based around achieving a score above a certain level for the HDQI. As part of the assessment process, ICBF will give breeders advice on how best to improve the overall index values of their herds. Only bulls from herds that achieve accreditation within 12 months will be considered for purchase as part of the programme. The herd can also use their accreditation in their herd promotion and ICBF will also help promote the herd to pedigree and commercial herd owners through the ICBF website, herdbooks and various forms of media.

2) Engagement with commercial producers:

In contrast to the previous programme, ICBF will directly purchase bulls for use as part of the programme from accredited herds. One thousand doses of semen will then be collected for each selected bull after which they will be sold (or slaughtered). Of these, 500 doses will be used for progeny tests and 500 will be put in storage for elite pedigree mating, once the bull has received its full proof.

Semen from the bulls will then be made available for purchase at a subsidised rate (€5 per straw) to participating herds provided they use 10-25 straws per year and records are sent back to ICBF. Producers can choose to use semen from more than one bull or more than one breed, but the minimum number of semen straws that needs to be used per bull is 5.

The changed format will be part of a new programme aimed at progeny testing more bulls, especially maternal bulls. ICBF will run the programme from bull selection to slaughtering selected progeny at Tully. Details of the overall programme will be published on the ICBF website when available (www.icbf.com). As with the previous format, it is planned that the activity will be overseen by a committee which will include a number of industry representatives.

Examples of Industry led beef focused initiatives currently running in the UK

As part of initial industry consultations, 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 unit recently built and run to record feed intake in cattle of 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 an Integrated Beef Supply chain that is successfully being run by Blade Farming Ltd is also included as an example of a model that could be useful to help develop a continuous supply of progeny to test from bulls of interest. An overview of each of the three examples is shown below.

1. <u>Breed-specific Testing Unit: BIG/Stabilisers</u>

In 2011 an industry led consortium was successful in gaining funding through the Sustainable Agriculture and Food Innovation Platform call for Sustainable Protein Production, for a four year project called IMPROBEEF. The main focus of the project was to establish and run a purpose built facility to collect individual feed intake records and help develop genetic evaluations for Net Feed Efficiency in the stabiliser breed of beef cattle. The consortium is led by the Beef Improvement Group but also includes: JSR Farming Ltd, Richard Keenan Ltd and SAC. The unit started operation with the first batch of animals starting to be recorded in January 2012

The unit includes four pens each with four GrowSafe feeding bins. The total capacity across all four pens is 80 cattle and the expectation is to record three batches per year. The primary focus is on recording young pure-bred bulls within the age range of 300-400 days of age. Within each test batch candidates are selected to ensure a range of less than 6 weeks in birth dates.

All the animals are allowed an acclimatisation period of around 21-25 days followed by an actual test period of 60 days during which they are weighed once a week. Ultrasound measurements of back fat and eye muscle area are measured on all animals at the end of the test period.

The diet fed is a TMR consisting of 50% forage supplemented mainly with barley. All feed bins are emptied prior to re-filling once a day. The dry matter of the ration is calculated twice a week using the oven and scales that are present at the facility. Dried samples are then stored in the freezer and sent for laboratory analysis in bulk. The unit is run by one dedicated person with back-up from other farm staff as needed.

The project has a high emphasis on bio-security. Only animals from 4 year TB testing areas are considered and all candidates must have tested negative for BVD and TB, and be vaccinated for BVD, IBR, PI3 and Pasteurella. A contract is signed between BIG and the owners of the cattle entering the unit which includes an agreement by the producer to accept liability for theft, injury or death of the animals whilst at the unit and the onus is therefore on them to take out any relevant insurance for the animals.

The facility will not generate sufficient records in the first few years to allow accurate EBVs to be generated, so the initial focus will be on ranking of young bulls on phenotypic measures of NFE until EBVs can be generated. It is planned that the top ranking bulls will be made available for use through the breed using Artificial Insemination. Candidates for the unit are selected from several herds so as to include progeny from each of the main bloodlines in the UK Stabiliser population.

Given the need for relatively tight calving patterns and high health status, a high level of buy-in and cooperation from breeders is seen as vital for the project's success. The need for tight calving patterns is likely to make it difficult to secure three batches of young bulls per year, and the possibility of testing one batch of related steers is being considered.

2. <u>Commercial Finishing Unit: Adam Quinney/Arrow Valley Feeders</u>

Following an ASDA Scholarship undertaken by Adam Quinney of Arrow Valley Feeders (AVF), ASDA's National Suckler Strategy Group was formed with Arrow Valley Feeders working with ASDA and ABP to build a progeny testing unit that became operational in October 2011. The main purpose of the unit is to help farmers make money from finishing their cattle as well as getting good data back.

The unit cost around £150k in total to build and equip appropriately. It is based on a slatted floor system with rubber mats and contains 17 pens each of which can hold groups of 20 animals for a finishing period of around 120 days with feed intake being monitored per group. The aim of the unit is to receive and finish animals within a four month period allowing an annual capacity of just over 1,000 animals.

As the unit needs to be at or near capacity all of the time, there is flexibility in the age of animals that are accepted, the main requirement is that they are around 120 days from finishing. Generally animals are taken in between 10 and 14 months, although they can be between 8 and 28 months as long as they are 40 days or more post weaning. Only young bulls and steers are accepted and there are stringent health conditions in place. A written contract is set up between the owner of the cattle and AVF with a separate written contract in place between AVF and ABP on the finance and support for the capital spend. A verbal contract is agreed between AVF and ABP on the price, there is no label involved due to the relatively low numbers of animals involved.

Animals are only sourced from BVD-free herds. On arrival all animals are vaccinated for IBR (if this has not already been done), and are placed in quarantine for 10 days. If any problems arise in the first week the producer pays for treatment or the animal is sent back. After that initial period, the unit then becomes responsible for any further health issues. The finishing unit is TB approved.

Animals are currently fed a maize based diet but the farm is investigating the possible use of co-products. The business model for the unit is to charge a daily management fee per animal, currently 60p, which covers everything apart from feed which is charged at cost (open book accounting). The margin on the management fee is around 4p. Accurate measurement of group intake is an important part of the business model.

This setup delivers a number of benefits to the participating farmers such as having a known cost for finishing an animal and fixed sale prices. As the unit can buy feed and vaccinations in bulk, the costs are often lower than for an individual producer. If producers have limited space or wish to free up more grazing land in summer and reduce workload in winter the commercial finishing unit offers particular advantages. If the animals are grouped by sire it is possible to monitor the performance of progeny from individual sires. A lot of experience has been gained (and costs incurred) in terms of setting up and understanding the software, therefore sharing experience with other units could help reduce their set up costs.

3. <u>Integrated Beef Supply Chain: Blade Farming franchise</u>

Blade Farming Ltd has been in operation for over 10 years and was acquired in 2011 by the ABP Food Group. The company business model is structured around an integrated beef supply system, predominantly using dairy and Aberdeen Angus crossbreds. The franchise currently has around 16,000 cattle in total with animals being finished at around 20 months. The system works at all stages of production allowing a high level of control and consistency throughout.

Blade purchases calves meeting its specifications of 10-28 days old, weighing a minimum of 45kg for Aberdeen Angus crosses and 50kg for dairy crosses. In addition the Aberdeen Angus crosses must have been sired by a pedigree registered bull. Blade work with Genus to encourage farmers to use approved sires available through AI and will pay a premium for these calves.

The calves are then reared to 3-4 months old on dedicated units, contracted by Blade, using a standard Blade protocol including one veterinary practice. The calves are fed on straw and calf rearer nuts and weigh at least 100kg when they leave the rearing unit. Strict health protocols are followed including TB isolation units for Aberdeen Angus crossbreds that are licensed and approved by Defra.

Blade then sells the calves on to contracted finishing units to be grown and finished by around 20 months of age. The calves must be grazed for at least 6 months and Blade works in collaboration with BOCM Pauls and Mole Valley Farmers to provide a specialised diet plan as well as nutritional and management advice. The animals are finished on a high cereal diet as well as a mineral supplement that includes vitamin E to enhance meat quality. The animals are weighed on a regular basis to ensure they are meeting their target weights and this allows the diet to be altered as required.

The business model for Aberdeen Angus crossbreds includes the potential to agree forward price finishing contracts with the finishing units that guarantee a premium price as long as the animals meet specific targets on weight. In order to secure the premium price, animals must weigh between 245-400kg dwt with targets of 270kgs for heifers and 300kgs for steers. There are deductions in place for under- or overweight animals.

Blade takes a 2% commission at the abattoir, Southern Counties Fresh Foods, before the meat is supplied to McDonald’s and Tesco. Blade also has a standard contract for example, for feed and software packages to ensure consistency so if recording were implemented on a system like this it would help deliver a good standard of data across a large number of animals. The current business model, however, only considers dairy crossbreeds and one beef breed.

Appendix 3: Modelling the potential impact of recording and numbers required

1. Objective

This part of the study had two main objectives:

1) To quantify the likely impact in terms of improving efficiency 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 sufficient "improved" animals to have 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.

2. Materials and methods

2.1. Modelling the impact of including feed use efficiency in current breeding programmes

If selection to improve some measure of feed use efficiency was to be done in the UK, it would most likely be by incorporating a chosen measure in current breeding programmes with selection alongside current economically important traits, rather than selection in isolation. Given the difficulties associated with recording individual feed intake, it would likely only be done on a proportion of the animals available for selection.

Previous UK studies 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 beef value index, 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 and benefits through selection.

The UK beef breeding industry can typically 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.

Given all these expectations, the approach used in this study was based on two parts. Part one investigated 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 be similar in other UK beef breeds. Part 2 was focussed on estimating the likely impact of the improvement in the pedigree population disseminating into commercial herds on industry profitability and GHGs.

As part of that overall approach, the effect of a series of variations was investigated, namely:

- Including records for feed use efficiency and carcass traits directly in the selection index
- Taking account of genetic improvement achieved through selection pressure on dams as well as sires
- Changing breeding goals and the selection index weights
- Increasing the level of recorded/improved bulls 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 them as new traits directly into 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 currently provided for some UK breeds (including the Limousin breed) through Signet, namely the Beef Value index. In using the Beef Value index it is assumed that recorded traits include: birth weight (BW), weight at 200 (WT200) and 400 days (WT400), muscle score (MS), fat depth (FD), muscle depth (MD), gestation length (GL) and calving difficulty (CD). The traits in the breeding goal were carcass weight (CW), carcass fat score (CFS), carcass conformation (CCS), gestation length (as a trait of the calf) and calving difficulty (as a trait of the calf). The new measure of feed use efficiency derived was Residual Feed Intake (RFI); measured post weaning and adjusted for ultrasound fat depth at the end of test ($RFI_{pw\text{-}fat}$) as suggested in Basarab *et al.* (2011). Given that crossbred cattle account for a high proportion of commercial cattle in the UK, the trait included in the breeding goal was $RFI_{pw\text{-}fat}$ in crossbred cattle.

The genetic and phenotypic parameter estimates assumed were primarily based on those used in genetic evaluations for the Limousin breed (Amer *et al*., 1998). Where parameter estimates were not available, further information was obtained from Roughsedge *et al.* (2005). Genetic and phenotypic parameters assumed for $RFI_{pw\text{-}fat}$ were based on estimates reported in the literature (Roughsedge *et al*., 2011, final report to Defra IF0149), but with the genetic correlation between RFI and fatness reduced to zero to represent the adjustment for ultrasound fatness measured at the end of test. More information on the phenotypic variances, heritabilities, genetic and phenotypic correlations assumed are shown in Table 1.

The breeding structure for the pedigree population was set up to reflect that seen in the recorded population for the UK Limousin breed, based on data from current genetic evaluations. It was assumed that approximately 40% of bulls selected for use are young sires (generation interval <3 years) and 60% are older sires (still breeding at 4 years of age). The average number of records collected over the animals' lifetime for each trait assumed for each selection candidate (bulls only), their paternal half sibs and progeny is shown in Table 2. Information from the dam was estimated separately from sires as dams have a different number of relatives. It is important to note that these average values were derived based on available data for the breed and the expected 40:60 ratio of young to older bulls used. In reality average numbers for young bulls would be lower and those for older bulls higher.

Table 1: Heritabilities (diagonal), genetic (above the diagonal) and phenotypic (below) parameters, and phenotypic variances (Vp) assumed for the recorded and goal traits

	BWT	WT200	WT400	MSC	FD	MD	GL-direct	CD-direct	RFI_{pw-fat}	CW	CFS	CCS	Vp
BWT	**0.23**	0.27	0.19	0.10	0.05	0.10	0.20	0.31	0	0.05	0	0	9.04
WT200	0.27	**0.33**	0.85	0.42	0.22	0.60	0.10	0.29	-0.16	0.50	0.80	0.18	807.45
WT400	0.19	0.85	**0.40**	0.53	0.12	0.55	0.05	0.10	-0.07	0.60	0.10	0.20	1589.71
MSC	0.10	0.48	0.43	**0.27**	0	0.63	0.19	0.07	0	0.30	0	0.60	1.32
FD	0.05	0.17	0.22	0.16	**0.29**	0.18	0	0.05	0	0.10	0.40	0.10	6394.73
MD	0.10	0.32	0.43	0.49	0.16	**0.26**	0.20	0.10	0	0.30	0.10	0.60	25184.19
GL-direct	0.20	0.07	-0.00	0.12	0	-0.01	**0.29**	0.21	0	0.10	0	0.10	23.81
CD-direct	0.31	0.02	0.03	0.01	0	0	0.11	**0.12**	-0.02	0.10	0	0.10	1.02
RFI_{pw-fat}	0	0	-0.02	0	0	0	0	0	**0.34**	-0.26	0	0	95852.16
CW	0.05	0.30	0.50	0	0	0	0	0	0	**0.44**	0	0	859.60
CFS	0	0	0	0	0.30	0	0	0	0	0	**0.13**	0	4.10
CCS	0	0	0	0.30	0	0.30	0	0	0	0	0	**0.11**	9.83

In the base scenario, it was assumed that genetic improvement was effected only through selection pressure being applied to bulls and that index values were not a consideration when selecting females to retain for breeding. The generation interval assumed for males was 5.58 years which was calculated as being typical for the Limousin breed.

The effect of two selection intensities being applied to bulls was considered, 0.1 and 0.2, which in the assumed population was equivalent to around 250 and 500 new bulls being selected for use each year. An investigation of the ratio of sires relative to the total number of bulls born within the Limousin population suggested that, in reality, a selection intensity of around 0.04 was in fact applied, however it was acknowledged that the index is unlikely to be the sole criterion on which selection decisions were being made. As a result, investigating the effects of selection intensities of 0.1 and 0.2 was deemed more appropriate.

Table 2: Assumed average number of records being collected during an animal's lifetime on itself and relatives for each bull selected for breeding within the pedigree population

Trait and information source name	Number recorded animals
BWT-direct (on candidate)	1
BWT-direct (on paternal half-sibs)	42
WT200-direct (on candidate)	1
WT200-direct (on paternal half-sibs)	24
WT400 (on candidate)	1
WT400 (on paternal half sibs)	15
MSC (on candidate)	1
MSC (on paternal half sibs)	8
FD (On candidate)	1
FD (On paternal half sibs)	5
MD (on candidate)	1
MD (on paternal half sibs)	5
GL-direct (on candidate)	1
GL-direct (on paternal half sibs)	26
CD-direct (on candidate)	1
CD-direct (on paternal half sibs)	65
BWT (on progeny)	18
WT200 (on progeny)	21
WT400 (on progeny)	15
MD (on progeny)	13
FD (on progeny)	12
MSC (on progeny)	12
GL (on progeny)	28
CD (on progeny)	21

In investigating the effects of recording $RFI_{pw\text{-}fat}$ and carcass traits and including them in selection indices, it was assumed that feed intake would not be recorded on the animal itself but rather on an average of 15 progeny over the bull's lifetime. As part of the investigation it was assumed that recording of both RFI_{pw-fat} and carcass traits within the population was at a steady state (i.e. was routinely done). In all scenarios 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.

Changing economic weights

The estimates of economic weights used in the base index were as reported in Amer *et al*. (1998) for the Beef value index, namely £1.2/kg for carcass weight, £-6.0/unit score for carcass fat, £7.0/unit score for carcass conformation £-1.0/day for gestation length and £-2.47/% for calving difficulty . An economic weight for RFI_{pw-fat} was calculated based on the expected contribution to improved profitability at the commercial farm level. Under that scenario it was assumed that differences identified during the post weaning recording period were reflected throughout the 24 months growing period for a finishing animal. The resulting economic value was £0.069 per kg DMI improvement (Peter Amer, Abacus, 2009).

Improvement in some of the goal traits under consideration in this report are known to have an impact of the GHG emissions from a beef production system, namely carcass weight and RFI. As part of a previous Defra study (FG0808), a biological model was developed to quantify the impact of an independent change in a selected trait on overall greenhouse gas emissions from an "average" beef system. This information was used to develop selection index weights that focus solely on their value in relation to reducing GHG emissions per unit for two units of interest: CO_2 eq./kg saleable meat and CO_2 eq./breeding cow. Index weights, taking account of the discounted genetic expressions were then used to derive alternative breeding goals for the two scenarios. These weights were also used to quantify the impact of response to selection on GHG emissions from a beef system and multiplied by the prevailing shadow price of carbon (CO_2 eq., Price *et al*, 2007) when disseminating genetic improvement to the wider population (Economics + SPC). The index weights derived for each scenario are shown in Table 3.

Table 3: Economic weights assumed for the current goal and three alternative goals more focused on reducing GHG emissions

	Current Breeding Goal (Beef Value) +RFI	GHG Weight (CO_2 eq./kg saleable meat)	GHG Weight (CO_2 eq./breeding cow)	Economics + SPC
CW	1.2	12.26	0.093	1.37
CFS	-6	0	0	-6
CCS	7	0	0	7
GL-direct	-1	0	0	-1
CD-direct	-2.88	0	0	-2.88
RFI_{pw-fat}	-0.069	-0.38	-0.00465	-0.01

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.

Impact in the commercial population

Given the pyramid structure of performance recording and genetic improvement dissemination in the beef industry we can assume that genetic improvement occurring in the pinnacle of the breeding structure will be disseminated through the purchase of 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 40-50% 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).

Discounted incomes were calculated for each of the goal traits based on the annual genetic gain in the trait units and their economic values discounted by the specific genetic expression coefficients considering time and number of expressions of the genetic progress and the number of bulls from the breeding programmes required to mate the industry females. A discount rate of 7% was used when discounting genetic expressions of goal traits over time.

The cumulative marginal net discounted return from 10 years of selection (at a steady state) 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.

The assumed numbers of bull used and cows mated each year in commercial herds were based on the information presented by Amer *et al.* (2007) and those detailed in the FAPRI-UK animal number projections which are shown in Table 4. 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.

This FAPRI-UK modelling system is used to inform policy makers of how changes in the policy instruments of the European Union’s Common Agricultural Policy and rules agreed under the WTO impact the individual agricultural sectors of England, Wales, Scotland and Northern Ireland, and the UK as a whole. The model includes macro-economic influences on the trajectory of agricultural production in the UK (e.g. global commodity prices and oil prices) with the baseline being re-estimated and re-calibrated annually. The projected numbers of animals in each livestock category, and the product they produce, are projected given macro-economic and local (economic/climate/structural) conditions and the GHG emissions projected assuming current management circumstance (Table 4). The most recent FAPRI figures are taken from the 2010 projections and include the historic performance of 2008 and 2009 and project until 2019.

Given the limited timeframe of the forward projections, when accounting for the impact of genetic improvement into the commercial slaughter population as part of this study, we assumed that numbers for year 0 were equivalent to those in 2008. Please note that the categorisation of FAPRI GHG emissions is based on the total number of dairy or non-dairy cattle. As part of this study we have compared the alternative genetic improvement strategies relative to GHG emissions in the baseline due to methane (enteric and manure) from non-dairy cattle.

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. This was assumed as it reflected the current estimated level of use in the UK. As part of this study the effect of increasing the percentage of cows mated from 50% to 90% was also investigated.

2.2 Number of recorded animals needed

In order to set up a breeding programme that can deliver good industry impact, sufficient records are needed to estimate breed specific genetic parameters, followed by the continued collection of a sufficient number of records 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 animals to record at both stages will depend on a wide number of factors e.g. the measure of feed efficiency used, number of sites and timescales of recording, capacity of the recording facilities, breeding 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 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.

Firstly the impact of recording purebred vs. crossbred animals was considered where RFI_{pw} in the commercial herds is included in the breeding objective and the genetic correlation between purebred and crossbred traits was 0.7. The effects of changing the number of bulls tested and of changing the number of crossbred progeny tested per bull were also investigated.

3. Results and discussion

The likely impacts at a UK beef industry level of selecting purebred animals based on the Beef Value index and four alternative indices are shown in Table 5. 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 over a period of 10 years, 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 £45.2 M. Including $RFI_{pw\text{-}fat}$ only as a trait in the breeding goal had only a small effect on the projected cumulative returns. Substantially larger increases were predicted when $RFI_{pw\text{-}fat}$ was 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.

By using population parameters for the UK Limousin breed we can be fairly confident that the rates of genetic improvement calculated are relevant for that breed. Given that the Limousin breed has the largest number of animals amongst UK terminal sire breeds, it is possible that lower rates of progress may be appropriate for the other breeds, suggesting that the values above (particularly for the base index) may be an overestimate of what is achievable in reality. However, it is important to point out that these values are more likely to be an underestimate of the total impact possible given that no account has been taken of a low selection intensity also being applied in selecting females, which would be expected to provide a further lift of around 15%, nor of a correlated improvement in RFI in the breeding females both at the purebred and commercial level, especially given that terminal sire breeds also account for a high proportion of the genetics of commercial breeding cows in the UK. Although the actual magnitude of the correlation is unclear, there is strong evidence from literature for a positive relationship between RFI measured post weaning and RFI in the mature cow. This positive association could confer a substantial additional benefit given that maintenance of the cow accounts for a high proportion of the overall cost and environmental burden of beef production. The maintenance of breeding cows and calf production is estimated to account for around 45% of the overall emissions (CO_2 eq.) from beef production (Wall, *unpublished*).

Changing economic weights

Changing the economic values and index weights to focus more heavily on GHG reduction provided only a small benefit in terms of reducing emissions and was achieved at the expense of a small reduction in farm level profit (Table 6), suggesting that nearly all the benefits 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.

Table 4: FAPRI (Aug 2010) baseline for the numbers of cattle (1,000 head), beef production (1,000 tonne) and GHG emissions (kt CO_2 eq.) from non-dairy cattle methane (enteric and manure) and total agricultural GHG emissions

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Historic		Projected									
Beef	1,621.0	1,622.0	1,607.5	1,608.2	1,589.1	1,571.4	1,567.1	1,568.6	1,570.4	1,575.4	1,583.9	1,597.4
Dairy	1,903.0	1,864.0	1,881.4	1,805.9	1,736.0	1,727.3	1,746.5	1,750.1	1,750.0	1,754.3	1,757.7	1,764.6
Total Cattle	9,902.6	9,891.9	9,875.6	9,769.5	9,610.1	9,495.2	9,446.4	9,418.7	9,402.2	9,403.3	9,417.0	9,449.1
Beef production	866.0	856.0	872.1	896.9	895.0	861.1	834.4	830.2	827.4	822.43	820.74	818.3
Non-dairy cattle enteric methane	8827.8	8795.4	8758.1	8722.7	8623.4	8507.5	8433.5	8399.3	8381.5	8378.0	8389.3	8416.8
Total agriculture GHG emissions	43590.5	43164.6	43114.4	42663.9	42298.0	41937.1	41692.3	41582.1	41492.7	41482.1	41520.9	41642.2

Table 5: 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*	✓	✓	✓	✓	✓
$RFI_{pw\text{-}fat}$			✓	✓	✓
CW					✓
CFS					✓
CCS					✓
Traits in the breeding goal					
CW	✓	✓	✓	✓	✓
CFS	✓	✓	✓	✓	✓
CCS	✓	✓	✓	✓	✓
GL-direct	✓	✓	✓	✓	✓
CD-direct	✓	✓	✓	✓	✓
$RFI_{pw\text{-}fat}$		✓		✓	✓
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 6: The impact of response to selection in the pedigree population with alternative breeding goal weights (all goals of records on RFI and carcass traits included)

	Current goal + RFI + carcass records + RFI records	GHG Weight (CO_2 eq./kg saleable meat)	GHG Weight (CO_2 eq./breeding cow)	Economics + SPC
Selection response in goal traits				
CW	2.38	2.41	2.34	2.38
CFS	0.00	0.01	0.01	-0.01
CCS	0.02	0.01	0.01	0.02
GL-direct	0.03	0.04	2.34	0.02
CD-direct	0.00	0.00	0.00	0.00
RFIpw-fat	-10.83	-10.93	-12.80	-7.24
GHG reduction (kt CO_2 eq.)	-1,254.9	-1,274.1	-1,266.9	-1,203.5
Industry (£ M CO_2 eq. at SPC)	£44.76	£45.45	£45.19	£42.93
Industry (Farm Profit £ M)	£54.01	£52.35	£52.83	£52.00
Cumulative benefit (£ M)	**£98.77**	**£97.80**	**£98.02**	**£94.93**

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 7).

Changes in level of use of recorded bulls in commercial herds

Increasing the level of use of recorded bulls in commercial herds had dramatic effects on industry level impacts (Table 7). 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 herds by even a small amount could deliver potentially large returns.

Table 7: The impact of the "current" breeding programme without and 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

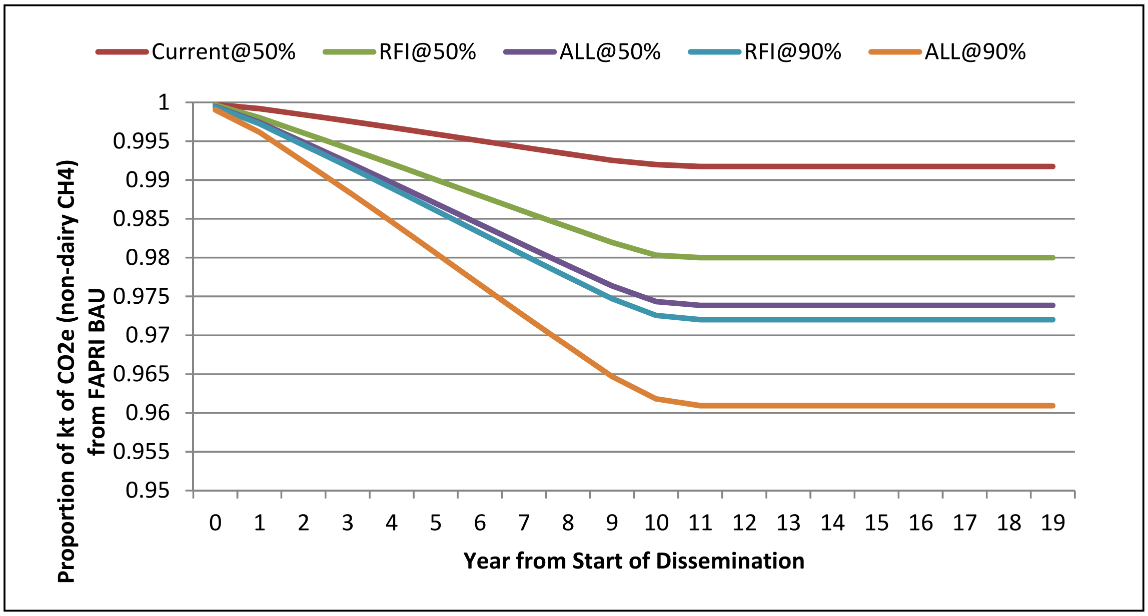
	Current + RFI	+Female genetic improvement	Current + RFI + Carcass	+Female genetic improvement
50% use of recorded bulls				
Industry (£ M CO_2 eq. at SPC)	£31.53	£37.59	£44.76	£51.02
Industry (Farm Profit £ M)	£43.06	£51.55	£54.01	£60.58
Cumulative benefit (£ M)	£74.59	£89.14	£98.77	£111.60
90% use of recorded bulls				
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

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.

We can see from the 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 which assumes status quo in terms of management and performance and therefore does not include ongoing genetic improvement.

The Climate Change Act requires that GHG 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).

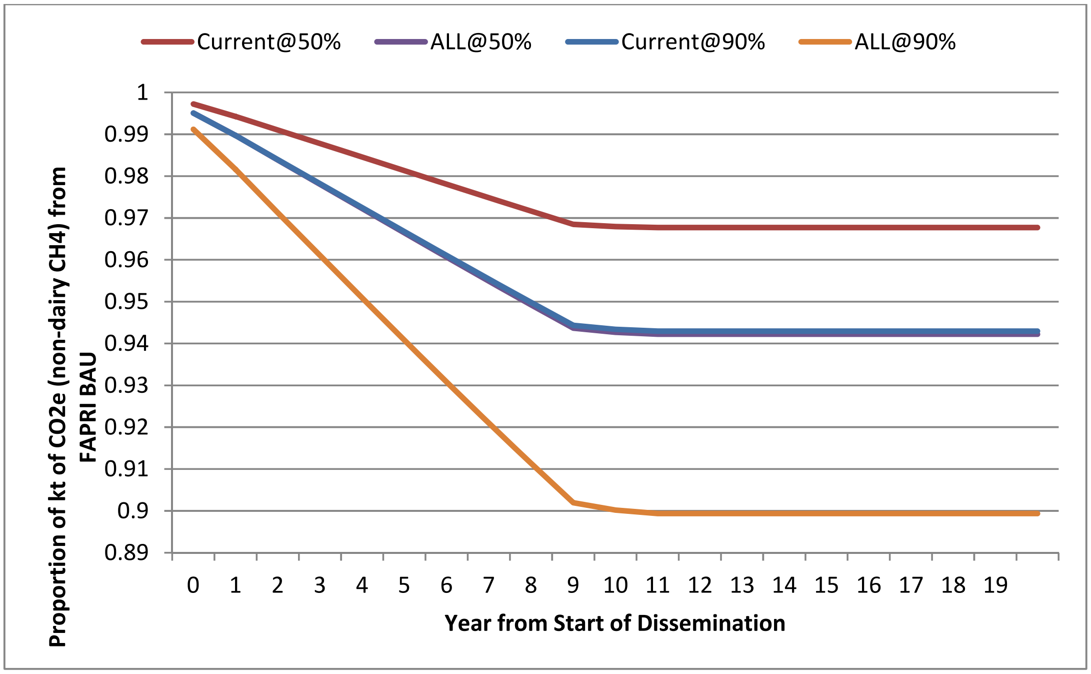
Figure 1: The amount of GHG abated due to alternative beef genetic improvement strategies at a population level relative to the FAPRI baseline



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 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 on 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). Here, 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 1 and 2, 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, that 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.

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*

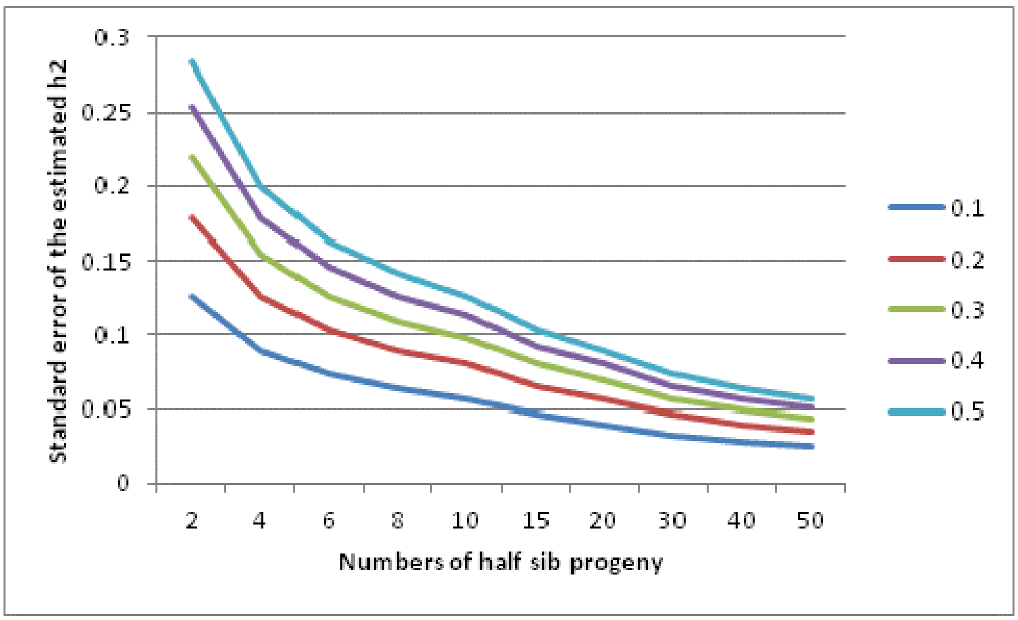
Numbers of animals required to estimate genetic parameters

To obtain genetic parameters with very small estimation uncertainty requires very large data sets. 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 (Figure 3). 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 (Figure 4). Higher numbers would be needed to obtain good estimates of genetic correlations with other traits, particularly were those estimates expected to be in the region of 0.10-0.2 as in the case of $RFI_{pw\text{-}fat}$. The likely standard errors for different estimates, when records on 1000 progeny of 100 sires are assumed, are shown in Figure 5.

Figure 3: Estimated standard error of expected h2 from half sib progeny of 100 sires selected at random from the population (assuming no dominance) and minimal background differences



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).

Figure 4: Estimated standard error of expected h2 from half sib progeny of 50 sires selected at random from the population (assuming no dominance) and minimal background differences

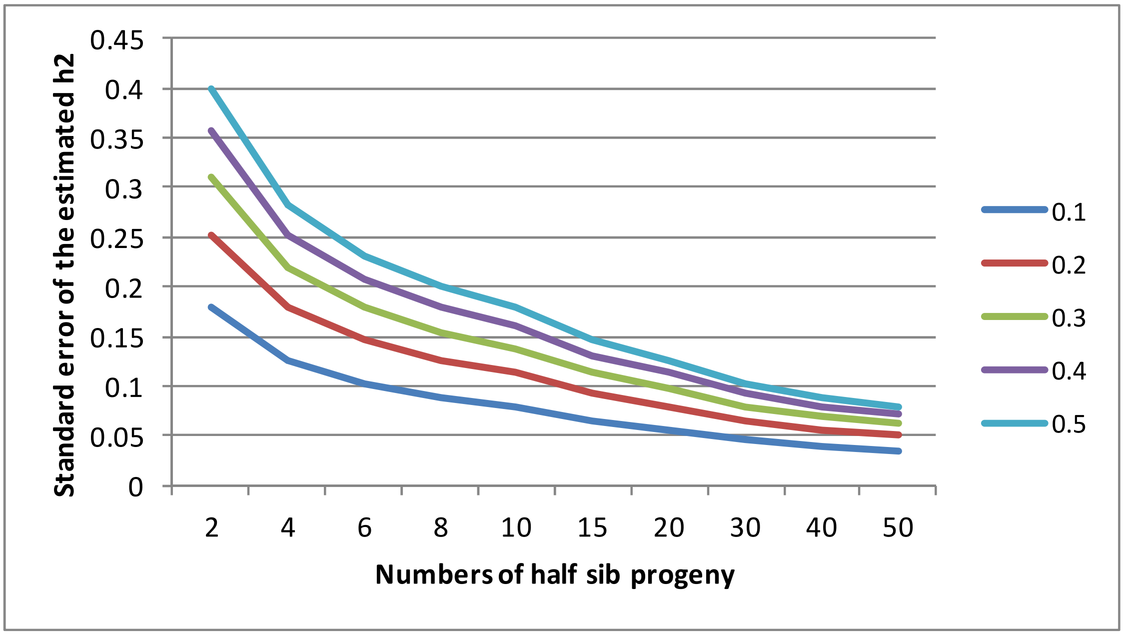
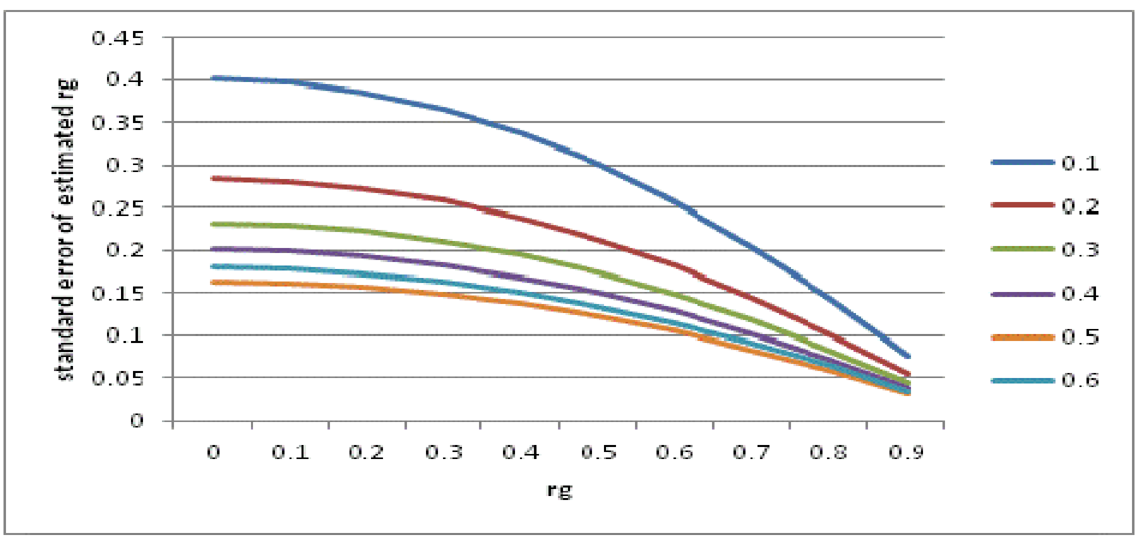


Figure 5: Estimated standard error of genetic correlations (ranging from 0.1 to 0.9) from half sib progeny of 100 sires with 10 half sib progeny each (assuming no dominance) for traits with equal h2 ranging from 0.1 to 0.6



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 would be considered as candidates for breeding.

The accuracy of an EBV 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. Table 8 illustrates the value of different familial information on the accuracy of an EBV for traits with two different heritabilities.

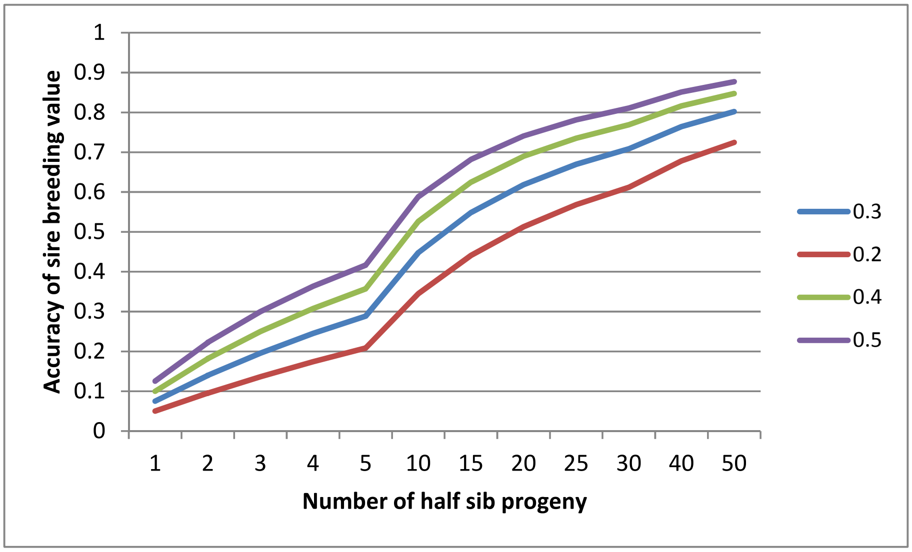
Table 8: The “value” of different sources of recorded information on the accuracy of an estimated individual breeding value

Information	h2=0.1	h2=0.3
Sire EBV (0.5)	0.25	0.25
Sire + Dam (0.5)	0.35	0.35
Sire + Dam (0.9)	0.51	0.51
Own performance (√h2)	0.32	0.55
Own + sire + dam	0.57	0.66
Mean of 10 half sibs	0.23	0.33
Mean of 1000 half sibs	0.49	0.50
Mean of 1000 full sibs	0.70	0.71
Mean of 20 progeny	0.58	0.79
Mean of 1000 progeny	0.98	0.99

If we assume (as done previously) that the main trait of interest is $RFI_{pw\text{-}fat}$, which has a heritability of around 0.3 and correlations with other recorded traits are very low (close to zero), then the values in Table 8 give a reasonably good approximation of the accuracy that would be expected given the availability of records on different relatives.

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. sires. 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 (Figure 6).

Figure 6: Accuracy of breeding values for sires with only records on half sib progeny for different heritability 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 countries and for some breeds, 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. Under those circumstances a correlation of 1 cannot be assumed.

Published estimates of the genetic correlation between purebred and crossbred performance are typically less than 0.7. In Table 9 we see that when the genetic correlation between purebred performance is 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 crossbreds 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 9 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 9: 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. 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. Such an approach should reduce the numbers of bulls needed to be tested to achieve a similar selection response. 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. Such an investigation was not possible within this study.

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 10 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 11). However it is important to note that the results in Table 11 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 10: 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 5*

Table 11: Impact of increasing the number of crossbred progeny tested per sire

	% change relative to n=15					
	n=5	n=10	n=15	n=20	n=25	n=30
Selection response						
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

Appendix 4: Economics of each recording option

This appendix details the process and assumptions that were made in calculating the estimated costs associated with each of the options for recording feed intake outlined in the main report. These costs are not designed to be a standalone assessment of the relative merits of each option but rather should be considered alongside the other information contained in the report.

1. Setup Costs

In order to provide as simple a comparison of the costs for the different systems under discussion as possible, it has been necessary to fix a number of the variables and to make some general assumptions about how a project like this could be implemented in practice. As in other parts of the report, a number of different systems are included considering both pure-bred and cross-bred setups in academic led (and recorded) and industry led (with owned or subcontracted recording). An additional scenario has been included for an industry led, subcontracted recording unit, with the producers retaining ownership of the cattle that are tested in the unit. Further discussion of the feasibility of this option is included in the full report.

Number of animals required to be recorded

It was assumed that 1800 animals are required to be recorded to enable the genetic parameters for a measure of feed efficiency to be estimated. It was also assumed that any dedicated facility established would have the capacity to record around 300 animals per batch and that it would be possible to record 3 batches of animals per year. Since the costs for building and equipping a unit are far greater than the annual running costs for a unit, it is assumed that 1800 recorded animals would be achieved on one facility over a two year period, rather than on two facilities recording for one year. As a result, for the academic led and industry led with own recording facility systems, the maintenance and labour running costs have been provided for a two-year period.

Building, equipment and sub-contracting

For the purpose of this comparison it was assumed that establishment of any new initiative that was academic led or industry led and owned, would require a new facility to be built and therefore the costs for building the unit are included in the calculation. The cost for building assumes that the site is already owned and therefore does not need to be purchased. If a site was required to be purchased this would likely add a significant sum to the total cost. For the equipment, it is assumed that GrowSafe units would be installed for each system as these are slightly cheaper than other options, require a lower level of technical and labour input, and provided data suitable for estimating genetic parameters. As the units are typically sold in 8 node units, it is assumed that 64 individual feeding nodes (i.e. 8 times 8 node units) would be required to record feed intake on batches of 300 animals (20 animals and 4 nodes per pen).

For the subcontracting option it was assumed that the cost of building and installing equipment in the unit would be covered by the subcontractor and recovered as part of a daily management fee (calculated here as 65p/animal/day) that would also cover all the day-to-day running costs for the system other than feed. However, it was assumed that the cost of the GrowSafe units was additional, and that there would be a cost associated with retro-fitting the units into the facility (£10K).

Labour

It was assumed that there were differences between units in staffing requirements. The industry led options both included a coordinator to deal with sourcing sufficient numbers of appropriate animals to be recorded. The cost budgeted for the coordinator includes travel and covers the two years predicted for setup of the genetic parameters. For the academic run facility, 2 stockmen, 2 technicians and 1 scientist would be required; however, these staff would also cover the coordination activities. Apart from a coordinator, the industry led with own recording facility has 2 stockmen budgeted, whereas in the industry led with subcontracted recording there are no additional direct labour costs (i.e. already included in the daily management fee).

Animal-related costs

There are some costs that will be essentially equal regardless of the system chosen, for example, feed, estimation of genetic parameters and setup for genetic evaluations. The veterinary costs are expected to be higher for pure-bred compared to cross-bred systems and for both cases in the industry-led, subcontracted recording system, these costs are covered by the management fee. Pure-bred systems will also require insurance costs for animals on the test facility to cover against disease outbreaks etc, although whether this would be covered by the unit operator or the producer is covered in the discussion in the main report.

An additional option for the industry led with subcontracted recording has been included in the cost table to cover a scenario where the animals remain owned by the producer. In this case, the producer would pay the management fee to the subcontractor as well as the feed costs etc and would therefore keep responsibility for any loss incurred on each animal. It was assumed that a fixed payment/discount of £75 per animal would need to be offered as an incentive to producers to engage in the project.

There are some other costs, not currently included, that would also need to be accounted for, e.g. transport of animals. Please also note that the costs represent those required to setup and generate ongoing RFI recording in one breed and so should be multiplied to consider more than one breed.

Table 1 details estimated costs to setup facilities for and record individual feed intake on 1800 animals.

2. <u>Ongoing running costs</u>

After the initial setup and recording of animals to estimate the genetic parameters for a measure of feed use efficiency, the facilities would need to be maintained to allow ongoing recording of animals for routine genetic evaluations. As the building and equipment costs have been covered in the initial setup they would not be required for this phase of the project. The other costs i.e. operation of the site and those costs relating to the animals in the facility, are expected to be the same as in the setup phase of the project.

Table 2 shows the expected costs per year, assuming that any facility was continued to be used at capacity (i.e. 900 animals per year).

Table 1: Estimated costs to setup facilities and record 1800 animals

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)
Capital costs (per facility)							
Building establishment	£500,000	£500,000	£350,000	£350,000	£10,000	£10,000	£10,000
Equipment and fitting costs	£400,000	£400,000	£400,000	£400,000	£400,000	£400,000	£400,000
Sub-total capital cost	*£900,000*	*£900,000*	*£750,000*	*£750,000*	*£410,000*	*£410,000*	*£410,000*
Non-capital, variable costs							
Building maintenance (2 years)	£40,000	£40,000	£30,000	£30,000	£421,200	£421,200	£0
Labour (2 years)	£480,000	£480,000	£160,000	£160,000			
Coordination (2 years)	£0	£0	£100,000	£100,000	£100,000	£100,000	£100,000
Non-capital, fixed costs							
Health programmes (per animal)	£30	£15	£30	£15	£0	£0	£0
Feed costs (per animal)	£160	£160	£160	£160	£160	£160	£0
Insurance	£350	£0	£350	£0	£350	£0	£0
Incentive payment (per animal)	£0	£0	£0	£0	£0	£0	£75
Genetic parameter estimation	£50,000	£50,000	£50,000	£50,000	£50,000	£50,000	£50,000
Setup for genetic evaluations	£30,000	£30,000	£30,000	£30,000	£30,000	£30,000	£30,000
Sub-total non-capital cost	*£1,572,000*	*£915,000*	*£1,342,000*	*£685,000*	*£1,519,200*	*£889,200*	*£315,000*
TOTAL	**£2,472,000**	**£1,815,000**	**£2,092,000**	**£1,435,000**	**£1,929,200**	**£1,299,200**	**£725,000**
TOTAL PER ANIMAL	**£1,373**	**£1,008**	**£1,162**	**£797**	**£1,072**	**£722**	**£403**

Table 2: Estimated annual ongoing running costs (recording 900 animals)

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)
Operational costs							
Building maintenance	£20,000	£20,000	£15,000	£15,000	£210,600	£210,600	£0
Labour	£240,000	£240,000	£80,000	£80,000			
Coordination	£0	£0	£50,000	£50,000	£50,000	£50,000	£50,000
Sub-total	*£260,000*	*£260,000*	*£145,000*	*£145,000*	*£260,600*	*£260,600*	*£50,000*
Animal-related costs							
Health programmes (per animal)	£30	£15	£30	£15	£0	£0	£0
Feed costs (per animal)	£160	£160	£160	£160	£160	£160	£0
Insurance (per animal)	£350	£0	£350	£0	£350	£0	£0
Subsidy (per animal)	£0	£0	£0	£0	£0	£0	£75
Sub-total	*£486,000*	*£157,500*	*£486,000*	*£157,500*	*£459,000*	*£144,000*	*£67,500*
Other costs							
Additional cost of running routine genetic evaluations	£250	£250	£250	£250	£250	£250	£250
TOTAL	**£746,250**	**£417,750**	**£631,250**	**£302,750**	**£719,850**	**£404,850**	**£117,750**
TOTAL PER ANIMAL	**£829**	**£464**	**£701**	**£336**	**£800**	**£450**	**£131**

A summary of these results is provided in the full report together with a discussion on the relative advantages and disadvantages of the different systems.