More Beef from Less Resources:

Targeting genetics that improve returns through feed efficiency of beef on dairy

Kellogg Rural Leadership Programme

Course 55 2026

Emma Owen

I wish to thank the Kellogg Programme Investing Partners for their continued support.

Disclaimer

In submitting this report, the Kellogg Scholar has agreed to the publication of this material in its submitted form.

This report is a product of the learning journey taken by participants during the Kellogg Rural Leadership Programme, with the purpose of incorporating and developing tools and skills around research, critical analysis, network generation, synthesis and applying recommendations to a topic of their choice. The report also provides the background for a presentation made to colleagues and industry on the topic in the final phase of the Programme.

Scholars are encouraged to present their report findings in a style and structure that ensures accessibility and uptake by their target audience.

This publication has been produced by the scholar in good faith on the basis of information available at the date of publication. On occasions, data, information, and sources may be hidden or protected to ensure confidentially and that individuals and organisations cannot be identified.

Readers are responsible for assessing the relevance and accuracy of the content of this publication & the Programme or the scholar cannot be liable for any costs incurred or arising by reason of any person using or relying solely on the information in this publication.

Scholar contact details may be obtained through the New Zealand Rural Leadership Trust for media, speaking and research purposes.

Executive Summary

The New Zealand dairy industry is a seasonal production system, requiring cows to calve annually to begin lactation. With an average herd replacement rate of approximately 22%, a large proportion of calves born each year are surplus to dairy replacement requirements (DairyNZ, 2021; Ministry of Primary Industries, 2022). As the industry seeks to move away from the current surplus calf model, there is an increasing need to develop profitable and sustainable pathways for these non-replacement calves. This raises an important question: how can greater value be created from surplus calves to improve both industry profitability and resource utilisation?

This project investigates the potential for genetic improvement in feed efficiency as a possible solution. The dairy industry faces a challenge of maximising the productivity and profitability of excess calves. To combat this, an increasing proportion of dairy cows are mated to beef sires. Improving feed efficiency of these sires and therefore the resulting progeny through genetic selection, can offer a promising solution. Enabling animals to convert feed into production more effectively while reducing production costs and environmental impacts.

A review of the literature was conducted to determine current knowledge and research available on feed efficiency, as well as identify opportunities for further development.

Trial data comprising of 371 animals, all tested using the same Vytelle SENSE feed efficiency facility, was analysed. Animals displayed normally distributed variation for Residual Feed Intake with a mean of 0.00 ± 0.68 with a range of 4.02. The trial results support findings from the literature, animals with improved feed efficiency consume less feed and have an ability to maintain growth and production.

Semi structured interviews were conducted on 17 industry stakeholders from a range of positions in the supply chain. Open-ended questions were asked to explore the motivations and barriers influencing beef on dairy strategies currently in place in New Zealand and Australia. As well as the potential for new growth in this space through the incorporation of feed efficiency and the implications of this on the wider industry.

Key Findings include:

The benefits of feed efficiency are achieved when animals maintain the same average daily weight gain but consume lower than average dry matter intake per day. Bringing the cost of production down on a per kg of liveweight basis. Feed efficient animals are therefore more profitable even if growth rates are similar.

Modelling conducted indicates that reducing the mean Average Daily Dry Matter Intake (ADDMI) of New Zealand's beef on dairy population by one kilogram of dry matter per animal per day could result in annual feed cost savings of approximately $51 million, while also freeing up enough feed to support an additional 87,500 animals

Feed efficiency traits are heritable; improvements are permanent and can be transferred across generations.

There is sufficient variation in feed efficiency within the population to enable effective selection to occur.

A strong correlation between improved feed efficiency and a reduction in enteric methane production enables feed efficiency to potentially be implemented as a methane mitigation strategy

Recommendations

- Further Research is required to: Develop a robust genomic model, to further investigate the possibility of utilising wearable technologies to record proxy traits, and to develop a better understanding of the linkage between feed efficiency to enteric methane production
- Industry education to demonstrate the value of improved feed efficiency and increase awareness of feed efficiency traits
- Develop a supply chain initiative for strategic sire selection
- Position feed efficiency as a dual-purpose productivity and emissions reduction trait
- Strengthen vertical integration and incentive signals

Acknowledgements

I would like to begin by acknowledging the Kellogg Programme delivery team. In particular, I would like to thank Lyndsey Dance, Craig Trotter, Renee Walker and Annie Chant for delivering an exceptional programme that is helping to develop and shape the future leaders of New Zealand's primary industries. I would like to extend the thanks to the guest speakers that gave up their time to speak to us. The Kellogg Programme has challenged my thinking, broadened my perspective, and motivated me to continue growing as a leader.

To my partner Troy, and my parents, thank you so much for your unwavering support, encouragement, and patience, not just through my Kellogg journey but always.

To Gary Kennett and Mal Montgomery, thank you for your continuous guidance, mentorship, and support it means so much to me. I would not be where I am today without your influence, and I am deeply appreciative of the opportunities, advice, and encouragement you have provided throughout my career.

A sincere thank you to the Meade family for hosting me and generously sharing your time, knowledge, and industry insights. The global perspective I gained throughout our discussions was invaluable and has significantly contributed to this project.

I would also like to thank my employer, CRV, for supporting me throughout my Kellogg journey. Your encouragement and willingness to provide the time and flexibility needed to fully engage with the programme is greatly appreciated.

Thank you to all the industry representatives who took part in my interviews. I appreciate the time you gave and greatly enjoyed our discussions.

Finally, thank you to the Kellogg 55 cohort. It has been a privilege to learn, grow, and share this experience alongside such an inspiring and passionate group of people. I feel privileged I have been able to experience this journey alongside you. I have no doubt that you will go on to make significant contributions to the food and fibre sector. I look forward to following your future successes.

Thank you all for your support, encouragement, and contribution to my journey.

Table of Contents

1. Introduction

Demand for New Zealand beef globally remains strong. New Zealand beef exports rose 6.9% in the year to March 2025 (Ministry of Foreign Affairs and Trade, 2025). Rising global beef prices, lower US cattle supply, and demand for grass fed beef have supported export growth (Ministry of Foreign Affairs and Trade, 2025). There is opportunity to more efficiently utilise New Zealand's powerful dairy herds to benefit from this global demand for beef.

The national New Zealand dairy herd rapidly expanded in the early 2000's, peaking in 2014 at 6.7 million cows (The Treasury, 2024). Since then, this has declined, the government imposed environmental restrictions and there has been a move to favour lower stocking rates but more efficient cows. Over the last 5 years total numbers have declined from 6.2 million to 5.75 million cows (StatsNZ, 2026). This has also caused changes in the utilisation of excess calves. As every cow must calve every year to bring her into lactation. The growth in the national herd created a strong demand for replacement heifers within the industry. There was also an opportunity and high value proposition for surplus dairy heifer calves to be live exported internationally. Annually New Zealand would live export upwards of 134,000 cattle. This was dissolved in 2023, coupled with a declining total herd number, creates a problem around the purpose of surplus calves in the industry (New Zealand Parliament, 2021; The Guardian, 2022).

The New Zealand dairy industry continues to increase the use of sexed semen to generate replacement heifers from its highest genetic merit cows (Rural News Group, 2024). At the same time, growing societal expectations and concerns around animal welfare have intensified pressure to reduce or eliminate the traditional bobby calf system. Currently New Zealand allows bobby calves, these are young calves usually between four and ten days of little value to be finished so are processed. Bobby calves give farmers a reliable outlet but the social license for the existence of bobby calves is running out. Milk companies are tightening up restrictions on numbers with a hope to move away from them altogether.

Consequently, a greater proportion of calves largely male will need to be integrated into productive supply chains that create value for both the dairy and beef sectors. This generates a challenge of how to best utilise the surplus calves. Using beef sires over the lower genetic merit dairy cows is the logical answer, this creates a "beef on dairy" calf that is of value for rearing and finishing. Over the last few years beef on dairy calves have grown in numbers and popularity, thought to be off the back of high global beef prices, supply chain pressure to reduce surplus calf slaughter, improved genetics and a want to create a more valuable product. However, a key challenge remains: how to finish an increasing number of animals within the constraints of limited land area and feed growing capacity.

There is increasing concern from society, export markets, policymakers, and the agricultural industry about the environmental impact of livestock production. As a result, there is a continual drive to improve production efficiency and reduce the environmental footprint of agricultural systems. In New Zealand, reducing greenhouse gas emissions while maintaining productivity is a key challenge facing the livestock sector.

This study considers the opportunity to further enhance the beef on dairy product through feed efficiency. It investigates why some animals "do more with less", can create higher liveweight gains off less feed. To explore the genetic and heritable links to feed efficiency that could be utilised to create successful sustainable and long-term value to beef on dairy calves.

1.1 Aim

The aim of this project is to investigate the potential of improved genetic feed efficiency as a value-add trait within New Zealand's beef on dairy industry. As the industry strives to reduce excess calves in the system, more dairy cows are mated to beef sires, the industry faces increasing pressure to maximise the productivity and profitability of the resulting progeny sustainably, while constrained by limited resources (land and feed). Feed efficiency improvements have the potential to address this challenge by creating a reduction in feed demand to produce the same amount of finished liveweight will allow more animals to be carried on existing resources. This report explores the role improved feed efficiency could play in New Zealand beef on dairy systems and the broader economic and environmental benefits associated with its adoption.

2. Literature Review

This literature review explores the current literature available on aspects of feed efficiency in cattle. The review focuses on the genetic component and some wider industry implications of feed efficiency. It investigates the ability to further develop genetic feed efficiency in the beef on dairy product and the potential barriers that would inhibit this.

2.1 Bobby Calves

The dairying system in New Zealand is largely seasonal, following the pasture curve. Cows calve in spring and milk through until late autumn/early winter when they are dried off in preparation for calving again in spring. Lactation lengths are targeted at 305 days.

The average dairy herd replacement rate in New Zealand is approximately 22% (DairyNZ, 2021; Ministry of Primary Industries, 2022). This replacement group is primarily made up of the highest genetic merit heifer calves retained for future herd replacements. The remaining calves are directed into alternative production pathways, including bull beef, beef on dairy systems, the sale of surplus replacement heifers, or they are processed as bobby calves.

Every year in New Zealand over two million calves between four and ten days of age are sent to be processed (Palmer A, et al, 2023). Bobby calves have become a major animal welfare, dairy efficiency, and dairy-beef integration issue in New Zealand agriculture. Subsequently, there is increasing industry interest in reducing bobby calf numbers by adding value to these animals, creating stronger economic incentives for them to be retained and utilised within other production systems.

Encouragingly bobby calf numbers are trending down. In 2025 numbers in the North Island reduced by over 18% and in the South Island 28% (CRV NZ , 2025). Thought to be caused by favourable beef prices over the past few seasons, along with improvements in the quality of beef genetics, increasing the uptake in beef on dairy strategies (Rabobank NZ, n.d)

2.2 Role of beef on dairy in New Zealand

The New Zealand beef industry is heavily dependent on the dairy industry, between 65-70% of beef slaughtered in New Zealand has dairy origins. This includes any cattle born on dairy farms or born to cows with dairy genetics. Highlighting how important dairy beef integrations are to the overall beef supply chain (Beef + Lamb NZ, n.d; Dairy Country n.d).

Beef sires are more commonly used over lower genetic merit or later calving cows in dairy herds. Designed to create a beef on dairy product that adds value to what otherwise would be a bobby calf. Significant genetic gains have been made in recent years to further enhance the beef on dairy product, including a focus on shorter gestation length, calving ease, growth rates and greater efficacy of sexed semen. Rabobank claims that beef on dairy has a potential value of excess of $1.2 billion annually if coordinated action across breeding, rearing and value chain can occur (Johnston, 2025). This report will investigate the opportunity to add value to the beef on dairy product through feed efficiency.

Beef on dairy refers to the breeding approach in which beef sires are strategically selected for use over dairy cows to produce crossbred calves with improved beef characteristics such as growth rate and carcase attributes. Dairy beef is the production and finishing system in which calves originating from dairy herds, including beef on dairy crosses, are raised and processed for beef production.

2.3 Defining Feed Efficiency

Feed efficiency is defined as the ability for an animal to convert feed into useful output such as body weight gain, milk, eggs, velvet or meat. In livestock production it describes how effectively an animal uses the nutrients and energy from feed to produce a product (Arthur & Herd, 2008)

2.4 Measuring Feed Efficiency

To successfully select for more feed efficient animals, individuals must be identified with a lower maintenance requirement (Silva C et al, 2023). There are several ways to measure feed efficiency in beef cattle. It is important to note that not all measures result in the same outcomes when used to make breeding decisions.

The most common measures for feed efficiency are Feed Conversion Ratio (FCR), Feed Conversion Efficiency (FCE), Residual Feed Intake (RFI) and Residual Average Daily Gain (RADG).

2.4.1 Feed Conversion Ratio

Feed Conversion Ratio is defined as feed intake compared to bodyweight gained, often applied at a group level rather than an individual animal basis (Berry D., 2008; Crews D. H., 2005). Animals with lower FCR's consume lower kg of feed per kg of body weight gained, (Figure 2)

FCR is one of the most widely used measures of feed efficiency, due to its ease of calculation, and its wide understanding, making it useful for comparing feed efficiency across animals, production systems, or time periods. It is a practical trait to measure, requiring only feed intake and weight gain. This means it is often used in many livestock production systems to monitor productivity, evaluate diets, and guide management decisions.

The main limitation of FCR is that it represents a gross measure of feed intake. Using FCR gives no way to distinguish between growth and maintenance requirements (Crews, 2005). This makes it difficult to select for animals with a lower maintenance requirement because FCR is representative of both growth rate and body size.

FCR has a strong correlation with growth rate, (Sainz et al., 2024). Arthur et al., (2001) reported a correlation of approximately 0.90 between FCR and growth rate. Due to the positive genetic correlation between the traits that make up FCR, Dry Matter Intake (DMI) (numerator), and the, Average Daily Gain (ADG) (denominator),selecting animals for improved FCR tends to lead to cattle that grow more rapidly but also reach a larger mature size and have higher maintenance energy requirements (Koots et al., 1999; Berry D. P. & Crowley J. J., 2012; Sainz et al., 2024).

2.4.2 Feed Conversion Efficiency

Feed Conversion Efficiency (FCE), the inverse of FCR (body weight gain divided by feed intake), is occasionally used as an alternative measure. While FCR expresses how much feed is required to produce a unit of gain, FCE expresses how efficiently feed is converted into body weight (Berry D., 2008). Both measures share the same inherent limitations.

2.4.3 Residual Feed Intake

Residual feed intake (RFI) was first proposed by (Koch R. M. et al., 1963). It is defined as the difference between actual feed intake and the expected feed requirements for maintenance of body weight and for weight gain. This is shown in Figure 1, lower RFI animals have the same average daily gain but consume less feed than expected. RFI is now a widely used concept in research and is increasing in frequency in breeding programmes.

(Sainz & Paulino, n.d; Sainz R. et al., 2023) found RFI to be a more accurate measure of feed efficiency because it separates intake into two different components, feed intake for a given level of production (expected intake) and residual (actual intake).

Importantly RFI measures feed efficiency independently of production traits like body size and daily gain in beef cattle and liveweight and milk production in dairy cattle (SAI (Berry D., 2008;Herd R. M & Arthur P. F., 2009). RFI is considered a more valuable trait to select for in a breeding population because it does not compromise other economically viable traits. Its ability to do this has meant RFI has grown in popularity in recent years (Detweiler et al., 2019;Berry D., 2008).

A graphical illustration of how RFI is calculated is shown in Figure 1**.** When using of the least square regression method. When using RFI to select cattle, low RFI animals are more efficient than high RFI animals. Figure 1 displays an example of how high or low RFI animals are defined in a population. The actual RFI of the individuals are displayed as the square dots and predicted dry matter intake (DMI) for the series of individuals is shown as the continuous line. Dots (individuals) that are above the predicted DMI line have positive RFI values (less efficient) while individuals below the predicted DMI line have negative RFI values (more efficient) (Berry D., 2008).

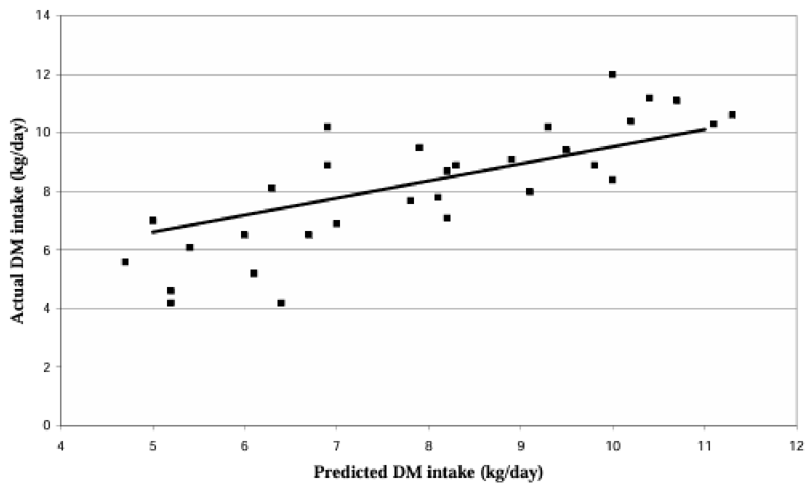

Figure 1- Scoured from Berry D., (2008).

2.4.4 Residual Average Daily Gain

Residual Average Daily Gain (RADG) is another commonly used measure of efficiency. RADG expresses the difference between an animal's actual weight gain and its predicted gain based on its DMI, body weight maintenance and fat cover (Wells, 2015). High RAGD animals have higher ADG for the same intake, (Figure 2)

At a surface level the concept of RADG appears to be similar to RFI as they both contain similar components, however, the two concepts work in very different ways. RADG standardises an individual's feed intake to compare differences in ADG, while RFI adjusts for growth and body size to evaluate differences in feed intake (Idowu, M et al., 2026). When using RADG as a selection tool, cattle with higher values are more desired as they have a greater ADG for the same amount of feed, the opposite is true for RFI.

2.4.5 Feed Efficiency Measures Comparison

There are advantages and disadvantages for each feed efficiency measure. The ratio traits (FCR FCE and RADG) are easy to calculate, explain and practically apply on farm. However, they are highly correlated with the traits used to calculate them. When genetic selection pressure is applied to either the numerator or denominator the effect is not evenly applied to both parts of the ratio. This can create unintentional consequences by placing more emphasis on selection for either reducing feed intake or increasing growth rate, depending on which trait varies more genetically.

Residual feed intake is advantageous because it is independent (either phenotypically or genetically depending on how it is calculated) from the regressor traits, allowing RFI to be applied without affecting production traits.

The disadvantages of RFI are that it is more difficult to calculate and can be more difficult to thoroughly explain. Depending on the method of calculating, sample population results may not be comparable to other populations including within population over time unless all raw data, including information on any potential changes in management and diet, is available.

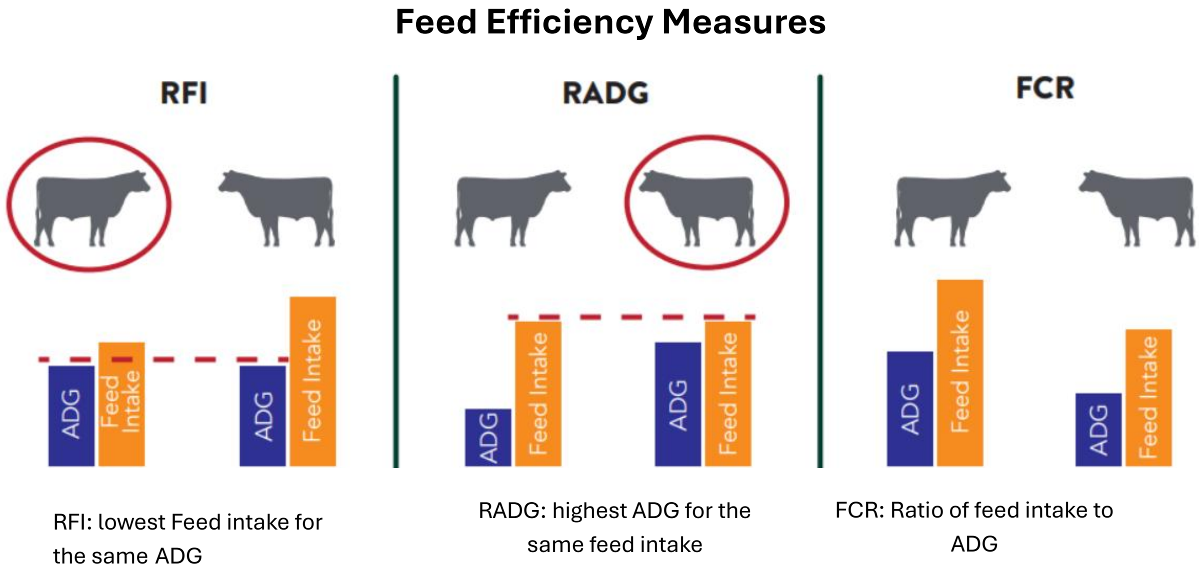

Figure 2- sourced from Vytelle. (n.d.) displays the differences in ADG and feed intake for animals selected for improved RFI, RADG and FCR as a feed efficiency measure

Figure 2 displays the differences in ADG and feed intake for animals selected for improved RFI, RADG and FCR as feed efficiency measure.

2.5 Physiological Differences

Genetics play a major role in determining feed efficiency. Cattle with improved feed efficiency can inherit traits associated with improved digestion, metabolism, cellular function and lower maintenance energy requirements (Basarab et al., 2013).

The most significant difference nutritionally between more and less feed efficient animals is the maintenance requirement. Maintenance energy refers to the energy needed for essential bodily processes such as respiration, circulation, digestion, and temperature regulation. Richardson and Herd (2004) reported that cattle with low RFI, often exhibit lower metabolic activity and reduced heat production. This allows a greater proportion of consumed energy to be directed toward productive functions such as muscle growth rather than basic maintenance.

Differences in body composition are another important physiological factor. Feed efficient cattle often deposit less internal fat and produce more lean muscle tissue compared with inefficient cattle (Basarab et al., 2013). Fat deposition requires more energy than muscle growth, meaning animals that accumulate excess fat tend to use feed less efficiently. Although Arthur et al. (2004) proved that it is possible for an animal to be feed efficient and maintain adequate fat levels. It is possible to achieve this through selection in a multi trait programme as RFI can be selected for in conjunction with other desirable traits

Hormonal regulation may also contribute to the observed differences. Efficient cattle may demonstrate improved regulation of hormones such as insulin and leptin, which influence appetite, metabolism, and nutrient partitioning (Herd & Arthur, 2009).

Feeding behaviour and activity levels differ between efficient and inefficient cattle. Nkrumah et al. (2006) showed that efficient cattle may spend less time eating, consume feed more slowly, and display lower levels of physical activity. Reduced activity lowers energy expenditure, contributing to improved feed conversion efficiency. Additionally, some evidence suggests that efficient cattle may have calmer temperaments and reduced stress responses, which can positively affect growth and metabolic performance (Llonch, P et al. 2016).

At a cellular level there are differences in the linkages of protons across the inner mitochondrial membrane that explains a very large part in the variances in feed efficiency. The linkage in the protons creates a gradient which affects how efficiently those protons turn into ATP (energy) (Sainz et al., 2024). More efficient animals are better able to convert that proton gradient into ATP. Increased mitochondrial function allows cattle to generate energy using fewer nutrients and less oxygen, reducing wasted energy and improving productivity (Richardson & Herd, 2004).

An animal's digestive system, particularly the rumen also impacts variances in feed efficiency. The rumen contains microorganisms that break down fibrous plant material and produce volatile fatty acids, which provide energy to the animal. Feed efficient cattle tend to possess rumen microbial populations that are more effective at extracting nutrients and converting feed into usable energy (Herd & Arthur, 2009). As a result, efficient cattle lose less energy to digestion and methane production. Methane is produced during rumen fermentation and is associated with a loss of energy that could otherwise be used for production (Nkrumah et al., 2006).

The data suggests that more feed efficient animals have more effective energy systems in general which leads to a better utilisation of consumed nutrients into energy. Other energy outputs such as heat loss and methane appear to often be reduced in these individuals.

2.6 Heritability

Heritability is a measure used in genetics to describe the proportion of variation in a trait, that is due to genetic differences among individuals, rather than environmental influences (Visscher P.M, et al, 2008). It is expressed as a value between 0 and 1, higher values indicate that genetics plays a larger role than the environment in determining the expression of the trait.

Heritability is important because it helps predict how effectively a trait can be improved through selection, traits with higher heritability tend to respond more quickly to genetic selection. Heritability is not necessarily constant in a population (Visscher P.M, et al, 2028).

RFI is a complex multi-gene trait, many different genes influence the resulting phenotype. However, there is conclusive evidence from the literature that RFI is heritable, although there is some debate in terms of the level of heritability. Berry D. P. & Crowley J. J., (2012) estimated through meta-analysis of 39 published articles that RFI in cattle had a range in estimated heritability of 0.07–0.62 and a median heritability of 0.33 ± 0.01.

RFI in cattle has a comparable heritability to other commonly selected for commercially relevant traits (McFarlane C. E., 2023 ;Koots K. R. et al., 1994;Kuehn L, 2026).

Table 1- the predicted heritability of commonly selected for production traits

Trait	Approximate Heritability (h^2)
Birth Weight	0.30 - 0.45
Weaning Weight	0.20 - 0.40
200 Day Weight	0.30 - 0.45
400 Day Weight	0.25 - 0.50
600 Day Weight	0.35 - 0.60
Average Daily Gain	0.25 - 0.50
Mature Cow Weight	0.40 - 0.70

Table 1 shows that RFI has comparable heritability to commonly selected in production traits. This enables genetic gain in RFI to be as effective as gains made in traits such as birth weight and growth.

2.7 Breeding Values

Breeding values are implemented within breeding programmes to estimate the genetic merit of an animal for a particular trait and to determine the value of that animal as a parent. A true Breeding Value (BV) represents the additive genetic effect that an animal can pass to its progeny (GenScript, n.d.). As progeny receives half its genes from each parent, the expected genetic performance of the progeny is based on half the BV of the sire and half the BV of the dam.

2.7.1 Estimated Breeding Values

In practice, the true BV cannot be measured directly, so breeders use Estimated Breeding Values (eBV's). eBV's are calculated using statistical models that combine information from the animal's own performance (phenotype), pedigree information from relatives, and performance records from progeny. These models remove environmental effects and estimate the genetic component of traits of interest (Das et al., 2021).

2.7.2 Genomic Breeding Values

As technology has advanced, breeding programmes have begun to include genomic breeding values (gBV's). These genomic predictions capture the actual genetic relationships between animals and improve accuracy of predictions of genetic merit (VanRaden, 2008).

gBV's are estimated by combining genomic marker information with phenotypic and pedigree data to improve the accuracy of genetic evaluation. Genetic markers such as Single Nucleotide Polymorphisms (SNPs), which are distributed across the genome, capture genetic differences between animals and help identify regions of DNA associated with economically important traits (Meuwissen et al., 2001). This process works by analysing large reference populations that contain both genomic data and performance records for traits such as growth rate, fertility, and feed efficiency. Statistical models are then applied to identify associations between DNA markers and these traits, allowing researchers to estimate how strongly specific markers contribute to genetic variation within the population (VanRaden, 2008).Once these associations are accurately established, young animals can be genotyped and their gBV's estimated even if they have not yet produced offspring or recorded performance data, resulting in shorter generation intervals and accelerated genetic gain.

Due to the heritable nature of feed efficiency traits, gBV's for feed efficiency have been developed called Net Feed Intake (NFI) which is conceptually the same as RFI (actual intake – expected intake) (BreedPlan, n.d). Widely used in Australia and North America, NFI is developed in and largely suited to feedlot systems. Therefore, NFI has not been commonly implemented in New Zealand, as a lack of research in local conditions or pastural systems result in low reliability. A large investment in gathering genetic and phenotypic data would need to be made for improvements to be seen.

2.8 Hybrid Vigour

Hybrid vigour, or heterosis, refers to the phenomenon where crossbred offspring outperform the average performance of their purebred parent, and in some cases, performance exceeds both parents (Mishra et al., n.d.). Heterosis results from favourable interactions among genes inherited from genetically diverse parents, (Cassell, 2007). Because these genetic interactions are complex and involve multiple genes, inheritance of heterosis is often non-linear and hard to predict.

The degree of heterosis generally increases with the genetic distance between the parent breeds. For example, crosses between unrelated breeds, such as Angus and Brahman, typically exhibit greater heterosis than crosses between more closely related breeds, such as Angus and Hereford, due to higher levels of heterozygosity.

2.9 Pasture vs Ration

Pasture-based and feedlot (ration based) cattle fattening systems differ in their effects on feed efficiency, largely due to differences in diet composition, digestibility, and energy availability. Feedlot systems often achieve higher feed efficiency than pasture-based systems because they rely on high concentrate, energy dense diets that maximise nutrient utilisation and can be tailored to different growth stages (Owens et al., 2010; NRC, 2016).

In feedlot systems, cattle are typically offered Total Mixed Ration diets (TMR) composed of cereal grains combined with protein supplements and roughage. These diets are highly digestible and rich in readily fermentable carbohydrates, which increase the availability of Metabolisable Energy (ME) per unit of feed consumed. These rations promote more efficient rumen fermentation, reducing energy losses and improving growth efficiency (Beauchemin et al., 2009; Owens et al., 2010). As a result, feedlot cattle generally have faster growth rates and lower FCR, resulting in less feed required per unit of liveweight gain (NRC, 2016).

In contrast, pasture-based systems rely on grazed forages, which are typically lower in energy density and more variable in quality. Even high-quality pasture contains increased levels of fibre, which reduce digestibility and limit the amount of energy that can be extracted from the diet. This results in greater energy losses during rumen fermentation, particularly as methane, and reduces overall feed efficiency (Van Soest, 1994; Mertens, 1994).

Variation in RFI in pasture-based systems that are not present in feedlots is predicted to be caused by increased energy expelled during grazing. Pasture grazing systems require increased physical activity due to walking and browsing, variation in pasture quality and availability, and differences in behavioural traits such as grazing selection. Therefore, some cattle that perform well in controlled feedlot environments may not perform as strongly under pasture conditions (known as re-ranking), while others may improve their relative performance.

Herd & Bishop, (2000) found only moderate correlations between feed efficiency measured in feedlots and pastural grazing conditions. This means some animals maintain high rankings across both systems, while others experience significant reranking. For example, an animal selected for superior grain conversion efficiency may expend more energy walking in pasture systems therefore are less efficient in this grazing environment. Alternatively, animals well adapted to forage digestion and grazing behaviour may outperform others under pasture conditions despite average feedlot performance (Kenny et al., 2018). As a result, New Zealand breeding programmes are increasingly focused on measuring feed conversion under forage diets rather than relying solely on overseas feedlot data.

The implications of improved feed efficiency on pasture for New Zealand agriculture are substantial. Because New Zealand's beef on dairy and beef industries depend heavily on pasture systems, selecting animals exclusively from feedlot tested genetics will not optimise productivity under local conditions. It is important to promote breeding objectives that emphasise pasture performance, feed efficiency on forage, and environmental sustainability in New Zealand. This approach aims to improve profitability while also reducing methane emissions and environmental impacts.

2.10 Methane and Greenhouse Gases

Methane is the primary component of natural gas and is responsible for approximately a third of the warming we are experiencing today. An estimated 60% of methane emissions are from agricultural, coal mining, landfills, natural gas and oil activities, the rest are from natural resources (UN Environment program, 2026; Mohajan. H, 2012).

Methane is considered especially harmful for climate change as it traps heat far more effectively than carbon dioxide (CO_2) over reduced time periods (Wuebbles, D. 2022). The life span of methane is far shorter than CO_2, an estimated 12 years compared with +100 for CO_2. However, molecule for molecule, methane warms the atmosphere significantly faster than CO_2. Methane delivers a large warming burst quickly. Over a twenty-year period, methane produced 80+ times more heat than CO_2 but over a 100-year period that reduces to an estimated 28-34 times more heat(UN Environment Program, 2026).

In recent years, increasing attention has been placed on reducing greenhouse gas (GHG) emissions from New Zealand's agricultural sector. Methane accounts for approximately 48% of New Zealand's gross greenhouse gas emissions, with around 91% of this methane originating from enteric fermentation in ruminant livestock (Climate Change Commission, 2024). Due to methane's high global warming potential and relatively short atmospheric lifespan, reducing methane emissions is considered a critical strategy for mitigating climate change. In October 2025, the New Zealand Government reaffirmed its 2050 emissions targets, aiming to reduce biogenic methane emissions by 14–24% below 2017 levels (New Zealand Government, 2025).

Enteric methane is produced as a by-product of microbial fermentation within the digestive tract of ruminants. Methanogenic archaea break down structural carbohydrates from feed, generating hydrogen (H_2) and CO_2, which are subsequently converted into methane and expelled primarily through eructation (Danielsson et al., 2017; Hook et al., 2010). In addition to its environmental impact, methane production represents a loss of dietary energy that could otherwise contribute to animal growth and productivity, making methane emissions both an environmental and production inefficiency (Johnson & Johnson, 1995; Tseten et al., 2022).

Livestock, in particular cattle because of the scale in which they are farmed, have been broadly branded as major emitters of methane and significant drivers of climate change (Liu et al., 2021). Livestock production has been growing to meet the global food demand, however, increasing demand for production does not necessarily result in a proportional increase of methane production.

Feed intake and quality of feed has a substantial influence on methane production through its effects on rumen function. Increased feed intake and/or intake of poor-quality feed generally raises rumen volume and the availability of fermentable substrate, promoting greater digestion of structural carbohydrates and consequently increasing hydrogen supply for methanogenesis (Gomes et al., 2013; Hegarty et al., 2007 ;Datt et al., 2017)

Animals with low RFI emit less methane than high-RFI animals. Nkrumah et al. (2006) reported moderate positive correlations between RFI and both daily methane production and energy lost as methane ($r = 0.44$; $P < 0.05$), indicating that less feed efficient animals tend to produce greater methane emissions. Similarly, Johnson et al. (2022) demonstrated a linear relationship between dry matter intake (DMI) and methane production (g CH_4/day). (Herd et al., 2004) suggest that low RFI cattle have an ability to eat less feed for the same growth and body size, less methane is produced because they generally consume less dry matter (DMI), therefore reduce rumen fermentation which results in the observed reduction in methane production. Low RFI cattle have more efficient energy production systems in general therefore they partition energy into production rather than outputs such as heat and methane (Nkrumah et al., 2006). Selecting for cattle for lower RFI may reduce methane emissions without negatively affecting animal growth or productivity.

Genetic selection presents a sustainable long-term strategy for simultaneously improving feed efficiency and reducing methane emissions in ruminants. Methane production and RFI possess moderate heritability, cumulative genetic gain across generations is achievable (de Haas et al., 2011). However, the implementation of these traits in commercial breeding programmes remains challenging due to the difficulty and expense associated with obtaining accurate large-scale phenotypic measurements for methane emissions and feed efficiency.

2.11 Effect of Selection for Feed Efficiency on Carcass Quality

There is apprehension that selecting for improved feed efficiency in beef cattle will negatively impact carcass quality, particularly carcass fatness. Adequate fat cover is important for carcass grading and market value. Fatness is associated with eating quality traits such as tenderness, juiciness, and flavour. Selection for low RFI is often associated with leaner animals because feed efficient cattle consume less feed than expected for their growth and body weight (Herd & Arthur, 2009). Fat tissue development requires more energy than lean tissue growth, animals with lower RFI may have less surplus energy available for fat accumulation (Kenny et al., 2018). As a result, feed efficient cattle are often reported to have reduced subcutaneous fat thickness and overall carcass fatness which can have an adverse effect on carcass quality and therefore value.

Concerns have also been raised regarding low RFI selection impacting on intramuscular fat (marbling). As marbling is a key determinant of meat quality and carcass grading in many beef markets, any reduction in this trait may represent a trade-off when selecting for improved feed efficiency. Several studies have reported either unfavourable or neutral associations between low RFI and marbling. Richardson et al. (2001) and Nkrumah et al. (2007) found that cattle with lower RFI tended to exhibit reduced marbling scores, although the magnitude of this relationship varied between populations and production systems. In contrast, Berry and Crowley (2013) reported only weak or negligible correlations between RFI and marbling, suggesting that genetic improvement in feed efficiency can be achieved with minimal impact on carcass quality. These findings support the use of multi-trait selection approaches, where improvements in feed efficiency can be achieved alongside economically important carcass traits, enabling genetic progress without compromising meat quality.

In terms of broader meat quality traits, the effects of selection for feed efficiency appear to be limited. Most studies report little to no consistent impact on tenderness, ultimate pH, or meat colour. Some reductions in sensory attributes such as juiciness and flavour have been suggested, likely as a consequence of lower intramuscular fat content, but these effects are generally small and inconsistent across production systems (Cafe et al., 2011; Herd & Arthur, 2009).

2.12 Effect of Selection for Feed Efficiency on Fertility

Selection for improved feed efficiency, particularly for low RFI, as discussed above is associated with reduced body fat reserves. Body fat reserves are critical for reproductive function because they provide an energy buffer to support key physiological processes such as puberty onset, oestrous cycling, conception, and early pregnancy maintenance. More feed efficient cattle typically consume less feed and deposit less fat, which alters energy balance and endocrine signalling pathways involved in reproduction (Herd & Arthur, 2009; Berry & Crowley, 2013). This will not be further discussed in this report as it is irrelevant to beef on dairy (a terminal product) but should be considered if feed efficiency is targeted within a breeding programme.

2.13 Effect of Feed Quality on Feed Efficiency

Digestibility of a feed is an influential factor affecting feed efficiency. Diets with higher digestibility allow animals to extract more ME per unit of feed consumed, improving growth rates or production at a given intake level (Waghorn G. C. n.d.). Poor-quality forages, which contain higher levels of structural carbohydrates, are less digestible with slow rumen passage rates, limiting voluntary intake and reducing overall efficiency. As a result, animals consuming low-quality diets must eat more to achieve similar performance, often with reduced efficiency (Mertens, 1994).

2.14 Incentives

More frequently incentives are being offered to producers who can prove they are reducing greenhouse gas emissions in their system. In New Zealand both Westpac and BNZ banks offer sustainability linked loans, that provide financial incentives tied to sustainability standards and emissions reductions (BNZ, 2022; Westpac NZ, 2023). Banks increasingly see climate exposure as a financial risk.

Large agribusinesses such as Pāmu, Silver Fern Farms, Fonterra and T&G Global have secured sustainability-linked finance where interest margins improve if climate and environmental targets are achieved (Westpac NZ, 2021;Silver Fern Farms, n.d.; Fonterra, 2022;T& G Global, 2022).

In New Zealand and internationally, large companies are more frequently being required to measure, disclose, and move towards reduction of greenhouse gases associated with their operations and products. Gradually there is an expectation of companies to account for emissions associated with products and supply chains. through their own activities, but also for emissions occurring throughout their supply chains and product lifecycles. These indirect emissions, known as scope 3 emissions, can include those associated with purchased goods and services, transport, and, in the case of agricultural products, emissions generated on farm. Many businesses are seeking to better understand, measure, and manage these emissions by engaging with suppliers, setting emissions reduction targets, and favouring lower-emission production systems. This is predicted to result in a demand for products to be sourced from low GHG emitting systems. The requirements differ depending on the sector and the type of emissions involved. Currently agriculture remains only partly covered (Ministry for the Environment, 2023). Increasingly consumers and export markets are conscious of their effect on the environment, calling for larger corporations to provide proof of lower-emission products and are driving this change.

3. Methodology

3.1 Data collection

This project used a mixed-methods approach to evaluate the on farm and wider industry implication of implementing a genetic component to feed efficiency in the New Zealand beef on dairy space. Data sources included a literature review to understand what research had already been undertaken and where the gaps are, an evaluation of a trial data set, as evidence to prove or disprove claims made in the literature and semi-structured interviews with industry stakeholders.

Mixed methods are recognised as a robust approach, allowing for incorporation of qualitative and quantitative data to enhance the strength and depth of insight (Schoonenboom & Johnson, 2017). This approach is particularly valuable in agricultural and animal science research, where integrating numerical data sets with contextual and experience information can improve interpretation and strengthen conclusions (Tariq & Woodman, 2013)

3.2 Quantitative research

Individual feed efficiency data was collected through Vytelle SENSE feed efficiency trials, which utilise individual feed intake and liveweight measurements to assess animal performance. Cattle are tested in contemporary groups and undergo a 10-day to 2-week adaptation period prior to the commencement of the trial to allow for diet and environmental adjustment. Depending on the objectives of the trial, the testing period typically ranges from 49 to 70 days.

Feed intake is measured using specialised feed “bunks” mounted on load cells that continuously record feed weight. Each bunk is equipped with an Electronic Identification (EID) reader that records an animal's identification tag whenever it places its head into the bunk to feed. Feed intake is determined by calculating the difference in feed weight before and after each feeding event.

Liveweight is monitored throughout the trial. Animals are weighed at the beginning and end of the testing period, with additional weight measurements collected at predetermined intervals. Walk over scales located at water troughs record front feet weights, which are then used within an algorithm to estimate liveweight.

Following completion of the trial, a range of feed efficiency traits can be calculated, including Residual Feed Intake, Average Daily Gain, Feed Conversion Ratio, Dry Matter Intake, liveweight gain, and contemporary group rankings for feed efficiency.

The trials were carried out on of rising 1 year old steers, heifers and bulls from 3 different farms and 9 different cohorts, while this is a large enough sample to give an indication of the current feed efficiency trait parameters it in not representative of the total population.

With permission from the owners, a raw dataset comprising 371 animals tested through the same Vytelle SENSE feed efficiency facility was obtained for use in this study. At the request of the owners, details relating to the facility and data source have been kept confidential.

3.3 Qualitative Research

A sample of 17 stakeholders from a range of areas in the industry were interviewed to give a wide array of perspectives on feed efficiency. Including dairy farmers, beef farmers, stud stock producers, feedlot owners, calf rearers, beef finishers, scientists, meat company representatives, rural professionals, breeding company representatives and a breed society representative. Stakeholders were interviews from Australia (7) and New Zealand (10) to gain a broader range of perspectives on the topic.

A mixture of face-to-face and video semi-structured interviews were conducted over three months (March-May). Open-ended questions were asked to the stakeholders to explore the motivations and barriers influencing beef on dairy strategies currently in place in New Zealand. As well as the potential for new growth in this space through the incorporation of feed efficiency and the implications of this on the wider industry.

Interviewees signed the Kellogg Rural leadership Programme standard consent form prior to the interview. That confirmed they were willing to partake in the project, and their answers would remain confidential and if direct quotes were used, their identity would not be revealed.

3.4 Data analysis

The collected information from interviews was qualitative in nature with results examined using thematic analysis. Thematic analysis is a method for identifying, analysing, and reporting patterns within data (Ahmed S. et al, 2025). This was completed manually by analysing interview transcripts. The aim was to identify core themes and sub-themes, commonalities and differences between the interviewees. That were then reviewed and validated by the research.

The raw data was analysed through basic statistical analysis, with the aim to gain some understanding towards agreeing or disagreeing with the findings in the literature.

3.5 Ethical considerations

An initial research proposal was submitted to Dr Craig Trotter, the professor overseeing the Kellogg programme. This provided assurance that necessary ethical considerations were taken into account. The semi-structured interview questions can be found in the Appendix. The questions were reviewed by Dr Trotter prior to the interviews.

4. Research Results - Quantitative

The data set involves 371 rising one animals that have been trialled through the same Vytelle SENSE feed efficiency facility. This data set involves raw trial results from 3 different breeding programmes (farm A, Farm B, Farm C), 9 different cohorts, three different breeds. The data consists of majority bulls (230) steers (57) and heifers (48).

Table 2 - displays the gender split, start weight, end weight, ADDMI and ADG of participants in the data set

	Number of participants	Start weight Mean (kg)	End weight mean (kg)	Average Daily Gain Mean (kg)
Bulls	230	351	445	1.42
Steers	57	255	313	1.08
Heifers	48	286	323	1.42
Total Participants	371	297	360	1.42

Table 2 displays the total number of number of animals that the data set is comprised of. It displays gender split, start weights, end weights, average daily dry matter intake and average daily gain.

Table 3- displays minimum, maximum, range, average and median values of the participants in the trial for key feed efficiency traits

	Minimum	Maximum	Range	Mean	Median
Average Daily Dry Matter Intake (kg)	5.31	13.21	7.9	8.97	8.92
Residual Feed Intake	-2.00	2.02	4.02	0.00	0.06
Feed Conversion Ratio	4.16	11	6.84	6.78	6.67

Table 3 displays the variation within the participants in the trial for key feed efficiency measures, average daily dry matter intake, residual feed intake and feed conversion ratio. The table shows large variation exists with the population for feed efficiency traits.

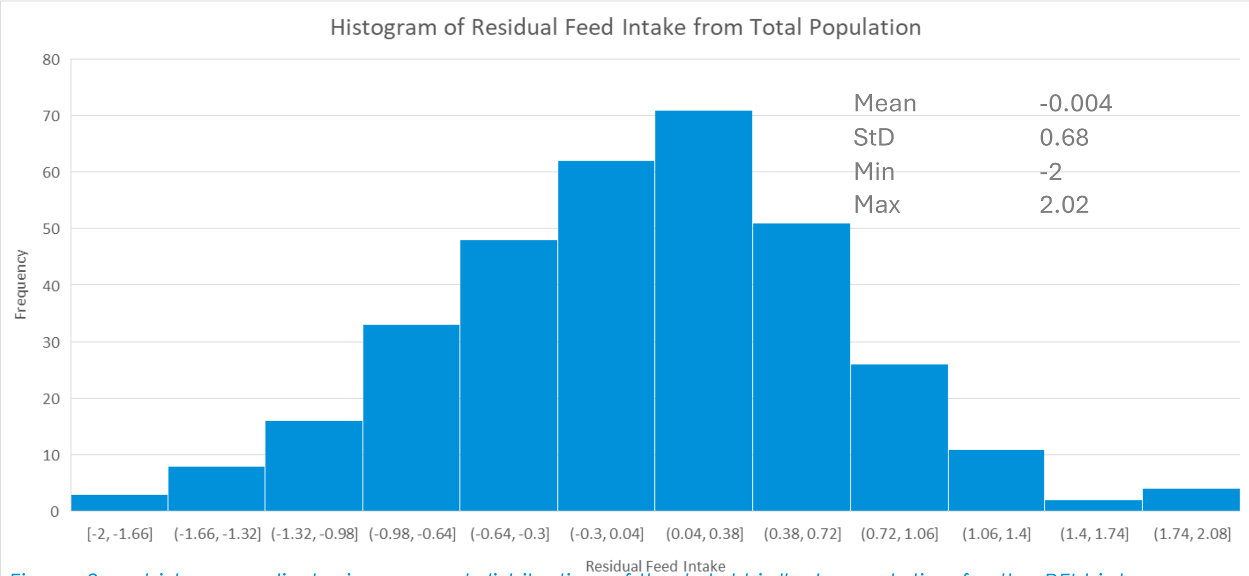

Figure 3 - a histogram displaying normal distribution of the total trialled population for the RFI trial

Figure 3 reveals the spread of RFI for the total trialled population of rising 1 purebred beef cattle. The RFI mean was -0.004. The data was normally distributed with an even standard deviation of 0.68 the most efficient animal had an RFI of -2, the least efficient had an RFI of 2.02

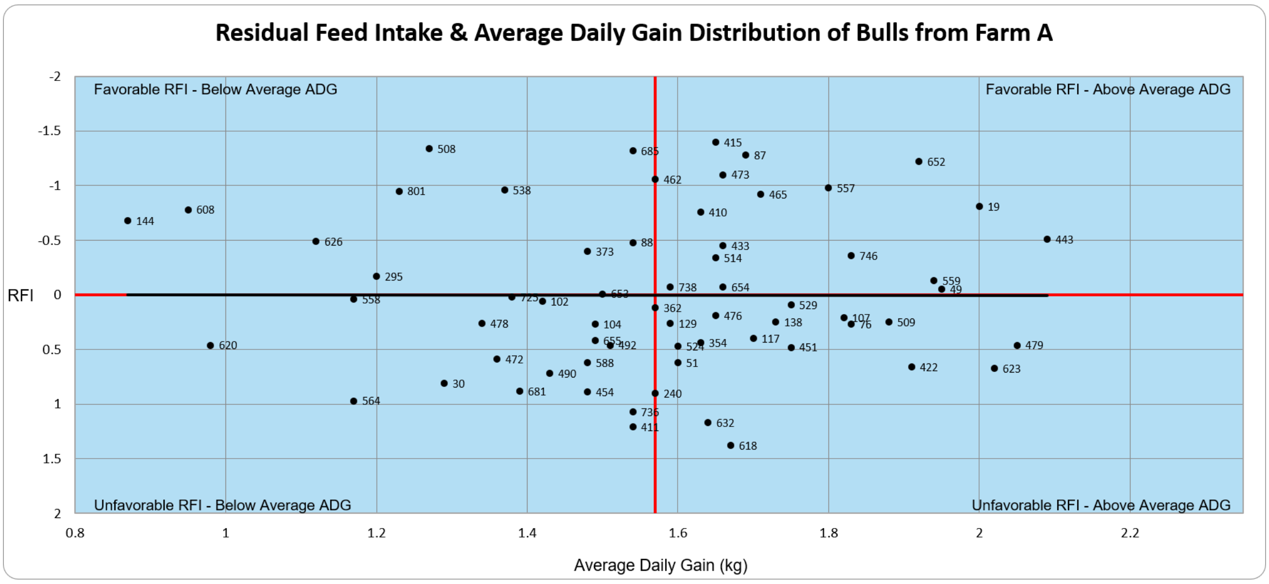

Figure 4- RFI and ADG scatter plot of a trial population of rising 1 bull's from Farm A. It shows the distribution with the population of ADG and RFI performance.

Figure 4 is a scatter plot of Residual Feed Intake and Average Daily Gain information from bulls from Farm A. taken from result of the Vytelle feed efficiency feed lot. It shows the distribution of the animals. The black line in the centre is a trend line which shows there is no correlation between ADG (growth) and RFI, the two traits are not correlated therefore RFI can be selected for in the population with no impact on growth.

5. Research Results - Qualitative

Seventeen interview participants where asked a series of questions focused on their perspective and experiences with feed efficiency, beef on dairy within the agriculture industry. These respondents comprised of:

- Representatives of primary producers (dairy farmers, beef farmers, stud stock producers, calf rearers)
- Stock agent
- Representatives from the meat processing sector
- Representatives from the research sector
- Representatives from genetic companies
- Vytelle SENSE feed efficiency feed lot owners
- Representative of a breed society

Some participants shared both their personal perspectives and the views of the organisations they represent. In several cases, participants fitted into multiple categories; however, for the purpose of analysis, they were assigned to the category they felt most strongly representative of. Key themes were identified across the seven categorised groups, and these are detailed below. Participants were interviewed from both the Australian (7) and New Zealand (10) agriculture sector

5.1 Summary of Interviews

5.1.1 Selection

A key theme identified throughout the interviews was the need for an accurate and reliable method of measuring feed efficiency. Unlike many production traits, feed efficiency is not directly observable as a phenotypic trait, making it difficult to record and quantify, particularly within pasture-based production systems. Participants frequently highlighted the principle that "if a trait cannot be measured, it cannot be managed," emphasising the importance of developing practical tools for on farm assessment and genetic selection.

Although several breed societies currently provide gBV's for feed efficiency, primary producers expressed concerns regarding their relevance to New Zealand production systems. Existing feed efficiency breeding values are largely derived from feedlot-based performance trials, where feed intake can be accurately measured under controlled conditions. Interviewees questioned the applicability of these breeding values to pasture-based systems, where animal performance is influenced by different environmental and nutritional factors. As a result, there was scepticism regarding the reliability of current feed efficiency predictions for animal selection within New Zealand grazing systems.

5.1.2 On Farm Benefits

Across all producer interviews, feed was consistently identified as one of the largest operational costs in beef production. Participants agreed that any improvement in the ability of livestock to convert feed into saleable product would have a direct positive impact on farm profitability. This was particularly evident among Australian producers, who highlighted the increasing frequency of drought conditions and feed shortages. Under such circumstances, maximising the productivity derived from every kg of feed becomes increasingly important.

Both genetic specialists recognised genetic improvement as an effective means of increasing feed efficiency. Unlike management interventions, genetic gains are permanent and cumulative, allowing improvements to be passed to future generations. Interviewees suggested that significant gains could be achieved relatively quickly if accurate and reliable selection tools were available, making feed efficiency an attractive target for genetic improvement programmes.

5.1.3 Environmental Considerations

Environmental sustainability emerged as a prominent theme across all levels of the supply chain. Participants consistently acknowledged the increasing public scrutiny of agriculture's environmental impact and the growing pressure from governments, consumers, and industry stakeholders to improve environmental outcomes.

For primary producers, concerns centred largely on GHG emissions, particularly methane. Many interviewees recognised the positive relationship between feed efficiency and methane reduction, noting that more efficient animals typically consume less feed and therefore produce lower methane emissions per unit of production. Consequently, genetic improvement in feed efficiency was viewed as a potential strategy for reducing the environmental footprint of beef production.

However, notable differences in attitude were observed between New Zealand and Australian producers. Australian participants described a more incentive-based approach, whereby improvements in environmental performance were increasingly rewarded through preferential market access and supply agreements with major retailers. In contrast, New Zealand producers largely viewed environmental change as being driven by regulatory pressure and the threat of future taxation. As a result, some participants perceived environmental regulations negatively, particularly when compliance measures were seen to reduce farm productivity or profitability.

5.1.4 Supply Chain Opportunities

Interviewees from across the supply chain highlighted the need for greater alignment and collaboration between industry sectors. Many believed that future progress in the beef on dairy industry would need to be driven by leadership at the processor and retailer level, with stronger vertical integration helping to align incentives throughout the supply chain.

Representatives from meat processing companies recognised beef on dairy as a high-quality product with strong international demand. Participants suggested that incorporating feed efficiency into breeding and production systems could further enhance the value proposition of beef on dairy products by strengthening New Zealand's reputation for producing pasture fed, environmentally sustainable beef. While current industry programmes supporting beef on dairy production were described as being in the early stages of development, there was broad confidence that, with continued industry support, these initiatives would expand and become increasingly influential in the future.

5.1.5 Social Licence and Industry Growth

The concept of social licence also emerged as an important consideration. Several participants noted growing public concern regarding the traditional use of bobby calves within the dairy industry and suggested that societal acceptance of current practices may continue to decline. Beef on dairy systems were viewed as one potential solution by creating additional value from calves that may otherwise have limited economic purpose.

Interviewees also suggested that improvements in feed efficiency could help address practical constraints associated with expanding beef on dairy production. More efficient animals require fewer feed resources to achieve target weights and may reach finishing weights more quickly. This could support higher stocking rates, improved land use efficiency, and greater capacity to incorporate additional calves into existing farming systems without proportionally increasing resource requirements.

5.1.6 Future Potential

Overall, participants identified feed efficiency as a trait with substantial potential to improve both the profitability and sustainability of beef on dairy systems. However, the successful adoption of feed efficiency within breeding programmes will depend on the development of accurate measurement systems, robust genetic evaluations, and reliable industry data. Improved tools would not only increase producer confidence in selection decisions but would also provide objective evidence of environmental gains. As research and technology continue to advance, feed efficiency has the potential to become a key driver of productivity, environmental performance, and long-term value creation within the beef on dairy sector.

6. Discussion

This study highlights the potential benefits of using beef sires with superior genetics for feed efficiency, enabling more production from fewer resources. The dataset showed clear variation in feed efficiency traits across the population, including the presence of highly efficient and less efficient outlier animals. This variation demonstrates that feed efficiency can be improved through genetic selection.

The findings emphasise the important role of genetics in determining calf value and show that selecting for improved feed efficiency can increase productivity, profitability, and environmental performance. By breeding from more efficient sires, producers can reduce the cost of production per kilogram of live weight and add value throughout the beef on dairy supply chain. The identification of feed efficiency outliers in the data highlights the opportunity for genetic improvement, making strategic sire selection a practical way to produce more efficient, higher-value animals.

6.1 Genetics

Strong consensus across interview participants was a genetic approach which represents the most effective way for implementing a feed efficiency strategy within beef on dairy systems. It is widely recognised that genetics play a fundamental role in determining how efficiently cattle consume and utilise feed. The permanent and cumulative aspect of genetic gain makes it an ideal tool for long-term improvement in feed efficiency, as benefits are retained and compounded across generations. Therefore, use of beef sires with greater feed efficiency would pass on these traits to their beef on dairy progeny

Figure 3 presents a histogram of 371 animals that were evaluated through the same Vytelle SENSE feed efficiency trial facility. The histogram illustrates a normal distribution of RFI within the population, revealing the presence of substantial genetic diversity for RFI. The distribution also indicates that a proportion of animals performed significantly better than average. Supporting the evidence in the literature that inherent differences in RFI exist within the population. This variation provides the opportunity for selective breeding. Given the heritable nature of feed efficiency traits, that selection for improved RFI is both possible and achievable.

By identifying and selecting high-performing animals within the population, it is possible to develop specialised beef sires suited to beef on dairy production, due to their improved feed efficiency alongside other commercially important traits. This represents a key point of value creation, as genetic improvements in desirable traits can be realised and transmitted throughout the entire production chain.

The literature provides clear evidence of the presence of physiological differences within animals that causes differences in expressed variations in feed efficiency. Feed efficiency is a complex multi-factorial trait, numerous different genes influence the resulting phenotype. Evidence in the literature suggests that feed efficiency is heritable. Berry D. P. & Crowley J. J., (2012) concluding a median heritability of 0.33 ± 0.01 for RFI. Heritability is critically important to be able to successfully select feed efficiency in a breeding programme.

Evidence from both interviews and the literature suggests that RFI is currently regarded as one of the "gold standard" measures of feed efficiency. As it results in reduced input costs and lower GHG emissions, without compromising animal growth performance or meat quality (Beef + Lamb New Zealand, 2024). Although this report focuses on beef on dairy systems, it is important to note that selection based solely on FCE or FCR can lead to increased mature cow size and therefore high maintenance cost, which may offset efficiency gains achieved through faster-growing progeny in breeding systems (Kennedy et al., 1993).

The lack of a reliable, commercially available metric for measuring feed efficiency was identified in the interviews as a major barrier to adoption. It was widely suggested that uptake of feed efficiency traits would increase significantly if more accurate and accessible measurement tools were available. A key challenge of feed efficiency is, that it's not a directly observable phenotypic trait and therefore cannot be reliably assessed through visual appraisal alone. This contrasts with traditional selection approaches in beef on dairy systems, where growth rate and liveweight gain are commonly used as primary indicators of performance. Conventionally, animals with the highest growth rates and heaviest weights are preferred, particularly where average daily gain is used as the main productivity metric. However, feed efficiency can contradict this assumption, as faster growing animals may achieve said higher weights through significantly greater dry matter intake compared with potentially smaller but more efficient counterparts. When evaluated on a feed cost per kilogram of dry matter intake basis, more efficient animals deliver greater economic value despite lower absolute growth.

The adoption RFI and related feed efficiency traits in New Zealand has been impeded by differences between research and commercial production environments. Most global feed efficiency research in cattle has been conducted under feedlot conditions, where feed intake can be measured accurately and environmental variation is tightly controlled. In contrast, approximately 95–99% of New Zealand cattle production systems are pasture based, feed intake in these systems is more difficult to quantify and greater environmental variability occurs (Morris, n.d.). These differences create challenges in directly transferring feedlot derived RFI rankings and gBV's for feed efficiency traits, such as NFI into pastoral systems. Although gBV's for feed efficiency are available, their reliability is lower under grazing conditions.

NFI exhibits moderate, but not complete, genetic consistency across environments. Therefore, animals identified as efficient in feedlot systems may not perform identically under pasture-based management due to genotype by environment interactions. This results in the re-ranking of animals between production systems and reduces the accuracy and transferability of selection decisions (Herd & Bishop, 2000; Kennedy et al., 1993). This uncertainty has contributed to industry scepticism regarding the reliability of feed efficiency measures in New Zealand systems. Further research under New Zealand grazing conditions is required to better understand these relationships and improve the predictive accuracy of genomic selection. In particular, the development of a robust New Zealand pasture-based reference population, supported by high-quality phenotypic data, would strengthen genomic prediction models and improve the accuracy of selecting for feed efficiency traits in New Zealand breeding programmes.

Figure 4 shows a scatter plot of the results of RFI and ADG from a trial of a contemporary group of bulls from the same breed and farm. The black line in the centre is a trend line. It shows there is no correlation between RFI and ADG (growth rate), this enables RFI to be selected for with no effect on growth, the two traits are independent of each other.

There is economic importance for both RFI and growth traits (such as ADG and 200, 400, and 600 day weights) in beef breeding programmes. RFI and growth traits are predicted to demonstrate similar heritability. However, in New Zealand breeding systems, RFI is often underutilised. RFI is a specific measure of feed efficiency independently of growth and body size by identifying animals that consume less feed than expected for their level of production. This makes it a valuable tool for improving efficiency without necessarily increasing mature size or maintenance requirements. In contrast, growth traits focus on the rate of weight gain, which can increase output but is also associated with higher feed intake and larger mature animal size. Growth traits are widely used and practical to understand, they are also easier and cheaper to measure. This has led to growth being highly integrated into breeding systems. RFI is more resource intensive to record and complex to apply, this is a limiting factor contributing to the lack of uptake in RFI seen in the industry. An integrated selection approach combining RFI and growth traits would likely provide a more balanced and effective breeding strategy.

Despite its potential value, RFI remains underutilised within New Zealand breeding systems. A key barrier appears to be a lack of understanding and confidence in the trait relative to more familiar growth measures. Growth traits are straightforward to interpret, are routinely recorded, and can be measured relatively easily and inexpensively, leading to their widespread integration into breeding programmes. In comparison, RFI is more complex to understand and requires specialised facilities to accurately measure individual feed intake, making data collection more resource-intensive and costly. These practical and knowledge-based barriers have likely contributed to the limited adoption of RFI within the industry. Therefore, while both RFI and growth traits have economic importance, improving stakeholder understanding of RFI is necessary to encourage wider uptake, particularly for seed stock producers, dairy farmers, rearers and finishers. An integrated selection approach that combines RFI with growth traits is likely to provide a more balanced and effective breeding strategy.

Suboptimal rumen development may negatively influence feed efficiency traits by reducing digestive capacity and ability to absorb nutrients. Animals with less developed rumens may require greater feed intake to achieve a given level of production, potentially resulting in less favourable RFI or NFI values (Cantalapiedra-Hijar G, et al, 2018). Poor rumen development early in life can have long-term implications for animal performance. In beef on dairy systems, calves are typically artificially reared, so calf rearers should implement effective rumen development plans from an early age.

This report and the literature clearly demonstrate that there are animals within the population that possess above average feed efficiency in both feedlot and pasture-based systems. However, existing research has primarily been conducted on weaned animals with fully developed rumens. What remains unclear is whether this efficiency trend also extends to milk consumption as a calf? Given the evidence that suggests feed efficiency is driven more by physiological differences than by feed type, it is reasonable to theorise that efficient animals would maintain improved feed efficiency throughout their entire lives, including infancy. This principle should be further researched. If this hypothesis proves true, it could provide significant advantages for calf rearers, who will further benefit from improved feed efficiency in young animals.

There is an opportunity to further investigate the effect of hybrid vigour on feed efficiency within beef on dairy systems. The success of composite cattle in many beef production systems demonstrates the value of combining complementary breed traits to improve overall animal performance. By crossing genetically diverse breeds, hybrid vigour can enhance desired traits. Given the widespread success of composite sires in beef on dairy systems, further research should be carried out into opportunities to improve productivity and profitability, through efficiency of hybrid off spring.

6.2 Implementation

The most effective way to implement feed efficiency in beef on dairy systems is through a coordinated approach that integrates genetic selection, data driven decision making, and supportive management practices. As beef on dairy production relies on genetic decisions made at the mating stage, improvements in feed efficiency must begin at the level of sire selection.

Genetic selection provides the most permanent and cumulative gains, as efficiency traits are passed across generations. There is an opportunity for tailored breeding programmes to produce beef sires specifically for beef on dairy production. With the goal to maximise the expression of commercially important traits including calving ease, gestation length, growth rate, feed efficiency, carcass performance, coat colour, and polled. These traits create direct influence on the value of calves, creating improvements that can be captured throughout the production chain.

Genomic selection should be utilised in breeding programmes to strengthen breeding selection, by enabling the identification of superior animals early in life, before performance data is available, therefore increasing the speed and accuracy of genetic gain.

Feed efficiency should not be selected in isolation. The most successful implementation occurs when it is incorporated into a balanced selection index. This multi-trait approach helps to avoid unintended consequences, such as reduced carcass fatness or increased mature size, which have been highlighted as negative effects of feed efficiency selection. By combining traits into an index, breeding programmes can improve feed efficiency while maintaining overall production and quality.

Alongside genetic improvement, effective implementation depends on the availability of accurate data and reliable evaluation systems. This has proved a challenge in New Zealand thus far, feed efficiency is difficult to measure directly at scale, particularly in commercial beef and beef on dairy systems, so genomic prediction and the use of proxy traits (e.g. frequency and length of grazing and rumination, bite rate) play an important role. Growth performance, feed conversion efficiency, and body condition measures can support the development of selection indexes, while reference populations with recorded feed intake data improve the accuracy of genomic evaluations. As data quality improves, the ability to identify genetically efficient animals becomes more precise, enabling improved long-term progress.

Management practices are essential to ensure that genetic potential for feed efficiency is fully expressed. Nutrition, health status, and environmental conditions all influence how efficiently animals convert feed into production. Reducing disease burden, minimising stress, ensure proper rumen development and providing quality feed early in life enhances feed utilisation and ensures that genetically efficient animals perform to their full potential.

The most effective implementation of feed efficiency in beef on dairy systems is achieved through the integration of genetic selection, multi-trait breeding strategies, robust data systems, and supportive management. Together, these components enable sustained improvements in efficiency while maintaining productivity and carcass quality across the supply chain.

6.3 Economic

6.3.1 On farm

The biggest cost for livestock farmers in New Zealand is feed (Herd R. M & Arthur P. F., 2009;Gomes et al., 2013). The interviews revealed a clear theme, that the key to being profitable on farm is to maximise utilisation of feed. Identifying animals that consume less feed to produce the same kg of liveweight (i.e. reduce the cost of production) is an effective approach to achieve this. As previously discussed, feed efficiency traits are heritable, making it possible to identify animals with superior feed efficiency, select them as breeding stock, and increase the frequency of these desirable traits within the population over time.

Figure 4 shows a scatter plot of the results of RFI and ADG from a trial of a contemporary group of bulls from the same breed and farm. Focusing on two individuals from the scatter plot, tag numbers 632 and 415. A summary of their trial results are displayed in table 5

Table 4 summary of trial results from bulls 632 and 415

ID	DOB	RFI	RADG	Start Wt.	End Wt.	ADG	Avg DMI	Raw F:G	Adj F:G	RFI vs. ADG Quadrant
632	6/08/2024	1.17	-0.02	440.10	518.70	1.64	11.42	6.97	7.35	Unfavorable RFI - Above Average ADG
415	10/09/2024	-1.40	0.16	500.80	579.80	1.65	8.92	5.42	5.23	Favorable RFI - Above Average ADG

Table 5 shows there is a 2.57 kg difference in feed intake to kg of live weight gain between the two bulls. Bull 415 has close to the population mean for ADDMI (Average Daily Dry Matter

Intake) but is below average for RFI. Bull 632 is above the population average for both traits. This results in 415 consuming less feed to gain the same average daily gain as 632.

Table 6 shows the effects in RFI on feed cost when applied to a real-world scenario. Table 6 models out the on-farm implications if sires 415 and 632 are beef sires used over a dairy herd and each bull has sired 100 calves. As the cows have not been tested for feed efficiency, they will have a base line figure of zero (no maternal effect) the table below shows results modelled at 50% influence of the sire.

As minimal research into the effect of RFI on calves fed milk has been conducted, for accuracy purposes this is modelled animals post weaning. The number of days on feed refers to the number of days an animal has be on a 100% grass-based diet.

Table 5 - the estimated theoretical impact of selection for RFI in sires

Bull Used	DM consumed 200 days on fed (kg)	DM consumed 400 days on fed (kg)	DM consumed 600 days on fed (kg)
632 sired progeny	1142	2284	3426
415 sired progeny	892	1784	2676
Weight difference/head	250kg/DM less	500kg/DM less	750 kg/DM less
Cost difference/head	$50.00	$100.00	$150.00
100 Progeny	$5,000	$10,000	$15,000
Feed saved	25 t/DM extra	50 t/DM extra	75 t/DM extra

*Feed cost is based on an estimated $200/tonne/DM (DairyNZ, 2024)

Table 6 shows the estimated theoretical impact of selection for low RFI traits in sires. Over 600 days in this scenario, trait selection of the sire can save a significant amount of money and feed. It's estimated that over 600 days the saving of 75 tonnes of dry matter could feed approximately. 12 head (with an estimated ADDMI of 10.2 kg/DM), increasing stocking rate and efficiency.

The average daily gain for these sires is essentially the same, but the average dry matter intake (per day) is significantly different. This is feed efficiency and this is where the on-farm cost or saving's lie. Small differences in feed efficiency per animal translate into large economic differences at herd scale, making feed efficient bulls more profitable even if growth rates are similar.

Sire 415 had an ADDMI close to the population mean but an above average RFI, while sire 632 was below average for both traits. This contrast highlights the variation in feed efficiency that exists within the population and table 6 shows that inefficiencies currently present on farms could be reduced through targeted genetic selection.

6.3.2 Influence of Improved Feed Efficiency at an Industry Level

In an industry context, New Zealand finishes approximately 700,000 beef on dairy animals a year (Ministry of Primary Industries n.d.). Table 7 models the potential industry savings annually resulting from a one kg reduction in the mean ADDMI per animal per day across New Zealand's beef on dairy population.

Table 6 - models of effect of reducing average DDMI by one kg per day, of beef on dairy animals in New Zealand over one year

	Current Mean ADDMI (9kg)	Improved Mean ADDMI (8kg)	Difference
Total kg of DM consumed per year	2.29 billion kg DM	2.04 billion kg DM	255.5 million kg DM
Total feed cost (NZD)	$459.9 million	$408.8 million	$51 million

*Table 7 Assumptions: the trial data is reflective of the population, current mean ADDMI is approximately 9 kg/DM/day. Price per kg/DM = $0.20 (DairyNZ, 2024)

Industry savings would be estimated $51 million annually. The reduction in DM consumed would result in feed saving of 255.5 million kg DM of feed, creating a sufficient carrying capacity to support 87,500 more animals.

6.3.3 Economic Influence of Sire Selection

As New Zealand farmers are largely price takers, the price received per kilogram of carcass weight or liveweight is determined by the market, leaving farmers with little to no influence over returns. Therefore, the biggest opportunity to drive efficiency and profitability is the rate at which feed is converted into saleable product

Table 7 – The estimated difference in gross profit of the sires 415 and 632

ID	ADG (kg)	ADDMI (kg)	Gross profit ($NZD)
632	1.65	8.92	5.22
415	1.64	11.42	4.72
Difference	0.01	2.5kg	0.50

*Assuming price per kg/DM = $0.20 and price per kg/liveweight = $7.00 (DairyNZ, 2024; Beef + Lamb NZ, 2025)

Table 8 shows the estimated difference in gross profit between sires 415 and 632. Assuming a feed cost of $0.20 per kg/DM and price of $7.00 per kg liveweight (DairyNZ, 2024; Beef + Lamb New Zealand, 2025), along with a difference in average daily dry matter intake of 2.5 kg, sire 415 is estimated to cost the farmer approximately $0.50 less per kg of liveweight produced compared with sire 632. This translates into an approximate improvement in gross profit of $0.25 per kg of liveweight for the progeny of sire 415 (assuming sire has 50% influence). For an animal with an estimated weaning weight of 100 kg and a finished weight of 500 kg, this equates to an overall gross profit difference of approximately $50.00 per animal, assuming a carcass yield of 50%. Regardless of the exact in take numbers improved feed efficiency reduces feed costs and frees up dry matter to be utilised for alternative production.

Tables 6, 7 and 8 above highlight the significant influence that sire selection can have on overall profitability within beef on dairy systems. Historically, the selection of beef sires for use over dairy cows has received relatively limited attention. However, there is evidence of a shifting trend within the industry, potentially driven by sustained high beef prices (Rabobank NZ n.d.). Dairy farmers typically apply considerable care in selecting sires for their dairy herds, this is understandable given genetic merit directly influences milk production and therefore system profitability. In contrast, beef sire selection for dairy cows has often been less strategic, with interviewees noting that sire selections are frequently based on availability or lowest cost as well as low birth weight and short gestation length traits, which can compromise the calf's future in the production chain. Beef sire selection plays a critical role in determining the value of resulting calves, attitudes need to change to maximise profitability from these calves.

The sire contributes significantly to the expression of desirable traits that influence value across the entire supply chain. As such, breeding objectives should be aligned not only with on farm dairy requirements but also with the needs of calf rearers, finishers, processors, and ultimately consumers, whether for domestic or export markets. At the dairy farm level, calving ease is essential to ensure confidence in dystocia-free calving and to maintain animal welfare and efficiency. Coat colour and breed type are also important, as they influence the ability to identify beef cross calves at birth and contribute to perceived market value.

For calf rearers and finishers, traits such as early growth rate, health, robustness, and feed efficiency are critical in ensuring efficient weight gain and reduced production costs. Additional traits such as polled status also add value by improving animal welfare outcomes and reducing management interventions. From the processor's perspective, carcass quality, yield, growth efficiency, and consistency are key drivers of value.

The consumer market is increasingly focused on eating quality, price, and sustainability narratives, placing further emphasis on aligned breeding strategies. These combined requirements highlight the need for more intentional sire selection within beef on dairy systems. Greater integration of breeding objectives across the supply chain would ensure that sires are selected not only for calf identification purposes but also for their ability to generate value at every stage of production. At present, proven high performing sires appear to be undervalued and underutilised within beef on dairy supply chains, despite their clear potential to enhance profitability across the entire system.

6.3.4 Wider Industry Implications

A key challenge in efforts to reduce bobby calf numbers is the finite land resource available within New Zealand for finishing additional animals. Retaining a greater proportion of these calves for extended rearing and finishing periods places increased pressure on existing pasture resources, creating system-level inefficiencies. As a result, these animals begin to compete directly with other established and often high value production systems, such as dairy replacements and beef finishing enterprises, for limited feed supply, land availability, and farm infrastructure. This competition can lead to a reallocation of resources that may reduce overall system productivity if not carefully managed.

The imbalance is created within the production system when large numbers of lower-performing animals are retained without corresponding improvements in feed efficiency or productivity. In contrast, the use of genetically feed efficient animals offers a potential mechanism to alleviate some of these constraints. As demonstrated in Table 6, more feed efficient cattle are able to convert pasture into liveweight gain more effectively, requiring fewer total feed resources per unit of production. This improved efficiency can help to reduce pressure on limited pasture availability, effectively "freeing up" feed resources within the system.

In practical terms, this creates the potential to either increase total stocking rates or reallocate land and feed to higher-value livestock classes without compromising overall productivity. Improved feed efficiency therefore not only enhances individual animal performance but also contributes to more efficient utilisation of land resources at the farm system level. In the context of New Zealand's restricted land use and pasture-dependent livestock industries, these improvements are particularly important for maintaining both economic and sustainable systems while managing the challenges associated with bobby calf utilisation.

Increasingly, large corporate organisations are being held accountable for their contributions to GHG emissions across their supply chains. As a result, they are being encouraged, and in many cases required, to measure and document emissions throughout the production chain. In response, we are starting to see major companies actively sourcing and, in some cases, paying premiums for products that demonstrate lower GHG footprints. This trend was frequently identified as a key motivation among Australian producers interviewed, particularly where market signals and corporate sustainability commitments are already influencing procurement decisions.

It is anticipated that similar incentive structures will become more prominent in New Zealand over time as global supply chain expectations continue to tighten. This shift is likely to create increased opportunities for primary producers who can provide verifiable evidence of reduced environmental impact. Feed efficiency then becomes particularly important, as it is strongly correlated with lower methane emissions in ruminant systems (Herd et al., 2004). gBV's for feed efficiency therefore offer a measurable and auditable way for farmers to demonstrate reductions in GHG emissions through decreased enteric methane losses. Therefore, improving feed efficiency not only enhances production efficiency but also strengthens the environmental credentials of livestock systems, positioning producers to benefit from emerging sustainability-linked market opportunities.

6.3.5 Supply chain

Countries such as the United States and several European nations have developed highly successful beef on dairy programmes, supported by strong coordination and alignment across the supply chain. Greater vertical integration between stakeholders has facilitated the development of breeding and marketing systems that capture value throughout the production chain. Allowing production to be more closely aligned with market requirements and consumer demand. This level of industry cohesion helps create clearer value chains, improves information sharing, and ensures that the financial benefits associated with higher value beef on dairy animals are recognised throughout the supply chain. As a result, producers are generally more willing to adopt genetic and management changes because there is confidence that premiums and market advantages will be consistently returned to them.

Feedback gathered from industry interviews within New Zealand suggested that stronger leadership and finical incentives from the upper levels of the supply chain, particularly meat processors, are critical for wider industry uptake. Participants indicated that although some programmes and premium schemes currently encourage the production of higher quality beef on dairy animals, many of these initiatives remain relatively small and are still in the early stages of development. Current schemes generally reward farmers for using targeted beef genetics over dairy cows or for producing calves that meet certain carcass or performance specifications. However, the scale and consistency of these incentives are not yet sufficient to drive widespread behavioural change across the industry.

Interview feedback suggested that meat companies are in a unique position to influence adoption because they have direct connections to export markets and are best placed to identify emerging opportunities for sustainably produced high quality beef products. By providing stronger pricing signals, long-term contracts, or verified sustainability premiums, meat companies could help reduce uncertainty for farmers considering investing in improved genetics and calf rearing systems. Greater processor involvement could also encourage stronger collaboration across the supply chain, helping align breeding objectives, calf supply, finishing systems, and market specifications.

Interviewed parties believed there is considerable potential to expand these initiatives if both meat company support and farmer participation increased. As international demand for sustainable and traceable beef products continues to grow, coordinated industry investment in beef on dairy systems could allow New Zealand to capture additional value from surplus dairy calves while strengthening the overall resilience of the red meat sector.

6.4 Environmental

As previously discussed, animals that possess improved feed efficiency have more effective biological energy utilisation, allowing a greater proportion of consumed nutrients to be used in productive outputs such as growth and muscle gain. As a result, less energy is lost through non-productive pathways including heat production, waste excretion, and importantly methane emissions (Johnson & Johnson, 1995; Tseten et al., 2022).

In contrast to short-term mitigation strategies that rely on feed additives or management interventions, genetic improvement is permanent (de Haas et al., 2011). RFI is strongly correlated with methane production, the literature shows that RFI is likely moderately heritable, indicating selectively breeding animals with superior feed efficiency has the potential to progressively reduce the emissions intensity of beef production systems while also improving biological and economic efficiency.

Importantly, methane production should not be viewed solely as an environmental issue, but also as a form of production inefficiency. Methane emissions represent a direct loss of dietary energy that could otherwise contribute to animal growth, maintenance, reproduction, or productive performance (Johnson & Johnson, 1995; Tseten et al., 2022). Therefore, reducing methane emissions through improved feed efficiency may simultaneously improve animal productivity and reduce feed costs.

Findings from industry interviews indicated that many farmers remain sceptical about current methane reduction strategies and technologies. A common perception among participants was that many proposed mitigation approaches provide limited direct benefit at the farm level and are instead viewed primarily as an additional cost or compliance burden. Farmers frequently expressed concern that some methane reduction initiatives may reduce productivity, increase management complexity, or require significant financial investment without generating clear economic returns. As a result, methane mitigation was often perceived as a "tick-box" exercise driven largely by regulatory requirements rather than a strategy that actively improves farm performance or profitability.

This perception highlights an important challenge for the wider adoption of environmental initiatives within the livestock sector. Farmers are generally more likely to adopt new technologies or management practices when they provide both environmental and economic advantages. Consequently, strategies that align emissions reduction with improved production efficiency are likely to achieve greater industry acceptance and long-term uptake.

The incorporation of RFI into breeding programmes presents a potentially attractive solution. Unlike some methane mitigation tools that may increase costs without improving productivity, selection for improved feed efficiency has the potential to simultaneously reduce enteric methane emissions while maintaining or even improving production and profitability. Animals with lower RFI consume less feed for the same level of production, meaning they require fewer inputs and lose less energy as methane during digestion. This creates an opportunity to reduce emissions intensity without compromising growth performance or production output.

Although this report is focused on the terminal beef on dairy product, it is recognised that improvements could be made in the dairy herd further enhancing benefits. When feed efficient genetics are incorporated into a herd, the benefits continue across future generations without requiring continual annual investment or major changes to farm systems. This differs from many short-term mitigation strategies that rely on repeated inputs or management interventions. Therefore, integrating RFI into breeding programmes may be more acceptable for farmers because it aligns environmental objectives with practical on farm.

6.4.1 Wearables

A major limitation to the use of RFI within New Zealand production systems is the difficulty of accurately measuring individual feed intake under pasture-based grazing conditions. Unlike feedlot systems, where feed intake can be precisely controlled and recorded, grazing environments introduce substantial variability in pasture availability, feed quality, animal behaviour, and intake estimation. This makes large-scale phenotyping for RFI both technically challenging and economically expensive within New Zealand's predominantly pasture-based livestock systems.

In contrast, methane phenotyping technologies are increasingly demonstrating the ability to produce consistent and repeatable measurements of animal emissions, even when measurements are collected early in life (Johansen, K. K et al., 2025). Evidence suggests that early-life methane measurements may be predictive of an animal's lifetime methane emission profile, supporting the potential integration of methane traits into future breeding programmes. As methane production is highly correlated to feed digestion and rumen function, there is growing reliability in the relationship between methane emissions and RFI.

One potential strategy to overcome the limitations associated with direct RFI measurement is to utilise wearable sensor technologies, capable of generating continuous phenotypic data related to feeding behaviour, grazing patterns, rumination, activity, and other indicators associated with feed efficiency. Advances in precision livestock farming technologies may allow indirect estimation of feed intake and efficiency in grazing animals without the need for expensive controlled feeding systems. In addition, investigating the genomic relationship between methane production and RFI may provide opportunities to use methane emissions as an indirect indicator trait for feed efficiency within breeding programmes.

Although methane production is influenced by several external factors may still function as a useful proxy for RFI when animals are managed under similar feeding conditions. However, some scepticism remains regarding the current accuracy and reliability of wearable technologies and indirect phenotyping methods for estimating feed efficiency traits. There is recognition within the industry that the technology may not yet be sufficiently advanced for widespread commercial implementation for the purpose of potentially measuring RFI. Considering the rapid pace of technological development within precision livestock farming suggests there is future potential for these tools to support large-scale genetic evaluation of feed efficiency and methane related traits in pasture-based production systems.

Alongside the growing shift by major food companies toward sourcing low GHG products. Governments and international trade markets are more frequently introducing environmental regulations and emissions standards that influence global agricultural trade. As climate change policies become more integrated into trade agreements and market access requirements, countries that can demonstrate lower-emission production systems are likely to gain a competitive advantage. This creates significant potential for new market opportunities for New Zealand within the global beef sector.

New Zealand is well positioned to become a leader in stainable beef production because of its predominantly pasture based farming systems, comparatively low use of imported feed, and ongoing investment in genetics, methane research, and production efficiency. By improving traits such as feed efficiency in beef on dairy cattle, New Zealand has the opportunity to further reduce emissions intensity while maintaining high levels of productivity and animal performance. This aligns strongly with the sustainability expectations of both international consumers and multinational food companies.

Being an early leader in this space is strategically important. Countries and companies that can provide verified low-emissions products are likely to be in the strongest position to secure premium export contracts, long-term supply agreements, and preferential access to environmentally conscious markets. If New Zealand can establish itself as a trusted supplier of sustainable beef products before competing nations, it will increase the likelihood of securing these future trade opportunities and maintaining international competitiveness as environmental standards continue to tighten globally.

6.5 Transtasman Comparison

An interesting observation that emerged throughout the interviews was the contrasting perspectives between stakeholders in the Australian (n=7) and New Zealand (n=10) agricultural industries regarding feed efficiency, genetic data, and environmental sustainability. These differences are believed to reflect variations in production systems, market pressures, environmental policy, and industry structure.

The participants in New Zealand that had put stock through the Vytelle SENSE feed efficiency trials, viewed feed efficiency data as a competitive advantage, the data provides a point of difference and potentially greater profitability. As a result, there appeared to be a more cautious approach toward openly sharing trial results, genetic information, or commercial findings. In contrast, Australian producers interviewed were generally more open and willing to share data, trial outcomes, and industry learnings. Feed efficiency research in Australia was more commonly viewed as an "industry-good" initiative, where collective progress in genetic improvement and production efficiency was considered beneficial for the wider sector. This reflected a broader industry level perspective on feed efficiency development and adoption.

Another significant difference related to the role of methane emissions and environmental sustainability. Methane reduction was a much stronger driver among New Zealand interview participants due to the threat of legislative pressure. The New Zealand agricultural sector has operated under increasing environmental scrutiny for many years, with growing pressure from government policy, emissions reduction targets, and public expectations surrounding environmental performance. This appears to have influenced industry attitudes, with many New Zealand stakeholders viewing feed efficiency and methane reduction as increasingly important for future market access and industry legitimacy. New Zealand's export economy relies heavily on maintaining a strong "clean and green" international image, particularly within premium food markets. As a result, sustainability and emissions reduction are closely linked to both trade competitiveness and consumer perception.

Australian participants, while acknowledging that environmental regulations and emissions expectations are likely to tighten in the future, generally appeared to face less immediate policy pressure than New Zealand producers. Consequently, the primary motivation for improving feed efficiency in Australia was centred more directly on productivity and cost reduction rather than emissions compliance. Many Australian interviewees discussed feed efficiency in terms of reducing feed costs, improving growth performance, and increasing profitability within production systems. However, several also noted that increasing corporate demand for low GHG products and the possibility of future sustainability premiums were beginning to create additional incentives for emissions focused breeding and management strategies.

Environmental conditions themselves also appeared to shape industry priorities differently between the two countries. In Australia, ongoing drought conditions and feed shortages were identified as major drivers of interest in feed efficiency. Producers highlighted that breeding more feed efficient animals could improve resilience by enabling cattle to better utilise limited feed resources during periods of environmental stress. Feed efficiency was strongly associated with risk management, business certainty, and maintaining profitability under increasingly variable climate conditions.

The structure of the beef and beef on dairy industries also differed between the two countries. In Australia, adoption of feed efficiency technologies and RFI selection appeared to be driven primarily by the straight beef sector, particularly within feedlot production systems where majority of cattle are finished. Beef on dairy production represented a smaller proportion of the market compared with New Zealand. Desired traits and sire selection within Australian beef on dairy systems appeared to be heavily influenced by calf rearers, finishers, and feedlot operators further along the supply chain.

In comparison, interview feedback suggested there may be greater vertical integration within some Australian beef on dairy systems, allowing stronger coordination between breeding decisions, calf production, finishing systems, and market requirements. This integration appeared to support more effective utilisation of beef on dairy animals and clearer alignment between genetics and end market specifications. The findings suggest that greater supply chain cohesion within New Zealand may help accelerate the adoption of feed efficiency technologies and improve the overall value captured from beef on dairy production systems.

7. Conclusion

The findings of this study demonstrate that improving the genetic feed efficiency of beef on dairy calves has the potential to create significant value across multiple areas of the supply chain. Selection for improved feed efficiency was shown to provide direct economic benefits to farmers and the industry, through a lower cost of production per kilogram of live weight, while also contributing to environmental sustainability through reduced feed requirements and lower enteric methane emissions. As feed efficiency is a heritable trait, these gains can be achieved through genetic selection with minimal additional on farm costs, making it a highly practical tool for improving production efficiency.

Growing global demand for sustainably produced beef also presents new market opportunities, as food processors, retailers, and consumers increasingly seek low emissions and environmentally responsible products. Improving feed efficiency therefore has the potential to strengthen New Zealand's position as a supplier of high-value, sustainable beef to international markets.

For widespread adoption to occur, the value of feed efficiency must be recognised throughout the supply chain. Seedstock producers, dairy farmers, calf rearers, and finishers must all see a clear economic benefit from selecting and producing more feed efficient animals. Industry-led incentives and market signals from processors and retailers are likely to play a pivotal role in driving uptake, while ensuring that the value generated is reflected at the farm level. The quantitative findings of this study support the conclusions of the wider literature and reinforce the opportunity for genetic improvement in feed efficiency to deliver long-term economic and environmental benefits across the beef on dairy sector.

8. Recommendations

Key messages from this project need to be shared with the beef and dairy industries using conferences, media, rural professionals, those in advisory roles and publications. There is an opportunity to add value to an underutilised product which has potential to improve animal welfare, efficiency and profitability on New Zealand dairy farms and beef farms. Specific recommendations are given below.

8.1 Further Research

8.1.1 Develop robust feed efficiency evaluation systems for pastoral conditions

Creation of a genomic breeding value that is functional in New Zealand grazing systems. This involves Investment in phenotyping programmes and the development of large reference populations to improve the accuracy and reliability of feed efficiency. This needs to happen by large numbers of animals trialled through feed efficiency trials. It is suggested that a multi -breed trial would be beneficial, this would require collaboration from industry bodies, commercial farmers, stud breeders and breed societies. An accurate evaluation tool will benefit both beef and beef on dairy breeding programmes. It is estimated that a reliable genomic model would take approximately 8–10 years to develop.

Once a reliable genomic model has been developed, feed efficiency should be incorporated into the Beef + Lamb New Zealand Dairy Beef Progeny Test. This would enable the collection of industry-relevant feed efficiency data on emerging beef on dairy sires and support the identification of genetics that improve productivity while reducing feed costs and environmental impact

8.1.2 Strengthen research linking feed efficiency and methane emissions

Given the potential relationship between feed efficiency and enteric methane emissions, continued investment in this area is recommended. Future feed efficiency trials should incorporate methane measurements to investigate the genetic relationship between these traits. This research could support the development of breeding strategies that improve both productivity and environmental sustainability by selecting cattle that are more feed efficient and produce lower methane emissions.

Beef + Lamb New Zealand is well positioned to facilitate this work through its existing trial sites. However, a collaborative approach involving AgResearch, DairyNZ, genetics companies, Massey University and Lincoln University would combine expertise in methane measurement, animal nutrition, genetics and beef on dairy production. A five-year collaborative research programme is recommended to generate the robust phenotypic and genetic data required to support future breeding decisions.

8.1.3 Investigate practical proxy measures of feed efficiency

Create industry driven incentive for the companies developing wearable technologies and other emerging tools to incorporate research that may identify proxy traits associated with feed efficiency. Developing lower-cost and more scalable measurement methods will improve the feasibility of collecting feed efficiency data and utilisation on commercial farms.

8.2 Industry Education

The industry should invest in education and extension programmes to improve awareness and adoption of feed efficiency technologies. While many farmers recognise feed as their largest cost and understand the potential benefits of improved feed efficiency, there is limited awareness of how these gains can be achieved or of the research already underway. The seed stock producers, dairy farmers, calf rearers and finishers need to see value in the trait and trust the eBV's that support it before uptake will increase.

Beef + Lamb NZ and/or DairyNZ led Industry driven coordinated initiatives, including demonstration trials, workshops, discussion groups and extension programmes, should be used to build confidence in feed efficiency and eBV's. There needs to be clear communication of the economic and environmental benefits. Feed efficiency research should be treated as industry good, with knowledge shared across the supply chain to maximise value and encourage widespread adoption. These should commence in parallel with research programmes

8.3 Develop a supply chain initiative for strategic sire selection

The New Zealand beef on dairy industry should adopt a coordinated, genetics-led approach to improving feed efficiency. This strategy should focus on the development of specialised beef on dairy sires using balanced multi-trait selection to enhance feed efficiency while maintaining other economically important production traits. To maximise value, breeding objectives must be aligned across the entire supply chain, requiring clear communication between bull breeders, genetics companies, dairy farmers, calf rearers, finishers, processors, and consumers.

Clear definition and communication of desired production outcomes will enable the development of calves better suited to market requirements. This strategy should be implemented following the initial research phase, once reliable pasture-based feed efficiency data is available, and farmers can clearly observe the value of selecting for these traits. At this point, strategic sire development can begin, with feed efficiency incorporated into breeding objectives and progressively utilised throughout the supply chain.

Industry education will be essential in supporting the successful adoption of this feed efficiency strategy across the sector and ensuring consistent understanding of its economic and environmental benefits.

8.4 Position feed efficiency as a dual-purpose productivity and emissions reduction trait

Feed efficiency should be recognised as a dual-purpose trait that delivers both economic and environmental benefits. By reducing the feed required to achieve the same level of production, more feed-efficient animals also produce less enteric methane per unit of output. Recognising feed efficiency as both a productivity and emissions trait would enable New Zealand to improve farm profitability while supporting industry climate objectives. Industry leadership from Beef + Lamb NZ and DairyNZ, supported by genetics providers, researchers and processors, will be essential to embed feed efficiency into breeding objectives and production systems. A phased implementation over the next five to ten years would allow time to strengthen the underlying science, develop reliable genetic tools and build industry confidence while delivering long-term genetic gain.

8.5 Strengthen vertical integration and incentive signals

To maximise benefits, stakeholders should work towards a more aligned vertically integrated approach that combines objectives across the supply chain. Greater collaboration between industry stakeholders would help ensure that animals are selected and managed to meet common production and market goals. This could be supported through clearer performance feedback, stronger information sharing, and incentive structures that reward traits associated with feed efficiency, growth, and carcass performance.

By improving alignment across the supply chain, the industry can better capture the value created through genetic improvement and encourage more consistent adoption of feed efficiency technologies. Without this coordinated approach, the benefits of feed efficiency are likely to remain fragmented and underutilised.

To support this alignment, a coordinated genetics-led programme for feed efficiency should be implemented across the beef on dairy sector. This should be led collaboratively by Beef + Lamb NZ, AgResearch, DairyNZ, and genetics companies, with input from processors and wider industry stakeholders. Industry alignment and initial data collection should begin immediately, with development and validation of feed efficiency measures and genomic tools occurring over the next 3–7 years. Full integration of feed efficiency into commercial breeding and sire selection systems is expected within 7–10 years, once robust data and reliable genetic evaluations are established.

9. References

Ahmed, S. K., Mohammed, R. A., Nashwan, A. J., Ibrahim, R. H., Abdalla, A. Q., M. Ameen, B. M., & Khdhir, R. M. (2025). Using thematic analysis in qualitative research. *Journal of Medicine, Surgery, and Public Health*, 6, 100198. https://doi.org/10.1016/j.glmedi.2025.100198

Alemu, S. W., Bilton, T. P., Johnson, P. L., Perry, B. J., Henry, H., Dodds, K. G., McEwan, J. C., & Rowe, S. J. (2025). Improving genomic prediction accuracy for methane emission and feed efficiency in sheep: integrating rumen microbial PCA with host genomic variation using neural network GBLUP (NN-GBLUP). *Genetics Selection Evolution*, *57*(1), 41. https://doi.org/10.1186/s12711-025-00987-x

Arthur, J. P. F., & Herd, R. M. (2008). Residual feed intake in beef cattle. *Revista Brasileira de Zootecnia*, *37*(spe), 269–279. https://doi.org/10.1590/S1516-35982008001300031

Arthur, P. F., Renand, G., & Krauss, D. (2001). Genetic and phenotypic relationships among different measures of growth and feed efficiency in young Charolais bulls. In *Livestock Production Science* (Vol. 68). www.elsevier.com/locate/livprodsci

Baranwal, V. K., Mikkilineni, V., Zehr, U. B., Tyagi, A. K., & Kapoor, S. (2012). Heterosis: emerging ideas about hybrid vigour. *Journal of Experimental Botany*, *63*(18), 6309–6314. https://doi.org/10.1093/jxb/ers291

Basarab, J. A., Beauchemin, K. A., Baron, V. S., Ominski, K. H., Guan, L. L., Miller, S. P., & Crowley, J. J. (2013). Reducing GHG emissions through genetic improvement for feed efficiency: effects on economically important traits and enteric methane production. *Animal : An International Journal of Animal Bioscience*, *7 Suppl 2*, 303–315. https://doi.org/10.1017/S1751731113000888

Basarab, J. A., Colazo, M. G., Ambrose, D. J., Novak, S., McCartney, D., & Baron, V. S. (2011). Residual feed intake adjusted for backfat thickness and feeding frequency is independent of fertility in beef heifers. *Canadian Journal of Animal Science*, *91*(4), 573–584. https://doi.org/10.4141/cjas2011-010

Basarab, J. A., Price, M. A., Aalhus, J. L., Okine, E. K., Snelling, W. M., & Lyle, K. L. (2003). Residual feed intake and body composition in young growing cattle. *Canadian Journal of Animal Science*, *83*(2), 189–204. https://doi.org/10.4141/A02-065

Basarab J, & Ominski K. (2014). *Feed Efficiency on Pasture*.

Beauchemin, K. A., McGinn, S. M., Benchaar, C., & Holtshausen, L. (2009). Crushed sunflower, flax, or canola seeds in lactating dairy cow diets: Effects on methane production. *Journal of Dairy Science* , *92*(5), 2118–2127.

Beef + Lamb New Zealand. (2024, October 2). *New Zealand's beef sector and scientists join forces to create environmentally efficient beef*. https://beeflambnz.com/news/nzs-beef-sector-and-scientists-unite-eco-efficient-beef

Beef + Lamb NZ. (2025, August 8). *Price trend graphs*. https://beeflambnz.com/industry-data/farm-data-and-industry-production/price-trend-graphs

Beef + Lamb NZ. (n.d.). *Key Points — Dairy's Role in New Zealand's Beef Supply*. Retrieved June 13, 2026, from https://beeflambnz.getcaitlyn.ai/c/a4df36c9-86a7-4ba4-8391-2decd02ba8d8

Berry D. (2008). Improving feed efficiency in cattle with residual feed intake. *Recent Advances in Animal Nutrition*, 8–12.

Berry D. P., & Crowley J. J. (2012). Residual intake and body weight gain: A new measure of efficiency in growing cattle. *Journal of Animal Science*, *90*(1), 109–115.

Berry, D. P., & Crowley, J. J. (2013). CELL BIOLOGY SYMPOSIUM: Genetics of feed efficiency in dairy and beef cattle1. *Journal of Animal Science*, *91*(4), 1594–1613. https://doi.org/10.2527/jas.2012-5862

BNZ. (2022, May 14). *BNZ launches NZ's first agribusiness sustainability-linked loan product*. https://www.mpamag.com/nz/news/general/bnz-launches-nzs-first-agribusiness-sustainability-linked-loan-product/405968?utm

Bottje, W., Pumford, N. R., Ojano-Dirain, C., Iqbal, M., & Lassiter, K. (n.d.). *INVITED REVIEW Feed Efficiency and Mitochondrial Function*.

BreedPlan. (n.d.). *Understanding Net Feed Intake EBVs*. Retrieved May 23, 2026, from https://breedplan.une.edu.au/understanding-ebvs/understanding-net-feed-intake-ebvs

Cafe, L. M., McKiernan, W. A., & Robinson, D. L. (2014). Selection for increased muscling improved feed efficiency and carcass characteristics of Angus steers. *Animal Production Science*, *54*(9), 1412–1416. https://doi.org/10.1071/AN14316

Cantalapiedra-Hijar, G., Abo-Ismail, M., Carstens, G. E., Guan, L. L., Hegarty, R., Kenny, D. A., McGee, M., Plastow, G., Relling, A., & Ortigues-Marty, I. (2018). Review: Biological determinants of between-animal variation in feed efficiency of growing beef cattle. *Animal*, *12*, s321–s335. https://doi.org/10.1017/S1751731118001489

Cassell B. (2007). Mechanisms of Inbreeding Depression and Heterosis for Profitable Dairying. *Agricultural and Food Sciences*.

Climate Change Commission - New Zealand Goverenment. (n.d.). *FAQ's: The Role of Methane* . Climate Change Commission. Retrieved March 7, 2026, from https://www.climatecommission.govt.nz/get-involved/exploring-the-issues/the-role-of-methane

Crews D. H. (2005). Genetics of efficient feed utilization and national cattle evaluation: a review. *Genetics and Molecular Research*, *4*(2), 152–165.

Crowley, J. J., McGee, M., Kenny, D. A., Crews, D. H., Evans, R. D., & Berry, D. P. (2010). Phenotypic and genetic parameters for different measures of feed efficiency in different breeds of Irish performance-tested beef bulls. *Journal of Animal Science*, *88*(3), 885–894. https://doi.org/10.2527/jas.2009-1852

CRV NZ. (2025, October 30). *Fewer bobby calves as dairy farmers shift to beef breeding*. https://www.ruralnewsgroup.co.nz/dairy-news/dairy-farm-health/fewer-bobby-calves-dairy-beef-growth-nz

Dairy Country. (n.d.). *Putting science into dairy beef debate*. Retrieved May 18, 2026, from https://dairycountry.co.nz/putting-science-into-dairy-beef-debate

DairyNZ. (2021, December). *Facts and Firgues* . https://www.dairynz.co.nz/media/2xucxamj/facts-and-figures-dnz30-001-updated-2021-web-optimised.pdf

DairyNZ. (2024, March). *Contract Grazing*. https://www.dairynz.co.nz/animal/heifers/contract-grazing

Danielsson, R., Dicksved, J., Sun, L., Gonda, H., Müller, B., Schnürer, A., & Bertilsson, J. (2017). Methane production in dairy cows correlates with rumen methanogenic and bacterial community structure. *Frontiers in Microbiology*, *8*(FEB). https://doi.org/10.3389/fmicb.2017.00226

Das, D. N., Karuthadurai, T., & Gnanasekaran, S. (2021). Genomic selection. In *Advances in Animal Genomics* (pp. 141–163). Elsevier. https://doi.org/10.1016/B978-0-12-820595-2.00010-2

Datt, C., Sharma, V. K., Dudi, K., Baban, B. N., Sharma, Ph. S., Negesse, T., Kundu, S. S., Dutta, M. M., Gupta, R., & Singh, D. (2017). Residual Feed Intake as a Tool for Selecting More Efficient Animals: A Review. *Indian Journal of Animal Nutrition*, *34*(3), 238. https://doi.org/10.5958/2231-6744.2017.00041.X

David Johnston. (2025). *Strategic moment for 'dairy' beef – New Zealand agriculture's $1.2 billion opportunity*. https://www.rabobank.co.nz/media-releases/2025/07102025-strategic-moment-for-dairy-beef-new-zealand-agricultures-1-2-billion-opportunity

de Haas, Y., Windig, J. J., Calus, M. P. L., Dijkstra, J., de Haan, M., Bannink, A., & Veerkamp, R. F. (2011). Genetic parameters for predicted methane production and potential for reducing enteric emissions through genomic selection. *Journal of Dairy Science*, *94*(12), 6122–6134. https://doi.org/10.3168/jds.2011-4439

del Claro, A. C., Mercadante, M. E. Z., & Silva, J. A. I. V. (2012). Meta-analysis of genetic parameter estimates of residual feed intake and of its component traits in cattle. *Pesquisa Agropecuária Brasileira*, *47*(2), 302–310. https://doi.org/10.1590/S0100-204X2012000200020

Detweiler, R. A., Pringle, T. D., Rekaya, R., Wells, J. B., & Segers, J. R. (2019). The impact of selection using residual average daily gain and marbling EPDs on growth, performance, and carcass traits in angus steers. *Journal of Animal Science*, *97*(6), 2450–2459. https://doi.org/10.1093/jas/skz124

Durunna, O. N., Mujibi, F. D. N., Goonewardene, L., Okine L. E. K., Basarab, J. A., Wang, Z., & Moore S. S. (2011). Feed efficiency differences and reranking in beef steers fed grower and finisher diets1. *Journal of Animal Science* , *89*(1), 158–167.

Fonterra. (2022, October). *Sustainable Finance Framework*. https://www.dairynz.co.nz/media/oglesqfm/nz-dairy-statistics-24-25

GenScript. (n.d.). *Biology Terms Dictionary*. Retrieved March 8, 2026, from https://www.genscript.com/biology-glossary/8857/breeding-value

Gomes, R. da C., Sainz, R. D., & Leme, P. R. (2013). Protein metabolism, feed energy partitioning, behavior patterns and plasma cortisol in Nellore steers with high and low residual feed intake. *Revista Brasileira de Zootecnia*, *42*(1), 44–50. https://doi.org/10.1590/S1516-35982013000100007

Hegarty, R. S., Goopy, J. P., Herd, R. M., & McCorkell, B. (2007). Cattle selected for lower residual feed intake have reduced daily methane production1,2. *Journal of Animal Science*, *85*(6), 1479–1486. https://doi.org/10.2527/jas.2006-236

Herd R. M, & Arthur P. F. (2009). Physiological basis for residual feed intake . *Journal of Animal Science*, *87*(14), 67–71.

Herd R. M., Arthur P. F., Hegarty R. S., & Archer J. A. (2002). Potential to reduce greenhouse gas emissions from beef production by selection for reduced residual feed intake. *Proceedings of the 7th World Congress on Genetics Applied to Livestock Production*.

Herd, R. M., & Bishop, S. C. (2000). Genetic variation in residual feed intake and its association with other production traits in British Hereford cattle. *Livestock Production Science*, *63*(2), 111–119. https://doi.org/10.1016/S0301-6226(99)00122-0

Herd, R. M., Oddy, V. H., & Richardson, E. C. (2004). Biological basis for variation in residual feed intake in beef cattle. 1. Review of potential mechanisms. *Australian Journal of Experimental Agriculture*, *44*(5), 423–430. https://doi.org/10.1071/EA02220

Hon Todd Mclay, Hon Simon Watts, & Hon Andrew Hoggard. (2025, October 12). *Government sets methane targets for 2050*. Beehive.Govt.Nz. https://www.beehive.govt.nz/release/government-sets-methane-targets-2050#:~:text=The%20Coalition%20Government%20has%20announced%20science%2Dbased%20targets,**First%20tools**%20Expected%20on%20farm%20in%202026

Hook, S. E., Wright, A.-D. G., & McBride, B. W. (2010). Methanogens: Methane Producers of the Rumen and Mitigation Strategies. *Archaea*, *2010*, 1–11. https://doi.org/10.1155/2010/945785

Idowu, M., Taiwo, G., Sidney, T., Morenikeji, O. B., & Ogunade, I. M. (2026). Hepatic transcriptomic signatures associated with divergent residual average daily gain phenotypes in beef steers. *Frontiers in Animal Science*, *7*. https://doi.org/10.3389/fanim.2026.1813033

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 2006 IPCC Guidelines for National Greenhouse Gas Inventories Third Authors/Experts Meeting: Industrial Processes and Product Use. (n.d.).

Jiang, W., Mooney, M. H., & Shirali, M. (2024). Unveiling the Genetic Landscape of Feed Efficiency in Holstein Dairy Cows: Insights into Heritability, Genetic Markers, and Pathways via Meta-Analysis. *Journal of Animal Science*, *102*. https://doi.org/10.1093/jas/skae040

Johansen, K. K., Kargo, M., Christensen, O. F., Bjerring, M., Løvendahl, P., & Buitenhuis, A. J. (2025). Repeatability and genetic parameters for phenotypes of methane emission in crossbred beef × dairy slaughter calves. *Animal*, *19*(4). https://doi.org/10.1016/j.animal.2025.101478

Johnson, P. L., Hickey, S., Knowler, K., Wing, J., Bryson, B., Hall, M., Jonker, A., Janssen, P. H., Dodds, K. G., McEwan, J. C., & Rowe, S. J. (2022). Genetic parameters for residual feed intake, methane emissions, and body composition in New Zealand maternal sheep. *Frontiers in Genetics*, *13*. https://doi.org/10.3389/fgene.2022.911639

Kennedy, B. W., van der Werf, J. H., & Meuwissen, T. H. (1993). Genetic and statistical properties of residual feed intake. *Journal of Animal Science*, *71*(12), 3239–3250. https://doi.org/10.2527/1993.71123239x

Kenny, D. A., Fitzsimons, C., Waters, S. M., & McGee, M. (2018). Invited review: Improving feed efficiency of beef cattle - The current state of the art and future challenges. *Animal*, *12*(9), 1815–1826. https://doi.org/10.1017/S1751731118000976

Koch Robert M. Swiger L.A. Chambers D. Gregory K.E. (1963). Efficiency of Feed Use in Beef Cattle, Journal of Animal Science. *Journal of Animal Science*, *22*(2), 486–494.

Koots K. R., Gibson J. P., & Wilton J. W. (1994). Analyses of Published Genetic Parameter Estimates for Beef Production Traits . *Centre for Genetic Improvement of Livestock, Department of Animal and Poultry Scirence*, *62*(5).

Kuehn L, E. B. S. W. (2026, March 18). *2026 ACROSS-BREED EPD TABLE AND IMPROVEMENTS*. Beef Improvement Federation . https://beefimprovement.org/2026-across-breed-epd-table-and-improvements

Kushwaha, R., Singh, A. K., & Kumar, M. (2016). Residual feed intake-An emerging system for selection of efficient animals: A review. *Agricultural Reviews*, *37*(1). https://doi.org/10.18805/ar.v37i1.9267

Lahart, B., Prendiville, R., Buckley, F., Kennedy, E., Conroy, S. B., Boland, T. M., & McGee, M. (2020). The repeatability of feed intake and feed efficiency in beef cattle offered high-concentrate, grass silage and pasture-based diets. *Animal*, *14*(11), 2288–2297. https://doi.org/10.1017/S1751731120000853

Liu, S., Proudman, J., & Mitloehner, F. M. (2021). Rethinking methane from animal agriculture. *CABI Agriculture and Bioscience*, *2*(1), 22. https://doi.org/10.1186/s43170-021-00041-y

Llonch, P., Somarriba, M., Duthie, C.-A., Haskell, M. J., Rooke, J. A., Troy, S., Roehe, R., & Turner, S. P. (2016). Association of Temperament and Acute Stress Responsiveness with Productivity, Feed Efficiency, and Methane Emissions in Beef Cattle: An Observational Study. *Frontiers in Veterinary Science*, *3*. https://doi.org/10.3389/fvets.2016.00043

Lovendahll, P., Difford, G. F., Li, B., Chagunda, M. G. G., Huhtanen, P., Lidauer, M. H., Lassen, J., & Lund, P. (2018). Review: Selecting for improved feed efficiency and reduced methane emissions in dairy cattle. In *Animal* (Vol. 12, Issue s2, pp. S336–S349). Cambridge University Press. https://doi.org/10.1017/S1751731118002276

McFarlane C. E. (2023). *An investigation of the genetic correlation of 200-, 400-, and 600- day weights between beef on dairyand beef calves*.

Mertens, D. R. (1994). *Regulation of Forage Intake* (pp. 450–493). https://doi.org/10.2134/1994.foragequality.c11

Meuwissen, T. H. E., Hayes, B. J., & Goddard, M. E. (2001). Prediction of Total Genetic Value Using Genome-Wide Dense Marker Maps. *Genetics*, *157*(4), 1819–1829. https://doi.org/10.1093/genetics/157.4.1819

Ministry for the Environment. (2023, January 18). *Mandatory climate-related disclosures*. https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/mandatory-climate-related-financial-disclosures/?utm

Ministry of Foreign Affairs and Trade. (2025, June). *Trade and Economic Update – Q1 2025: New Zealand Exports show growth and resilience despite global trade uncertainty*. https://www.mfat.govt.nz/en/trade/mfat-market-reports/trade-and-economic-update-q1-2025-new-zealand-exports-show-growth-and-resilience-despite-global-trade-uncertainty

Ministry for Primary Industries. (2022, February). *Dairy cattle population model. Dairy cattle population model*

Ministry of Primary Industries. (n.d.). *Unlocking the potential of dairy-beef* . Retrieved June 20, 2026, from https://www.mpi.govt.nz/dmsdocument/71668-Unlocking-the-potential-of-dairy-beef

Ministry of the Environment. (202 C.E., April 15). *Previous Greenhouse Gas Inventories*. Ministry of the Environment.

Ministry for the environment - GHG-inventory-2024-Snapshot. (n.d.).

Ministry of Primary Industries. (n.d.). *Unlocking the potential of dairy-beef* . Retrieved June 20, 2026, from https://www.mpi.govt.nz/dmsdocument/71668-Unlocking-the-potential-of-dairy-beef

Mishra S. K., Kumari N., Bharti N., & Reddy R. K. (n.d.). *HETEROSIS AND HYBRID VIGOUR IN CROP PRODUCTION* (Vol. 9).

Mohajan. H. (2012). Dangerous effects of methane gas in atmosphere. *International Journal of Economic and Political Integration*, *1*(2), 3-10.

Morris, S. T. (n.d.-b). *79 SHEEP AND BEEF CATTLE PRODUCTION 1.5 SHEEP AND BEEF CATTLE PRODUCTION SYSTEMS*.

National Research Council. (2016). *Nutrient Requirements of Beef Cattle* (8th ed.). National Academies Press.National Academies Press.

New Zealand Parliament. (2021, October 21). *Have your say: Proposed changes to ban live exports under the Animal Welfare Act 1999*. https://www3.parliament.nz/en/pb/sc/committees-press-releases/have-your-say-proposed-changes-to-ban-live-exports-under-the-animal-welfare-act-1999

Nkrumah, J. D., Okine, E. K., Mathison, G. W., Schmid, K., Li, C., Basarab, J. A., Price, M. A., Wang, Z., & Moore, S. S. (2006). Relationships of feedlot feed efficiency, performance, and feeding behavior with metabolic rate, methane production, and energy partitioning in beef cattle1. *Journal of Animal Science*, *84*(1), 145–153. https://doi.org/10.2527/2006.841145x

Nkrumah J., Okine E. K., Mathison G. W., Schmid K., Li C., Basarab J. A., Price M. A., Wang D. Z., & Moore S. S. (2006). Relationships of feedlot feed efficiency, performance, and feeding behavior with metabolic rate, methane production, and energy partitioning in beef cattle. *Journal of Animal Science*, *83*(1), 145–153.

NRC. (2015). *Nutrient Requirements of Beef Cattle, 8th Revised Edition*. National Academies Press. https://doi.org/10.17226/19014

Owens, F. N., Sapienza, D. A., & Hassen, A. T. (2010). Effect of nutrient composition of feeds on digestibility of organic matter by cattle: A review1. *Journal of Animal Science*, *88*(suppl_13), E151–E169. https://doi.org/10.2527/jas.2009-2559

Palmer, A. L., Beausoleil, N. J., Boulton, A. C., & Cogger, N. (2021). Prevalence of Potential Indicators of Welfare Status in Young Calves at Meat Processing Premises in New Zealand. *Animals*, *11*(8), 2467. https://doi.org/10.3390/ani11082467

PASTURE AND FEED FORAGE QUALITY. (n.d.).

Prakash Anand, Saxena Vishesh Kumar, & Singh Manish Kumar. (2020). Genetic analysis of residual feed intake, feed conversion ratio and related growth parameters in broiler chicken: a review. *Worlds Poultry Science Journal* , *27*(2), 304–317.

Rabobank NZ. (n.d.). *Strategic moment for 'dairy' beef – New Zealand agriculture's $1.2 billion opportunity*. Retrieved May 18, 2026, from https://www.rabobank.co.nz/media-releases/2025/07102025-strategic-moment-for-dairy-beef-new-zealand-agricultures-1-2-billion-opportunity

Richardson, E. C., Herd, R. M., Archer, J. A., & Arthur, P. F. (2004). Metabolic differences in Angus steers divergently selected for residual feed intake. *Australian Journal of Experimental Agriculture*, *44*(5), 441–452. https://doi.org/10.1071/EA02219

Rural News Group. (2024, October 4). Using sexed semen on elite cows.

Sainz, R. D., Baldi, F., Temp, L. B., & Ribeiro, L. B. (2024). Estimation of genetic parameters for maintenance energy requirements and residual feed intake in Nellore cattle. *Journal of Animal Breeding and Genetics*, *141*(6), 643–655. https://doi.org/10.1111/jbg.12870

Sainz, R. D., & Paulino, P. v. (n.d.). *Residual Feed Intake*. Retrieved https://escholarship.org/uc/item/9w93f7ks

Schoonenboom, J., & Johnson, R. B. (2017). How to Construct a Mixed Methods Research Design. *KZfSS Kölner Zeitschrift Für Soziologie Und Sozialpsychologie*, *69*(S2), 107–131. https://doi.org/10.1007/s11577-017-0454-1

Silva, C. S. da, Leão, J. M., Lage, C. F. A., Coelho, S. G., & Campos, M. M. (2023). Residual Feed Intake as an Efficiency Metric for Pre-Weaning Dairy Calves: What Do We Know? *Life*, *13*(8), 1727. https://doi.org/10.3390/life13081727

Silver Fern Farms. (n.d.). *Silver Fern Farms secures industry-leading sustainability-linked financing*. Retrieved May 14, 2026, from https://silverfernfarms.com/nz/en/our-company/our-news/SL-finance

StatsNZ. (2026, April 16). *Beef cattle numbers on the rise*. https://www.stats.govt.nz/news/beef-cattle-numbers-on-the-rise

Tariq, S., & Woodman, J. (2013). Using mixed methods in health research. *JRSM Short Reports*, *4*(6). https://doi.org/10.1177/2042533313479197

T&G Global. (2022, June 28). *T&G takes bold step towards low carbon future with Sustainability-Linked Loan*. https://tandg.global/tg-takes-bold-step-towards-low-carbon-future-with-sustainability-linked-loan

The Gradian. (2022, September 22). *New Zealand bans live animal exports from April 2023*. https://www.theguardian.com/world/2022/sep/29/new-zealand-bans-live-animal-exports-from-april-2023

The Treasury. (2024, August). *FEU Special Topic: The outlook for dairy exports*. https://www.treasury.govt.nz/publications/research-and-commentary/rangitaki-blog/feu-special-topic-outlook-dairy-exports

Tseten, T., Sanjorjo, R. A., Kwon, M., & Kim, S.-W. (2022). Strategies to Mitigate Enteric Methane Emissions from Ruminant Animals. *Journal of Microbiology and Biotechnology*, *32*(3), 269–277. https://doi.org/10.4014/jmb.2202.02019

UN Environment Program. (2026). *Facts about Methane*. https://www.unep.org/explore-topics/energy/facts-about-methane

UNDERSTANDING FEED QUALITY. (n.d.).

VanRaden, P. M. (2008). Efficient methods to compute genomic predictions. *Journal of Dairy Science*, *91*(11), 4414–4423. https://doi.org/10.3168/jds.2007-0980

Visscher P.M, Hill W. G, & Wray N. R. (2028). Heritability in the genomics era — concepts and misconceptions. *Nature Reviews Genetics* , 255–266.

Vytelle. (n.d.). *Understanding and comparing feed efficiency measures*. Retrieved March 21, 2026, from https://vytelle.com/tools/understanding-and-comparing-feed-efficiency-measures

Waghorn G. C. (2007). Waghorn G. C - What is metabolisable energy. *Proceedings of the New Zealand Grassland Association*, 69, 153–159.

Wakchaure, R., Ganguly, S., Praveen, K., Sharma, S., Kumar, A., Mahajan, T., & Qadri, K. (2015). Importance of Heterosis in Animals: A Review. In *International Journal of Advanced Engineering Technology and Innovative Science*.

Wells, J. B. (2015). *THE IMPACT OF SELECTION USING RESIDUAL AVERAGE DAILY GAIN AND MARBLING EPDS ON GROWTH PERFORMANCE AND CARCASS TRAITS IN ANGUS CATTLE*.

Westpac NZ. (2021, October 26). *Pāmu and Westpac NZ agree market-leading Sustainability-Linked Loan*. https://www.westpac.co.nz/about-us/media/pamu-and-westpac-nz-agree-market-leading-sustainability-linked-loan

Westpac NZ. (2023, June 14). *Westpac NZ launches Sustainable Farm Loan and Sustainable Business Loan*. https://www.westpac.co.nz/about-us/media/westpac-nz-launches-sustainable-farm-loan-and-sustainable-business-loan

Wuebbles, D. (2002). Atmospheric methane and global change. *Earth-Science Reviews*, *57*(3–4), 177–210. https://doi.org/10.1016/S0012-8252(01)00062-9

10. Appendix

10.1 Interview Questions

Primary producers

Can you please tell inform me about your production system?

What influences the decisions you make regarding to sire choice?

How important is feed efficiency in your system? Is it a trait you have previously considered?

Where are the biggest supply chain limitations for you?

How are environmental legislations or incentives influencing the production system you are involved in?

What are the biggest challenges and opportunities you see facing beef on dairy currently?

Calf rearers – specified

Where do you source your calves from?

What are you looking for when purchasing calves?

As a purchaser of beef calves, how much influence can you have on sire use or selection?

Industry representatives – specified

Where do you contribute to beef on dairy?

What are the opportunities and limitations?

What motivated you to get involved?

How can Beef on dairy better meet market demands?

What schemes are currently in place to incentives beef on dairy production?

What is demand like for New Zealand and dairy beef globally?

What countries does New Zealand beef end up in?

What do Beef on dairy strategies look like overseas?