Ministry for Primary Industries
Manatu Ahu Matua

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DairyNZ

TRANSFORMING THE DAIRY VALUE CHAIN

Farming | Processing & Supply Chain | Ingredients & Dairy Solutions | Consumer Products

A PRIMARY GROWTH PARTNERSHIP PROGRAMME

FINAL REPORT

FEBRUARY 2011 - JANUARY 2018
(PREPARED BY PROGRAMME MANAGEMENT OFFICE)

Foreword

On behalf of the Steering Group, I am pleased to present this final programme report on the *Transforming the Dairy Value Chain Primary Growth Partnership Programme*.

Described by a panel of international dairy experts as world-leading, this unique partnership has accelerated thinking and promoted game-changing research, innovation and input into new, higher-return dairy products, gene technology, capability-building and improved data standards and connectivity, to name a few. These advances would not have been possible without the combined effort of farmers, industry partners, scientists, researchers and government.

The partnership is on target to achieve its economic goals: by 2025 the dairy sector delivering an additional $NZD 2.7 billion in benefits to New Zealand every year. The successes don't stop at the farm gate. Our proudest achievements have delivered educational, environmental, and social gains that benefit all New Zealanders:

- Enabling a fundamental shift in our international reputation – moving our nation from a respected global trader in bulk milk and powders to a world leader in targeted dairy products, ingredients and high-value foods, beverages and infant formula.
- Attracting and using the minds of some of this country's best and brightest to the industry, our universities and research organisations. Dozens of our top scientists and students are working on PGP-funded dairy projects that are boosting the nation's intellectual property, while raising the reputation and excellence of New Zealand's agricultural research.
- Nurturing a pipeline of future dairy workers and leaders through education and partnerships with New Zealand Young Farmers and schools.
- Developing science and smart thinking that's advanced our farmers' capabilities and capacity for change, driving massive improvement in management of not only nutrients and effluent, but also people, pasture, stock and environmental impacts.

You will see many more examples of the programme's achievements in this report.

On behalf of the Steering Group, Fonterra and DairyNZ, I would like to congratulate, and offer our sincere thanks, to all those who have contributed to the success of this programme over the last seven years, and particularly the Programme Manager, Dr Andrew Fletcher. It's one of the greatest successes of the programme – farmers, scientists, industry groups, service providers and the government working together to make a difference. Delivering jobs to grow our regional economies, high-value returns to boost the national economy, a smarter workforce and a productive, sustainable dairy sector. That's real transformation.

Chris Kelly – Chair

Transforming the Dairy Value Chain Programme Steering Group

Executive summary

Dairying is the foundation on which New Zealand's economy, society and culture is built. No other industry or sector has made as significant a contribution to the country's wealth and prosperity.

In 2010, the industry's two main partners – DairyNZ and Fonterra – identified several key challenges that needed to be addressed to ensure the New Zealand dairy sector remained competitive in international markets, and delivered regional and national gains at a sustainable pace.

Challenges to be addressed included:

- Growing the global presence of the New Zealand food industry beyond the constraints of the New Zealand biosphere.
- Meeting increasing consumer demands for new products, improved management practices (e.g., animal welfare), greater quality assurance and identification.
- Responding to international developments (e.g., increasing regulation, climate change, free trade opportunities and protectionism).
- Adapting to increasing resource constraints (e.g., land area and potential restrictions on nitrogen and water use) and pressure from the New Zealand government and public for progress on meeting environmental goals.
- Fostering collaboration amongst a fragmented New Zealand research and development system with competitive tensions between research groups.

Responding to those challenges, and delivering the benefits envisaged, would require transformational change in the sector right across the dairy value chain – pre- and post-farm gate. Recognising this, in 2011, the industry, in partnership with the Ministry for Primary Industries (MPI) launched a world-leading, seven-year, $170m innovation programme through the Primary Growth Partnership (PGP) – ***Transforming the Dairy Value Chain (TDVC).*** Led by DairyNZ and Fonterra, with MPI support, the programme also included other commercial partners: Synlait, LIC, New Zealand Young Farmers, Agricultural Services Limited, Landcorp Farming and ZESPRI.

The vision for the programme was to enable a transformation of the dairy sector creating increased value for New Zealand by 2025 through game-changing innovation and research in the dairy value chain that delivers economic, social and environmental benefits, and ensures New Zealand's ongoing success as a dairy industry world leader. Through transformation of the sector, the aspirational goal of the programme was to increase benefits to New Zealand by $NZD 2.7 billion every year from 2025.

Closely aligned to the strategies of the major industry investors, DairyNZ and Fonterra, projects under the TDVC programme were broken down into five key themes of dedicated research and innovation under 13 workstreams, right along the value chain, pre- and post-farm gate.

Pre-farm gate initiatives focused on boosting on-farm productivity, while minimising dairy's environmental footprint. Examples include new technologies, improved information sharing, enhanced advisory services and building on-farm skills and capabilities.

- **Theme 1: On-farm innovation and research:** Projects focused on developing a range of innovative technologies, opportunities and information to enable future sustainable dairy production growth, with a reduced environmental impact.
- **Theme 2: Capability and capacity:** Projects aimed at building the dairy industry's capability, developing support networks and attracting more people to work in the sector.

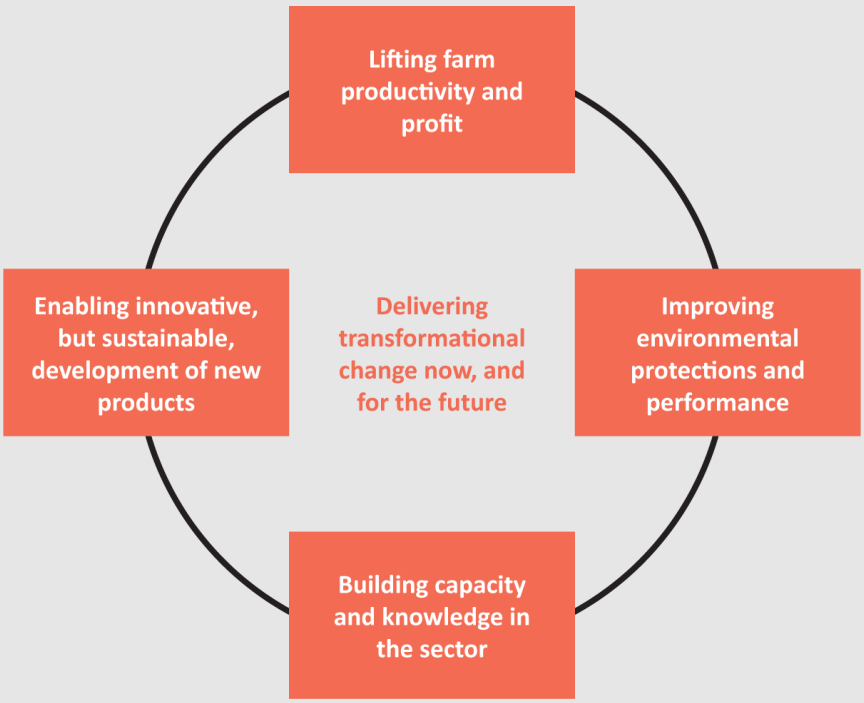
Having established these foundations for sustainable milk production, research beyond the farm gate focused on human nutrition, food structures, processing and food quality management. A key aim of this work was to improve processes in manufacturing and supply, developing new product ranges for New Zealand and international markets.

- **Theme 3: Food structures:** Projects aimed at developing New Zealand as a world leader in food structure design, by working with our best and brightest university students, guided by a panel of internationally recognised leaders in food structure design. Outcomes from the university projects are then transferred in-house for further development to meet a growing consumer demand for healthier customised foods.
- **Theme 4: Quality management:** Projects aimed at creating new tools to enable efficient and sustainable dairy processing technologies that will give New Zealand a competitive advantage internationally and enable profitable growth in new dairy regions.
- **Theme 5: Nutrition and health:** Projects aimed at providing robust scientific evidence on the health benefits of dairy products including infant formula, and products to support mobility and ageing.

Benefits delivered by the *Transforming the Dairy Value Chain* programme

Through partnership, investment and cutting-edge innovation and research, the TDVC PGP programme has enabled transformational change within the New Zealand dairy sector, and as a result, the programme is on target to achieve its aspirations: delivering an additional $NZD 2.7 billion in benefits to New Zealand every year. Value includes economic, environmental and social benefits, that extend beyond farms alone, to research centres and universities, schools, firms, factory floors and further into international markets.

Over its seven-year duration, the TDVC PGP programme has delivered on its goals:



Increased on-farm productivity – the industry measure is profit from productivity. The target is

$1090 per hectare,

and it's currently tracking at an average of

$808 per hectare,

nearly double the 2010 profit from productivity per hectare.

Improved advice and nutrient, effluent and animal welfare management through rural professional schemes means farms can produce more milk within environmental limits, delivering an estimated

$282 million

in benefits to New Zealand through reduced costs and losses avoided.

Increasing genetic gain of dairy cattle –

a **0.3%** improvement

in gain between 2010 and 2016 is adding around

$60 million

to the sector each year. The target is 1.5% per annum rate of gain and is currently tracking at 1.35%.

Research into pasture persistence have resulted in improvements in farm management and plant breeding. Average milk solids production has increased to

1063 kg per hectare,

from 902 kg in 2010.

Investing in projects to attract, grow and retain people and build leadership. Case studies show that farms with healthy and skilled teams, strong business management skills and access to advisory services are around

$50,000

more profitable each year. For every 10% of dairy farms, that's an extra

$60 million per year.

Primary ITO Level 4 completions have increased by

60% since 2013,

indicating that increased value is being placed on higher farm skills and knowledge.

World-leading science to develop new mozzarella products, resulting in Fonterra investing

$72 million

to double the capacity of the Clandeboye plant, and approving a further

$240 million

for the next expansion stage.

Advances in science and research in the development of new creams better equipped to handle supply chain variations. As a result, Fonterra accelerated plans to upgrade the Waitoa UHT facility to enable production of an extra

40,000 MT

of UHT creams per year.

World-leading nutritional science that's provided the evidence to support adding milk gangliosides to infant formula, leading to a complete refresh of the ANMUM product range.

Detailed outputs from each of the 13 workstreams or "roadmaps" are outlined on pages 34-53 and include:

The development of new products including:

- New product launches to enable the Fonterra foodservice strategy including mozzarella cheese and UHT creams.
- New infant and follow-on formulas under the ANMUM™ brand and new infant and follow-on ingredients for sale by NZMP™.
- New formulations and a new marketing positioning for the ANLENE™ brand.

Services and capabilities now available to the dairy sector including:

- Improvements in genetic gain for the national herd and tools to screen out undesirable mutations.
- Standards and mechanisms to support the exchange of data between different organisations, reducing the burden of multiple data entry and improving overall data quality.
- Trained and certified rural professionals able to provide advice to farmers in key areas affecting the profitability and environmental performance of the farm.
- New analytical technologies that support timely milk allocation decisions.

Benefits outside the dairy sector including:

- Availability of trained and certified professionals to provide advice to farmers in other agricultural sectors.
- Wider application of data standards and data connectivity.
- New fruit management protocols for ZESPRI to support improved supply chain management resulting in better fruit quality and lower losses.

The scale and scope of the programme has also enabled world-leading science and sharing of knowledge that wouldn't have been possible with industry players acting alone – boosting the efficiency, health and production of New Zealand farms and farmers, supporting vital environmental goals and enabling the development of exciting new dairy products. Over the coming years, the programme will continue to deliver benefits to New Zealand as those new, higher-return products become commercially viable and new scientific knowledge is applied to the sector. Already, more than $500 million has been invested to bring these new products to market.

More than 600 people have been involved in the projects under the programme, delivering more than 2,000 written outputs. More than 16 patents have been filed for new processes and products. That's all helping to build New Zealand's reputation as a global dairy leader, able to compete against some of the world's largest countries and corporations. On farms, in the offices of rural professionals and companies, in our schools, research labs and universities, the PGP programme has built knowledge, capacity and capability, future-proofing the sector for generations to come.

Also, key to the programme's success has been the relationships built between its partners – industry (DairyNZ and Fonterra and other industry partners), Ministry for Primary Industries and research providers. Through collaboration and shared investment, the programme will continue to be able to deliver game-changing research and innovation across the sector, accelerating thinking and making progress for New Zealand that might not have been possible without that combined effort.

This report provides a summary of the programme since its initiation in 2010. In addition to the key achievements and outputs, this report also covers key learnings from operation of a programme of this scale, that will be useful for programmes of a similar scale, scope and complexity in the future.

7 YR	**$163M**	**$2.7B**	**$500M**
Seven-year duration	$NZD 163 million investment (of $NZD 170 million originally planned)	Projected benefits of $NZD 2.7 billion per year by 2025	More than $NZD 500 million of downstream investment of to commercialise outputs
2,000	**16**	**600**	**60**
Approximately 2,000 written outputs	At least 16 patent applications (further applications are under consideration)	More than 600 people involved in the delivery of projects	Almost 60 postgraduate research degrees completed

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Programme purpose

The **vision** for the DairyNZ, Fonterra and Ministry for Primary Industries (MPI) partnership, embodied in the Transforming the Dairy Value Chain (TDVC) PGP programme, was a transformed dairy sector that delivers increased economic, social and environmental value to New Zealand.

The **purpose** of the programme to was to enable this transformation by addressing key challenges, opportunities and gaps along the dairy value chain.

The programme aimed to fulfil its purpose by being a world-leading public-private partnership with the following distinctive features:

- A strategy and business-led approach that is problem and opportunity based.
- A holistic approach to dairy innovation that addresses the challenges of effective knowledge and technology transfer as well as the generation of new knowledge.
- Development of world-leading concepts along the whole dairy value chain.
- Flexibility to align to industry objectives and adapt to a changing strategic environment.

In August 2014 as a product of a strategy and governance workshop the programme was renamed **"Transforming the Dairy Value Chain"**. Prior to this – in the original Business Plan – the programme title, vision and purpose were outlined as follows:

Innovation to Transform the Dairy Value Chain

Transformational platforms of research, training, and knowledge transfer pre- and post-farm gate

Leading to accelerated:

- ***Commercialisation of new economic opportunities for dairy and food companies, and,***
- ***Adoption on-farm of existing and novel, practices and technology that reduce environmental footprint whilst improving productivity.***

Once established, the platforms will be available to be leveraged and extended by other primary industries.

This original title and vision captured the strong focus of the programme on developing capabilities across the innovation system to support a transformation of the dairy sector. While the title of the programme changed, the focus of the investment remained on creating these transformational platforms that have provided the foundations for further investment by industry to capture the targeted benefits.

The **programme scope** is defined by the dairy value chain - from activities on the farm, through to health and nutrition benefits to consumers from new dairy-based products.

Context for the programme

Dairying is a cornerstone of the New Zealand economy and one of the country's largest export sectors, making it vital for New Zealand's prosperity that the sector continues to innovate and transform to remain competitive in international markets, and deliver regional and national gains at a faster pace.

As early as 2009, industry partners DairyNZ and Fonterra identified several key challenges that needed to be addressed to put the dairy sector in a stronger position both sides of the farm gate. Market failure had

resulted in gaps in the overall innovation system that needed to be closed, which required the creation and development of capabilities outside of the organisations themselves (e.g., training rural professionals), including within the government research and development (R&D) sector (e.g., New Zealand universities and Crown Research Institutes (CRIs)). These activities were beyond the current investment remit and scope of both DairyNZ and Fonterra and would generate a public benefit outside of the dairy sector itself, strengthening the case for public sector investment. Even areas that, in hindsight, appear to have had strong commercial drivers for investment (e.g., food structure research on rapid mozzarella production) first required the development and growth of new skills and capabilities within the wider R&D system. This strong theme of capability development fitted with the PGP remit – stretching thinking and looking for innovative ways to achieve outcomes for the primary sector that benefit New Zealand's environment, economy and society.

Recently, volatile commodity prices had emphasised the need to build more resilience into the dairy value chain, by reconnecting pre-farm gate and post-farm gate initiatives and people. This included a focus on farm profitability over productivity – including a decreased reliance on imported feed – and increasing the portion of milk production that is sold through a value-add channel to deliver additional margin and profits back to shareholders and mitigate the extremes of commodity price cycles.

Figure 1 below illustrates one aspect of the challenge facing the industry. Rapid growth from 1990 to 2010 had delivered significant value to the New Zealand economy, but this was accompanied by similar growth in the environmental footprint of dairy farming. To enable further growth required that the sector think differently – by separating production volume gains from any additional environmental impact and increasing the profit from existing milk productivity.

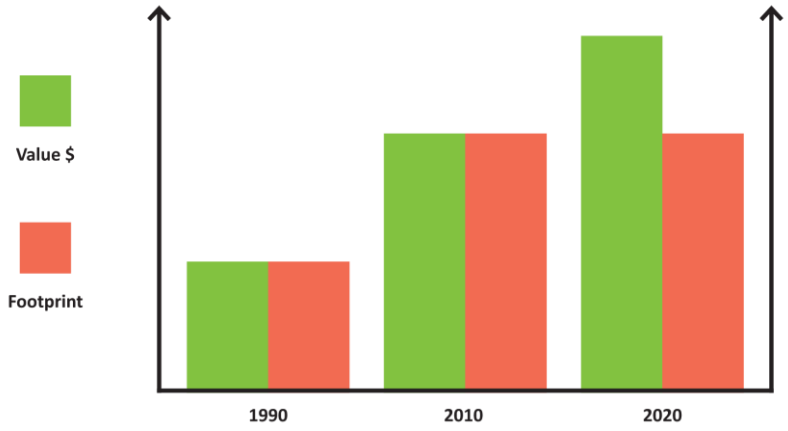

Figure 1: Growth of New Zealand dairy farming in productivity and the related environmental footprint– (illustrative only)

Challenges to be addressed included:

- ***Growing the global presence of the New Zealand food industry beyond the constraints of the New Zealand biosphere.***
- ***Meeting increasing consumer demands for new products, improved management practices (e.g., animal welfare), greater quality assurance and identification.***
- ***Responding to international developments (e.g., increasing regulation, climate change, free trade opportunities and protectionism).***
- ***Adapting to increasing resource constraints (e.g., land area and potential restrictions on nitrogen and water use) and pressure from the New Zealand government and public for progress on meeting environmental goals.***
- ***Fostering collaboration amongst a fragmented New Zealand R&D system with competitive tensions between research groups.***

Alignment with industry strategies

The need for innovation and transformation within the dairy sector to respond to these challenges is outlined in the strategies of both the major industry investors – DairyNZ and Fonterra.

The DairyNZ ***Strategy for New Zealand Dairy Farming 2009/2020*** outlined five essential outcomes for the industry:

1. The ongoing needs of individual farmers for business security, combined with increasing input costs and growing international low-cost milk production lead to **Outcome 1: Increased farm profitability.**
2. Growth and ownership changes in dairy farming mean that more people are needed on farms and in supporting industries. The increased complexity, diversity and volatility of dairy farming means that skill levels across the industry needs to improve. These factors combine to drive **Outcome 2: Talented and skilled people are attracted to, and retained by, the dairy industry.**
3. Because of reliance on the international market, New Zealand dairy farming can only capture growing international demand for dairy products and deliver to farmer and economic aspirations by achieving **Outcome 3: An internationally competitive milk supply maximises returns to farmers.**
4. The industry had a mixed reputation for workplace and environment practices, which poses risks around regulation and attracting people. However, there are market opportunities associated with New Zealand's good reputation for product quality and safety. Together these drive **Outcome 4: Industry reputation enhanced locally and globally.**
5. Government and society and farmers had shared, but not identical, goals for the nation's economy and use of natural resources. Emerging pressures on the economy and resource use highlighted the need to align these goals and led to **Outcome 5: Achievement of shared goals through genuine partnerships between industry and government and the wider community**.

The corresponding ***Fonterra Strategy*** focused on three areas of future development:

1. **Leverage opportunities in core business**
   - Optimise our New Zealand and offshore manufacturing, logistics and global milk sourcing capabilities.
   - Lead changes in how global commodity markets function (e.g., Global Dairy Trade) with substantial benefits for our core business.

2. **Be the leading global provider of innovative dairy solutions to major global food companies**
   - Partner of choice of major regional and global ingredients, nutritional and foodservice customers.
   - Leverage already strong relationships with major food companies to extend the range of ingredients and dairy solutions.
3. **Grow earnings from attractive consumer positions in Asia, Australasia and Latin America**
   - Build and extend high-profile brands in Asia and launch in China.
   - Build on our strong Australasian and Latin American consumer positions.

Fonterra underwent a strategy refresh in 2012. The primary outcome was an increased focus on developing the consumer products and foodservice arms of the business as part of *turning the wheel* to increase the revenues associated with the milk pool.

Investment rationale

The vision: **A transformed dairy industry delivering increased value for New Zealand by 2025 through game-changing innovation and research in the dairy value chain that creates economic, social and environmental benefits, and ensures New Zealand's ongoing success as a dairy industry world leader.**

The goal: ***Increase benefits to New Zealand by $2.7 billion every year from 2025[1].***

Benefits of this scale could only be delivered by leveraging the full potential of the entire dairy value chain.

Figure 2 and Figure 3 illustrate the four main ways in which the programme aimed to deliver the desired economic benefits (represented in green):

1. Improved profitability of dairy land *(Themes 1 and 2)* – through a combination of new technology and improvements in farm management.
2. Growth in the sustainability of land used for dairy production – enabling increased milk production whilst addressing social and environmental considerations *(Theme 2).* Note – while the figure below shows an increase in land use against a constant base, there was a significant risk both profitability and land use would contract rather than remain constant without the outputs of the programme.
3. Growth in the proportion of milk allocated to value-add activities – delivering enhanced gross margin *(Themes 3 and 5)*.
4. Improved efficiency, quality and price achievement for New Zealand dairy products– resulting in reduced post-farm gate costs, higher revenues, and improved gross margin *(Theme 4)*. Although the available margin in these areas is small on a liquid milk equivalent *(LME)* basis, the volume of production to which this may apply leads to significant benefits.

[1] Revised from 2020 to 2025.

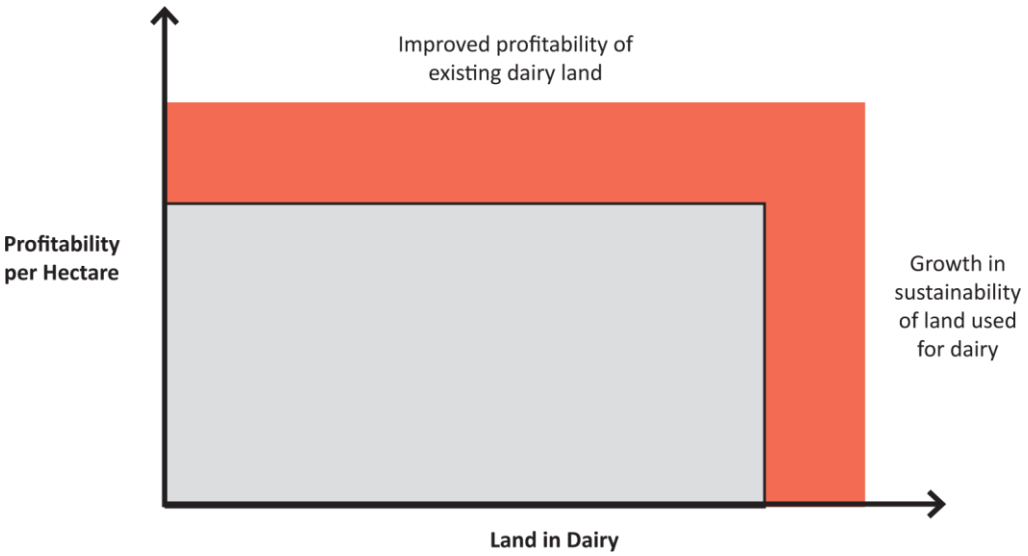

Figure 2: Potential on-farm impacts of the programme

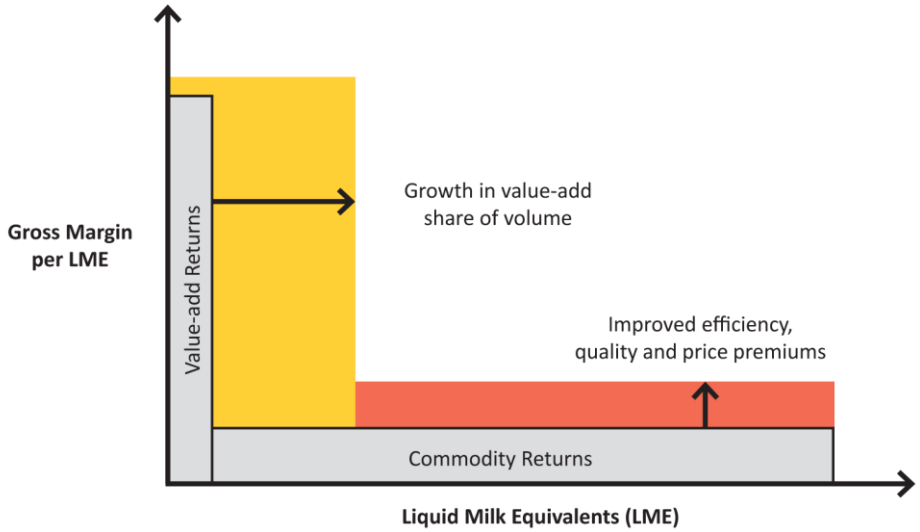

Figure 3: Potential post-farm gate impacts of the programme

Note: The change in Fonterra's strategy in 2012 increased the emphasis on the third benefit *(growth in value-add)* at the expense of the fourth *(improved efficiency)*.

Investment focus

From the challenges identified in 2010, achieving a sustainable transformation of the dairy sector required different actions at different points along the dairy value chain. At the highest level, growing a sustainable and competitive milk supply in New Zealand was – and still is – critical for the development of value-added products and services. At a project level, activities within the programme focused on enabling change to address the individual needs and challenges of a section of the value chain. Only when the programme is considered in its entirety is the required transformation of the value chain realised. *(The primary exception to this was in the designer milks aspect of the on-farm technology roadmap - where compositional characteristics of consumer products and associated claims of benefits are being driven by changes in on-farm practises).* Emerging work within Fonterra on the link between farming practises and the purchase choices consumers make *(either in the choice of which brands they support or the price they are prepared to pay)* was beyond the scope of this programme.

This led to a focus within the on-farm end of the programme on enabling sustainable and profitable growth in New Zealand milk production by:

- Providing on-farm science and technology *(Theme 1 – Innovation: Resilient cows, On-farm technologies, Dairy data network).*
- Developing new approaches to ensuring farmers have access to quality advice and have the skills and capability required for the future *(Theme 2 – Capability: More and better advisors and advice, Better farm decision-making).*

Having established these foundations for sustainable milk production, activities to add value beyond the farm gate included:

- Science to inform the development of new products to deliver physical and sensory characteristics *(Theme 3 – Food structure design: Endgame mozzarella, Endgame creams, Signature milks)* and technically related work on kiwifruit structure *(ZESPRI roadmap).*
- New approaches to processing and food quality management to maximise the efficiency of processing and supply chain activities while preserving quality *(Theme 4 – Food processing: Process analytical technology, Food safety and quality).*
- Providing robust scientific evidence of nutritional benefits associated with dairy products and components *(Theme 5 – Foods with robust health and wellness benefits: Mobility and protein quality, Paediatrics).*

Progress in these areas required growth and better alignment of capabilities in the R&D and advisory sectors. Consequently, many of the R&D projects had strong secondary objectives relating to the development of people and capabilities.

Operation of the programme

This section details the key operational features and changes in the programme over the seven-year term. Several lessons and insights that are valuable for the operation of future programmes of similar scale are also covered.

Programme structure and management

Figure 4 shows the final programme structure with 13 "roadmaps" or workstreams grouped in 5 themes, reporting through a single programme manager to the programme steering group (PSG).

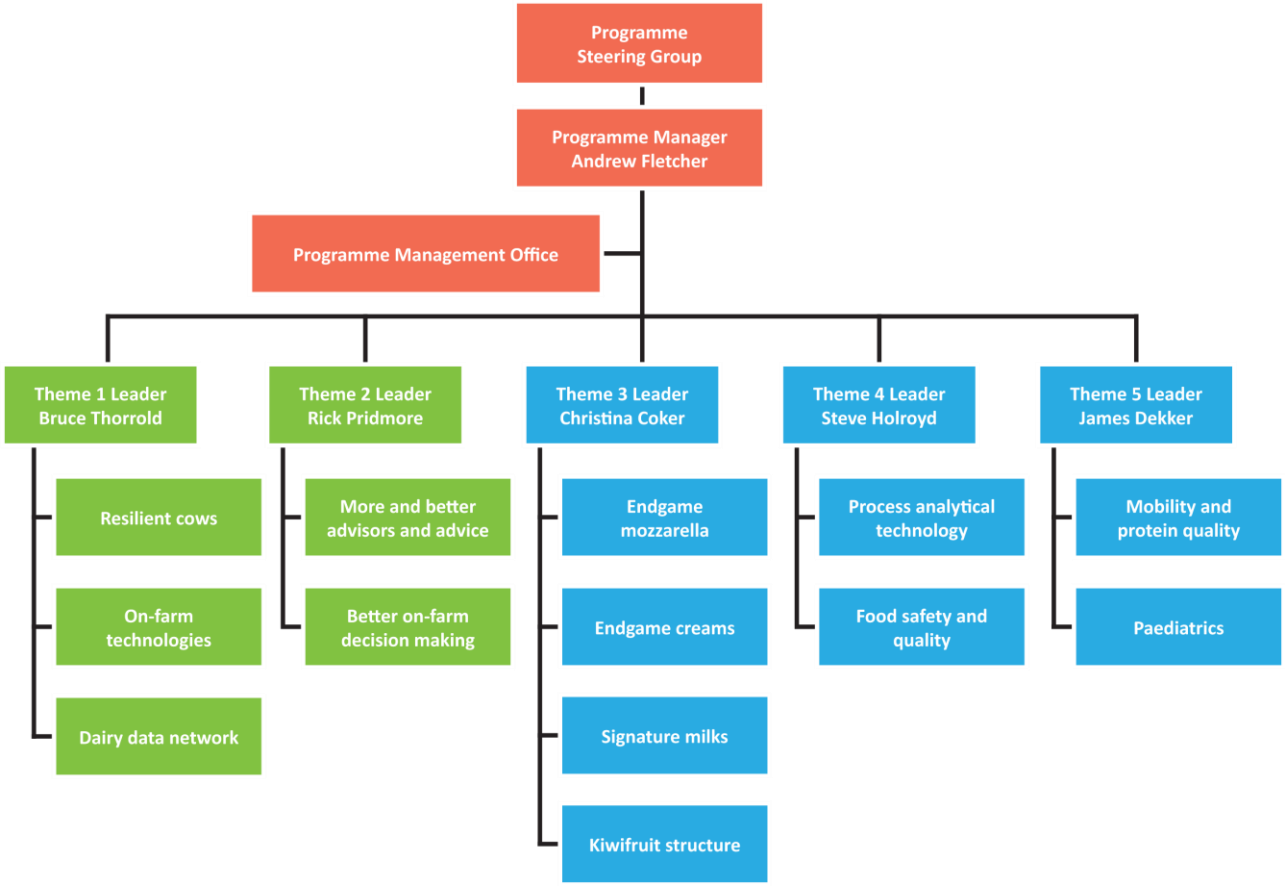

Figure 4: Final programme structure including the 13 roadmaps (workstreams) under each of the 5 programme themes

Each "roadmap" or workstream consists of many individual projects targeting an outcome or objective of the overall programme.

For example:

The Resilient Cows roadmap within Theme 1 – "Innovation" contains two workstreams focused on improving the genetics of cows – bovine genomics work led by LIC, and phenotypic studies led by DairyNZ.

The two roadmaps within Theme 5 – "Foods with Robust Health and Wellness Benefits" represent streams of activity with different end targets:

- Mobility and Protein Quality (targeting the scientific substantiation of the benefits of dairy protein for supporting mobility with expected benefits through the ANLENE™ brand and sales of protein ingredients by NZMP™).
- Paediatrics (targeting the scientific substantiation of primarily cognition benefits for infants through the consumption of dairy lipid and carbohydrate-based ingredients with expected benefits through the ANMUM™ brand and sales of specialty paediatric ingredients by NZMP™).

The individual projects, timings, interdependencies with other projects, and their connection to future outcomes and benefits under each of the 13 workstreams was mapped out in a detailed chart. It is from these charts that the term "roadmap" is taken.

Changes to the programme structure implemented

The programme was originally structured as two substantially independent sub-programmes led by DairyNZ and Fonterra, containing a total of five themes spanning the dairy value chain, and governed by a single programme steering group (see Figure 5).

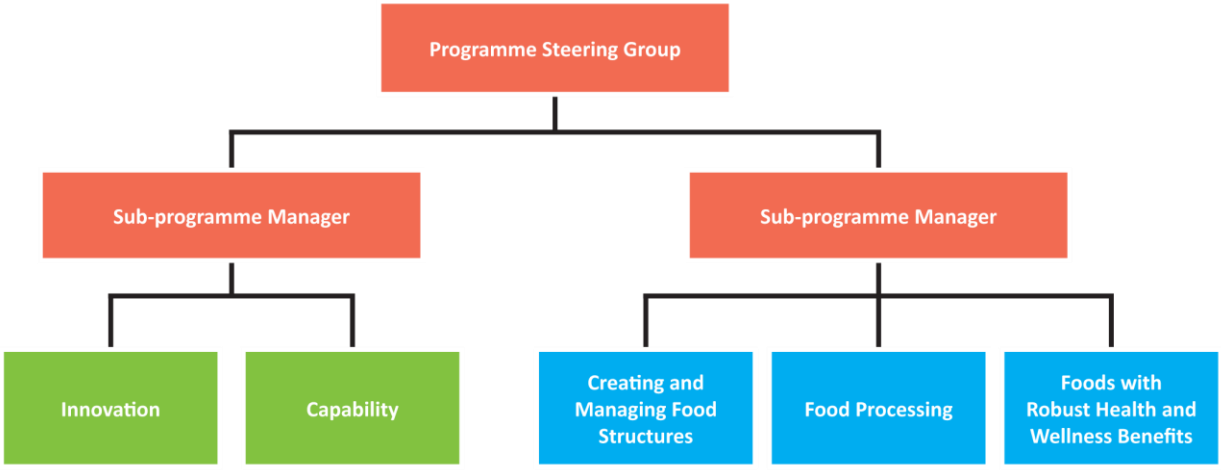

Figure 5: The original Transforming the Dairy Value Chain Programme structure

A single overall programme manager was appointed during the 2015 financial year and the "roadmaps" were created in 2015 as part of the development of the 2016 Business Plan. Notably:

- The appointment of a single programme manager provided a consistent approach across the entire programme and enabled changes in the reports and documents prepared for the PSG, providing a structure and style that supported more efficient governance. The appointment also enabled progress on development of the benefits realisation framework and a consistent risk management framework.
- The creation of the roadmaps provided a structure for all the subsequent programme reporting and enabled the PSG to have visibility of the impact of individual projects on the overall programme goals.

Programme governance

Overall, the PSG has worked well together, particularly once the approach to management and governance of the programme was amended in the 2014-15 financial year.

Importantly, the scale of the programme was sufficient to command senior leadership attention from the industry investors which gave necessary weight to PSG discussions and decisions. A significantly smaller programme would have resulted in governance being delegated to lower levels in both DairyNZ and Fonterra commensurate with internal authorities and responsibilities.

Throughout the programme, there was governance continuity from the two main industry partners with Dr Tim Mackle (DairyNZ) and Dr Jeremy Hill (Fonterra) onboard throughout the programme.

Following a programme progress review conducted by Deloitte in 2015, the composition of the PSG was altered to include the appointment of an independent chair, Chris Kelly, by MPI in consultation with the industry partners. Having an independent chair, with relevant industry experience, brought useful additional perspectives to the programme, as well as a range of additional external contacts.

In 2016, to recognise the desirability of having a Fonterra Management Team member involved in the PSG – but recognising the limitations on their ability to attend meetings – it was agreed that Fonterra might

have three nominated members of the PSG. However, in any situation requiring a vote these three members could collectively only exercise two votes.

Strengths of the PSG included:

- An independent chair with good credibility in industry and government circles.
- Sufficient seniority of the membership to commit the partner organisations.
- Continuity of membership.
- A focus on outcomes, benefits and risks.

Partnership

A key dimension of the success of the programme has been the partnerships established between the various participants. This includes between:

- Industry partners, particularly between DairyNZ and Fonterra.
- Industry partners and MPI.
- Industry partners and the provider organisations working within the programme.
- Research providers.

These relationship impacts have been enabled by the scale, scope and duration of the programme.

Relationship between industry partners

The experience and success of TDVC PGP programme has resulted in much greater collaboration within the sector, and with research partners – delivering tremendous benefits and resulting in all parties being committed to finding future opportunities to genuinely work together in collaboration across the supply chain.

Industry – MPI relationship

The programme has contributed to a significant improvement in the relationship between both DairyNZ and Fonterra, and MPI. As participants in the programme's governance, the MPI representatives could identify areas of synergy between the TDVC workstreams and other activities within the Ministry (including, but not limited to, other PGP programmes) and make connections. Areas within the programme that benefited from this included:

- Dairy data network – including the Farm Data Standards and *DataLinker*. MPI itself is a major contributor and customer of on-farm data and has also supported by bringing multiple sectors together to address key issues in this space.
- Food safety and quality – providing a channel for taking outputs on statistical sampling to Codex.
- Nutrition – ensuring early conversations about the scope of potential health benefit claims and the level of evidence required.
- Industry training and capability needs – ensuring connection across multiple PGP programmes active in this area. There is good alignment between work conducted in PGP programmes and wider primary industry work on capabilities.

Amongst the other PGP programmes, the TDVC PGP programme has the strongest synergies with the Red Meat Profit Partnership (RMPP), which is attempting to address several similar challenges within the red meat sector. Early in the development of what became RMPP, there were discussions between the programmes of the management practises, advisory and adoption capability work within TDVC and how these might be applied to the red meat sector, which faced similar challenges. Several spin-off benefits were identified and consequently TDVC and RMPP have co-invested in many the data and capability development projects.

The programme also benefited from having a senior manager from the Ministry of Business, Innovation and Employment (MBIE) attending the programme steering group meetings. This helped to identify areas of potential overlap or synergy between TDVC and MBIE investments. From an MBIE perspective, this resulted in valuable insight into the joined-up nature of the programme along the value chain; a current

view of dairy industry issues; and links between MBIE activities and TDVC helping to inform MBIE strategic decisions. The scale and breadth of TDVC was an important contributor to these benefits.

Relationships with providers

As a direct consequence of the TDVC programme, Fonterra has adopted a new way of working with its key research providers, characterised by a high degree of openness and co-development of projects to address critical challenges. This was a conscious goal of the programme and evolved over time as the parties worked together and built trust. This directly benefited the programme by unlocking a wider range of ideas and building a greater engagement between the wider team and the programme goals. This is evidenced in the following quote from the Food Structure Expert Panel.

> ***"The openness and in-depth information provided by Fonterra, provided all involved scientists authentic insight, not only into the problem to be solved, but also its context. Openness benefited both partners. It gave the academics greater scope to think around the problem, and it opened the industrial partner to new ideas and approaches not previously realised."***

This new way of working is now embedded as part of Fonterra's approach to external R&D.

As part of the genetic sequencing work, LIC has partnered with other research organisations to create new bioinformatics capability. Partner organisations include The University of Auckland, University of Liege, the United States Department of Agriculture, HudsonAlpha Institute for Biotechnology, Iowa State University, Department of Primary Industry Victoria, Australian Genomic Resource Facility, AgResearch Invermay, Cold Spring Harbour Laboratories, Illumina and Neogen. Through the programme, LIC accessed the capabilities of the New Zealand e-Science Infrastructure programme (NeSI) to run computationally intensive Genome Wide Association Study (GWAS) experiments.

The TDVC partnership has also provided DairyNZ and other pre-farm gate investors with the mandate and capacity to reach beyond delivery of direct benefit to farmers. It's allowed building and strengthening of near-farm service providers and development of collaborations with commercial entities. The approach empowered entities already in the value chain to deliver outcomes that have transformed the way they operate and interact with farmers and other organisations.

For example:

- The farmer wellness and well-being project involved over 15 organisations spanning public and rural sectors, research and front-line service providers. As a result, significant programmes such as GoodYarn and Health PitStops have been deployed. Organisations are collaborating to provide synergies and the attitude to mental health and wellbeing has changed as evidence by the following quote from a DairyNZ regional leader.

> ***"The most significant change I have noticed is how many farmers are prepared to talk about wellness compared to five years ago. It is no longer a surprise to me if a farmer wants to talk about stress and the impact it is having on their health. I can think of several examples recently of 'stress-related' conversations I have had with farmers (in one case it was severe enough to recommend the farmer directly to their GP for immediate help). Five years ago, these conversations would never have taken place."***

- The work of DairyNZ, the NZ Institute of Primary Industry Management (NZIPIM) and leading farm management consultancy firms in co-developing the Dairy Farm Systems accreditation process is a

good example of a collaborative endeavour, delivering the set of skills required to be a competent dairy farm systems consultant.

This enhanced level of collaboration is an important part of the ongoing delivery of many of the services developed by the programme, that will continue to deliver benefits in the future.

Relationships between research providers

The programme has been very successful in bringing together a range of New Zealand and international research providers to work collaboratively on key topics. The scale and scope of the TDVC work programme enabled the creation of multi-organisation research teams to tackle the technical challenges facing industry. The longer-term nature of the programme investment helped to create an environment where collaboration between research providers was actively encouraged, breaking down traditional barriers created through the competitive nature of much of the R&D funding system.

The scale and impact of these relationships is seen in the Food Structure Design area where over 100 people from 12 organisations have contributed to the development and delivery of the research programme. This interaction has been carefully fostered through convening regular expert panel reviews covering the entire scope of the theme, where researchers presented their work for discussion with their peers and the visiting experts. A consequence of this is that the organisations are now spontaneously partnering amongst themselves, including sharing postgraduate students and submitting joint funding proposals.

Initially, the TDVC programme battled against a culture of unhealthy competition built up over many years since the Crown Research Institutes (CRIs) were formed and the competitive funding model was established.

The programme's activity in fostering collaboration occurred ahead of the development of the National Science Challenges, which have also sought to foster collaboration rather than competition across the New Zealand R&D sector. PGP and other government investment programmes should continue to emphasise, and encourage, collaborative behaviours within the R&D sector for the benefit of New Zealand.

Programme scope

One of the strengths of this programme, and the wider PGP scheme, has been the ability to address challenges right along both the value chain and the innovation system, targeting investment where the need is greatest. This is a marked difference from other New Zealand government investment schemes which have historically tended to focus only on the R&D aspects. This flexibility has been particularly important for the on-farm section of the programme where one of the key challenges has been growing enough capability and expertise to be able to implement what is often known science in a consistent manner across over 10,000 businesses. The TDVC programme is not alone in addressing this challenge of practise change with RMPP and the New Zealand Avocados Go Global PGP programmes both reflecting similar themes in their work programme.

The longevity of the programme has also been a key success factor. While the long-term study of pasture persistence just would not have been possible without the seven-year term, other areas of the programme have also benefitted. Many of the science areas have progressed through two generations of projects with sufficient duration within the programme for outputs and lessons from the initial activities to be refined and improved through follow-up investigations, resulting in a great depth of scientific understanding. Outside of the science areas, the programme duration was also critical to the development of the various training and certification initiatives, providing the opportunity to scope, develop, trial, implement, review and streamline/redevelop new training schemes within the programme lifetime.

The flexibility given to the PSG to govern the programme was also critical in enabling the programme to adapt to new findings and changes in the external environment. This encouraged greater risk-taking, as the failure of one line of investigation did not result in termination of the programme but allowed redirection of effort into another more promising area of study or research. A comparison of the initial and final view of programme investment across the different themes shows, at a high level, how the focus shifted from

how the programme was originally conceived. Once the initial programme operational challenges were addressed, the annual business planning process provided a robust mechanism for steering the programme along its seven-year journey.

Benefits realisation framework (BRF) and adoption planning

As noted in the achievements section of this report (see pages 30-60), the TDVC PGP programme is on track to deliver very significant benefits to the dairy sector and the wider New Zealand economy. From an economic perspective, the aspirational goal of delivering benefits to New Zealand of $2.7 billion looks attainable. However, this will be achieved by 2025, rather than the original 2020. The programme is also generating a range of social and economic benefits that are much more difficult to quantify.

Two aspects of programme operations relating to benefit capture are considered below:

- Measuring and communicating benefits.
- Planning for adoption and benefit capture.

Measuring and communicating benefits

One of the challenges with a programme of this scope and scale has been the ability to succinctly convey the expected benefits, and the way the outputs of the programme are critical to the achievement of these benefits.

Several of the benefits are not directly and independently observable (e.g., measuring the impact of trained rural professionals or a fully competent farm team on the profitability of dairy farms). To close this gap, DairyNZ commissioned several reports over the life of the programme that provide a connection between the outputs of the programme and movement in broader industry measures. A challenge in some of the early case studies was a desire by the reviewers to apportion benefits between multiple contributing activities rather than take a holistic approach that considers the enabling role of individual activities within a broader *system* (i.e., if A, B and C are all necessary to achieve an outcome with value X then considered individually the benefit of A, B or C is X, as without any one of these components X would not be realised). A consequence of this was the portion of the benefit attributed solely and directly to the TDVC programme was a small fraction of the total impact.

Another challenge faced by the programme in expressing the benefits, which was not adequately solved, was establishing appropriate measures for the social and environmental benefits of the programme in a manner comparable with the economic impacts. With a significant portion of future partnership innovation activity likely to target environmental and social benefits as primary rather than secondary drivers, establishing a shared approach to "valuing" these aspects of programmes will be essential.

Planning for adoption and benefit capture

The outcome-based thinking driven by the roadmaps and BRF development was particularly valuable in the areas of the programme where the path to market was more complex.

For most of the product-related science, the path to market was reasonably straightforward with science outputs being adopted into the design of commercial product development projects as part of the industry investors' commercial innovation pipelines.

For other areas - such as the capability work in Theme 2 - this was less clear and the discipline of developing an implementation roadmap and associated benefit realisation plan help to crystallise thinking about the work required over the final years of the programme. Bringing aspects of this work in at an earlier point in the programme life would have helped to shape the nature of the projects.

Collaboration with RMPP has provided additional benefits from several of the data and capability projects, as well as providing a safety net should these struggle in the first years of post-programme operation.

Programme communications

Over the last three years of operation, the programme generated a significant volume of media articles showing the impact of a deliberate focus on communications and the employment of a dedicated communications manager. These items, many including stories about the people working in the programme, provide a good perspective on the scope and scale of the work undertaken.

However, the early stages of the programme were characterised by a very low level of communication.

As the programme matured, the lack of communications became an issue due to the lack of *externally visible* achievements. This was identified as a major issue for the programme in the consolidated risk assessment prepared following the appointment of a single programme manager in FY2015, and was also called out as an area for action in the progress review (on page 24).

Risk management

The major assumptions on which the programme investment was made included:

1. ***The dairy and food industries will continue to play a critical role in the New Zealand economy.*** The risk that corresponds to this assumption is that there is a major collapse in the New Zealand dairy and food sector and that this collapse renders the sector unable to make a significant contribution to economic growth. This is unlikely unless:
   - *New Zealand is no longer cost-competitive* – one of the programme goals was to mitigate this risk through improving productivity and profitability across the entire value chain and addressing the impact of the industry on the environment to ensure it remains cost-competitive through to, and beyond, 2020, or,
   - *New Zealand is subject of a major food scare* – this would delay realisation of benefits, although the programme also helps mitigates this risk through enabling the New Zealand food industry to grow beyond the constraints of the New Zealand biosphere and repatriate profits. The programme also sought to address this risk through the development of world-leading food assurance and control systems.

2. ***The R&D programmes deliver the research, science and technology (RS&T) outputs required.*** The corresponding risk is *poor or late delivery of the RS&T outputs*, which would be mitigated through:
   - Building critical mass in the key focus areas by linking, coordinating, and growing New Zealand-based capabilities.
   - Employing world-class individuals into key roles.
   - Active programme management both sides of the farm gate.
   - Complementing New Zealand capabilities through international networks.

3. ***The RS&T outputs are converted into commercial outcomes.*** The risk is this doesn't happen for the following reasons:
   - *Poor strategic alignment* – a low risk based on the governance and management structures proposed for the programmes, with the co-investors taking an active role in setting direction in all phases of the innovation chain.
   - *Poor RS&T delivery* – see above.
   - *Poor technology transfer* – a large portion of the pre-farm gate investment is directed towards improving technology transfer onto farms, post-farm gate strong alignment of pre-competitive RS&T with commercial strategies will drive uptake and implementation.
   - *A major collapse in the New Zealand dairy and food sector* – see above.

The risks around the *successful delivery (2)* and *adoption (3)* of programme outputs remained a feature of the programme risk register throughout the programme life. The other major category of risks related to the reputation and public profile of the programme and partners.

Comments on the impact of all three categories of risk are given below**.**

Project execution

Several projects were delayed due to the difficulty in finding suitable people – particularly post-doctoral researchers and PhD candidates. However, as a key output of the programme was increased capability within the sector, the programme did not compromise on selecting quality people.

There were inevitable delays in delivery of several of the programme projects. Pre-farm gate, this meant that some projects scheduled to finish six months before the end of the programme were still being completed in the last month. Post-farm gate, the impact was more significant with a few projects continuing beyond the end of the programme, with the remaining costs to be carried solely by industry. The financial impact of this is noted below as additional investment.

Adoption

As the end of the programme approached, there was a particularly strong emphasis on adoption and transition planning to ensure outputs were managed effectively beyond the lifetime of the programme. In almost all cases, this was successfully achieved. The role of the roadmaps and benefits realisation planning in supporting this success has been previously discussed.

One risk that emerged strongly in FY15 and FY16 was the potential that adoption of programme outputs – and thus the delivery of benefits – would be impacted by the low dairy pay out **(see Figure 6)**, squeezing the ability of both farmers and Fonterra to invest. However, the impact of this does not appear to have been too significant, mitigated by the strong strategic alignment of the programme, which ensured outputs were amongst the leading candidates for any investment available.

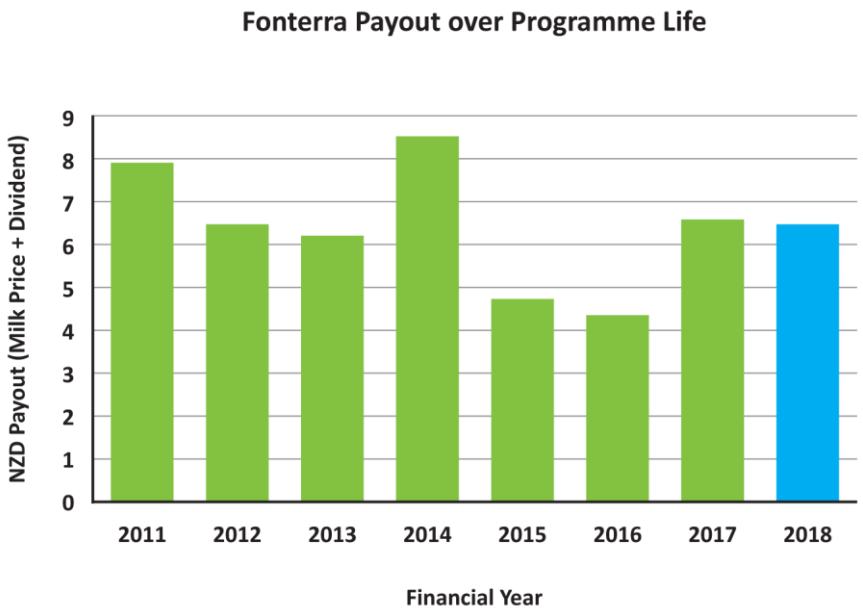

Figure 6: Fonterra pay out (milk price and dividend) over the life of the programme

Over the life of the programme, the strategies of the industry partners evolved. If anything, this strengthened the strategic alignment of the programme outputs.

- The changes in the ***Dairy Industry Strategy*** saw many of the programme goals fully incorporated into industry thinking.
- The changes for Fonterra were potentially more dramatic with a shift from a "value-added ingredients" focus towards driving additional volume and value through consumer and foodservice channels. The primary impact of this change was a repositioning of science originally intended to support ingredient sales towards the development of new consumer offerings.

Programme reviews

Over the life of the programme, the following reviews were conducted:

1. Financial process reviews for both Fonterra and DairyNZ.
2. A mid-term progress review.
3. A review of the programme Summary of Benefits.

The key findings - and resulting changes - from these reviews are summarised below.

Primary Growth Partnership Financial Management: Assurance on Fonterra's Use of Funding (17 December 2013)

Conclusions

"Fonterra's financial management systems (including systems for budgeting and forecasting, financial management reporting and monitoring, cost allocation and payment processes) for PGP funding and co-funding are suitably robust and effective."

Recommendations and actions taken:

Recommendation (1) for MPI: The Ministry might want to consider whether, given the size of this PGP programme, it might require some similar assurance work done on the financial management of the programme before the programme is completed in 2018.

Recommendation (2) for MPI: The requirement for a separate bank account for holding PGP funding contributions should be removed.

This was implemented and the clause requiring a separate account deleted from restated programme contract.

Recommendation (3) for Fonterra: The cashflow forecasts for the remaining four years of the programme 2014-15 to 2017-18 need to be revised as part of the next round of business planning. We would endorse the need for this exercise.

This was implemented as part of business plans from May 2014 (2015 Business Plan).

Recommendation (4) for Fonterra: There might be some benefit from Fonterra and DairyNZ developing a process that allows them to have a more effective combined view of total programme spend/budgets etc. to reflect the overall programme financial picture.

A combined financial summary was introduced for the February 2014 PSG meeting and overall programme reporting was integrated from the Q4 report for 2014 (August 2014 PSG meeting).

Primary Growth Partnership: Assurance on DairyNZ's Management of PGP Funding (7 May 2014)

Conclusions

"We conclude that DairyNZ's financial management systems (including systems for budgeting and forecasting, financial management reporting and monitoring, cost allocation and payment processes) for PGP funding and co-funding are suitably robust and effective."

Recommendations and actions taken:

Recommendation A for MPI and DairyNZ: MPI to work with DairyNZ to reach mutual understanding of the PGP Agreement with respect to timing of claims for reimbursement of expenditure from PGP funds.

Changes were made to ensure providers were paid on actual expenses and payment withheld if work was delayed. DairyNZ project payment schedules were also realigned to match the PGP programme quarters.

Recommendation B for DairyNZ: DairyNZ to develop and implement a revised reporting approach for the PSG which allows for greater clarity and transparency. This should include more information on how each

project links to the achievement of theme objectives and details of any additional costs being funded by levies DairyNZ for any given project.

Changes were made to the financial reporting in both the detailed report for the on-farm components and the overall programme report. Additionally, the inclusion of "roadmaps" within the 2015 business plan improved the connection between individual projects and theme objectives.

Recommendation C for DairyNZ: Review processes for capturing in-kind contributions and clarify the nature of LIC's ongoing provision of $100,000 per annum of in-kind contribution to the PGP programme.

DairyNZ, Synlait and LIC provided additional information to MPI on in-kind expenditure in June 2014. Synlait changed from in-kind contributions to cash in F16.

Transforming the Dairy Value Chain Primary Growth Partnership Programme: Progress Review (27 July 2015)

Conclusions

"On balance we believe there is a strong likelihood of the Programme achieving significant economic impacts and important industry change. However, there are a range of challenges and areas that we believe need to be addressed in order to maximise the opportunity for successfully achieving the intended outcomes."

Recommendations *and* actions taken:
Development of a benefits realisation framework

The programme management office developed a detailed Benefits Realisation Framework (BRF) that identified specific programme outputs, post-programme adoption indicators, and targeted benefits for each of the programme roadmaps. With 148 measures, this proved unwieldy and of limited use in communicating the impact of the programme to external stakeholders or tracking programme impact beyond the 31 January 2018 end date.

In 2016, a simplified Summary of Benefits was developed that focused on nine key benefits of the programme. The Summary of Benefits was subsequently reviewed against several criteria by Deloitte (see below).

Increased focus on communications

A dedicated communications manager was appointed in September 2015, remaining in place until August 2017. Over this period, the programme was mentioned in almost 500 media items – not including publications by the industry investors.

Establishment of a programme management office

Prior to the review, the PSG had taken the step of appointing a single programme manager with oversight over the entire programme, with dedicated support within DairyNZ and Fonterra. Following the review, we added a dedicated communications/engagement resource and made some changes to strengthen the leadership of individual themes.

Reviewing the composition of the PSG

An independent chair (Chris Kelly) was appointed to the PSG and the master programme contract amended to enable this and other changes in the operation of the PSG.

Focus on adoption planning

The quarterly reports and business plans were modified to include a focus on BAU transition and adoption planning. Specific adoption plans were developed for on-farm projects where the adoption paths crossed organisational boundaries and realising the benefits depends on end-users (farmers, rural professionals, companies) adopting the programme outputs and applying them within their own businesses.

Summary of Benefits Review (22 March 2018)

Conclusions

"On balance, nothing of significance came to light during the review. However, we note that there are inherent risks with certain aspects of the information reported, particularly with respect to relevance and repeatability."

Through the process of this review, modifications were made to the workbooks and documentation used to support the summary of benefits to improve the repeatability of the analysis when this is transferred to MPI from Fonterra. This included fully documenting the sources of all figures and, where appropriate, providing cross-checks using data from different sources.

Mid-term reviews and course corrections

The history	Development of new networks and methods for capability-building comes with challenges – establishing an entity, developing a design that provides a value proposition for engagement and delivers growth in skills and wellbeing, supports niche needs, and reaches the critical mass to become self-sustaining. Six areas of engagement were developed under objective 2.8 (Better on-farm decision-making), with four undergoing formal independent review in the middle of the programme (2014-15). Reviewers engaged with the project teams and industry stakeholders to consider progress so far, the ability to deliver on the projects' goals, as well as assessing current relevance. Two projects - Professional Land Managers and Farmer Wellness and Wellbeing (FWW) – were redesigned because of the findings and recommendations, and their project leadership was also changed. Reviews of the leadership pipeline and Centre of Excellence in Farm Business Management resulted in resetting of priorities and an increased focus on delivering a sustainable model (independent of funding). It should be noted that five of the six areas underwent leadership changes during the seven-year project term.
Key learnings and changes	All the projects needed several years to establish and test their position. DairyNZ's detailed contracting and monitoring system, along with its collaborative approach, allowed DairyNZ Strategy and Investment Leaders (SILs) and the PSG to maintain close oversight. Independent mid-term reviews provided an excellent pause point to check progress towards outcomes, consider the changing industry environment and any emerging opportunities. Although difficult at the time, the changes in project leadership provided considerable benefits with engagement and refocus. In the case of the FWW, project delivery was brought in-house to provide a stronger mandate to use DairyNZ and national networks in a multi-agency approach. Establishment of steering groups, advisory committees or Trusts were required to increase governance and consultation with industry. In a couple of cases, setting these up from the beginning would have allowed for smoother, or earlier redirection of projects when they were struggling.
The future	Mid-term reviews provided the opportunity for resetting direction and priorities. They were key for management of delivery, reassessing goals and supporting a focus on post-PGP programme transition. Although some project areas have not met expectations, all projects have made ground-breaking changes that would have not been possible without a long-term commitment from industry and government. In the post-farm gate section of the programme, the external expert panel meetings convened at regular intervals for each of the three themes provided a similar function and were critically important to the direction and success of the research programme.

Programme investment

Summary

- Overall programme investment was $NZD 162.7 million, 96 percent of the original programme budget.
- Pre-farm gate investment was $NZD 97.7 million, almost exactly matching the original budget.
- Post farm gate investment was $NZD 65 million, which is 90 percent of the original budget.
- The industry partners will invest a further $NZD 1.7 million to complete project milestones that now fall outside the programme investment period.
- Total industry *investment* (including the delayed milestones) is $NZD 83.4 million, giving an overall investment ratio of 50.7 percent industry, compared with 50.3 percent in the original business plan.
- The programme has invested more on nutrition and health (22.0 / 10.5), and less on manufacturing and supply *chains* (10.7 / 27.5) than originally envisaged.

The table below summarises expenditure at a sub-programme level over the programme life.

Table 1: Summary of investment between pre- and post-farm gate activities over the programme life (excluding delayed project costs)

		2011 Actual $ million	2012 Actual $ million	2013 Actual $ million	2014 Actual $ million	2015 Actual $ million	2016 Actual $ million	2017 Actual $ million	2018 Actual & Forecast $ million	Total Actual & Forecast $ million
Pre-Farm Gate	Industry	4.3	6.8	6.4	6.5	6.7	5.8	6.5	1.8	44.9
	MPI	5.7	8.9	7.8	7.5	7.0	7.1	7.4	1.5	52.8
	Subtotal	10.0	15.7	14.2	14.0	13.8	12.9	13.9	3.3	97.7
Post Farm Gate	Industry	-	5.2	3.2	6.1	6.6	4.9	5.1	5.7	36.8
	MPI	-	2.2	2.9	5.1	5.4	4.1	4.1	4.5	28.2
	Subtotal	-	7.4	6.0	11.3	11.9	9.0	9.2	10.2	65.0
Total Dairy PGP Programme	Industry	4.3	12.0	9.5	12.6	13.3	10.7	11.6	7.5	81.7
	MPI	5.7	11.1	10.7	12.6	12.4	11.2	11.4	6.0	81.1
	Subtotal	10.0	23.1	20.2	25.2	25.7	21.9	23.1	13.5	162.7
Cumulative Dairy PGP Programme	Industry	4.3	16.3	25.9	38.5	51.8	62.6	74.2	81.7	81.7
	MPI	5.7	16.8	27.5	40.1	52.4	63.6	75.1	81.1	81.1
	Subtotal	10.0	33.1	53.3	78.6	104.3	126.2	149.3	162.7	162.7

2010 Business Plan

The original business plan for the programme outlined a combined programme investment of $NZD 170.3 million, comprising 85.7 million of industry investment and 84.6 million from MPI. The proposed split across the programme's five themes is shown below:

Table 2: Summary of original investment levels by programme theme ($ million)

Theme	On-farm innovation	Building capability	Food structures	Manufacturing and supply chains	Robust health and wellness
Industry	21.9	22.8	18	19.5	3.5
MPI	23.3	29.8	16.5	8.0	7.0
Total Theme	45.2	52.6	34.5	27.5	10.5
Pre and Post	**97.8**			**72.5**	

Final investment

The projected final programme investment is $NZD 162.7 million, of which industry will have contributed 81.7 million and MPI 81 million. This is distributed as shown below:

Table 3: Summary of final investment by programme theme ($ million)

Theme	On-farm innovation	Building capability	Food structures	Manufacturing and supply chains	Robust health and wellness
Industry	21.5	22.5	16.4	6.1	12.4
MPI	23.2	29.1	12.5	4.7	9.5
Total Theme	44.8	51.6	28.9	10.7	22.0
Pre and Post	**97.7 (incl. 1.3 PMO)**			**65 (incl. 3.4 Admin & PMO)**	

In additional to the above, there is a further $NZD 1.7 million of investment in post-farm gate R&D that will be made by the industry partners to cover project payments that now fall outside of the investment term of the programme. Including this brings the post-farm gate investment to $NZD 66.7 million, and total programme to $NZD 164.4 million.

Industry investment

Table 4 below shows the industry investment broken down as it was in the original plan and the final position of the programme.

Table 4: Summary of investment by industry partner

Industry Investor	2010 Business Plan	Final Investment
Fonterra[2]	47.3	37.5
DairyNZ	29.7	29.9
LIC	3.5	9.5
Young Farmers	1.7	1.7
Synlait	1.1	1.0
Landcorp	1.1	0.5
Agricultural Services Limited	0.7	0.7
ZESPRI	0.7	0.9
Total industry	**85.7**	**81.7**

[2] Includes ViaLactia Biosciences (VLB).

The largest change is a lower than planned Fonterra investment. This consists of two components – the largest being the decision in 2011/12 by Fonterra/VLB to exit bovine genomics research – including VLB investment through Theme 1. This resulted in the increase in LIC investment in this area. Overall, the impact was a shift of approximately 6 million in investment between Fonterra and LIC, but an overall neutral effect on industry investment. The remainder of the change is due to the lower overall investment in post-farm gate R&D.

Lessons

Initially, individual projects were subject to different funding ratios between the industry and government investors, on top of a difference between the two sub-programmes (On-farm: 45.6% Industry: 54.4% MPI, and post-farm: 56.5% Industry: 43.5% MPI). The original intent of this was to differentiate between projects based on the extent to which proprietary benefits were expected to accrue to the industry investors. This approach proved to be unwieldy, adding complexity to the programme and accounting for little real benefit – especially as the balance of investment within the programme moved over time – and undermining the objective of a single integrated programme. The funding ratios for post-farm gate projects were normalised from the middle of the 2013 programme year.

Figure 7 shows the rate of investment over the programme life. The post-farm gate work programme took longer to get underway than originally anticipated. This, coupled with the termination in FY13 of the process redesign work, led to a $NZD 6 million investment lag by the end of FY13.

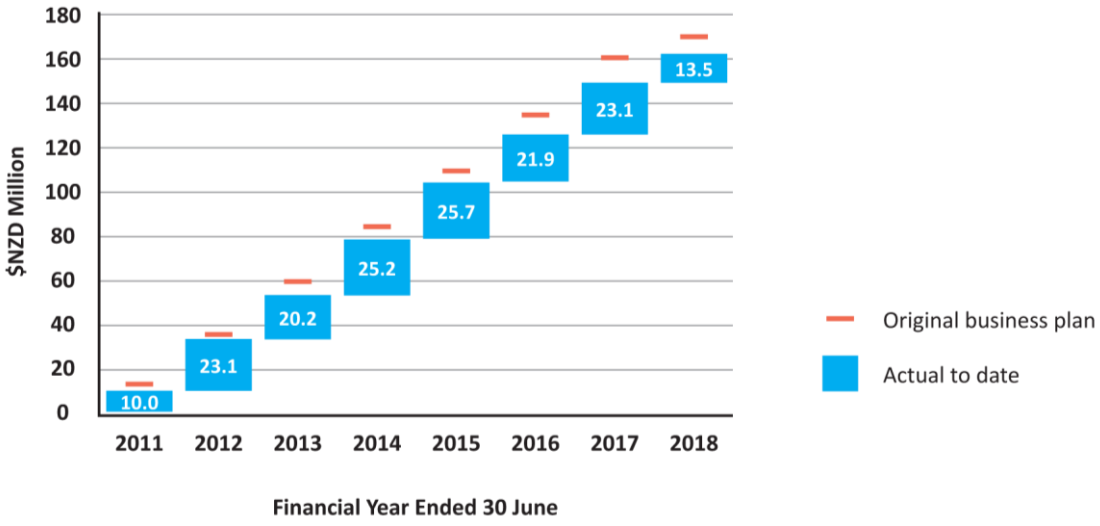

Figure 7: Annual and cumulative programme investment against the original Business Plan

Programme achievements

Throughout its lifetime, the seven-year TDVC PGP programme has produced a significant level of outputs in terms of both scientific and technical knowledge, and the development of people capabilities, along the dairy value chain that directly benefit New Zealand's economy, and environmental and social goals. In most cases, application and adoption of the programme outputs is underway and the commercial benefits are starting to be realised.

The aspirational goal set at the commencement of the programme was for the TDVC PGP to enable transformation of the dairy industry, delivering benefits to New Zealand by $NZD 2.7 billion every year from 2020. The programme is still on track to deliver this scale of impact, but the timeline has been revised to 2025, as the original timeline did not allow sufficient time for the adoption and further development of outputs and building scale in the resulting commercial operations.

For example: science and technology for the design of new products goes into the front-end of the commercial product development process. For new-to-the-world products, this typically takes two to three years to reach the commercialisation point. If new processing assets are required, these take between one and two years each to design and build. Building to a scale that involves four or more factories could, therefore, take up to ten years from the time the research results are available.

The scale and scope of the programme has enabled a much broader science base than otherwise would have been possible for the industry investors acting alone. This breadth and depth of technical understanding means there is a much greater chance of successfully progressing outcomes into commercialisation.

Outputs

Outputs are the direct results of the programme activities and form the basis for adoption by industry participants.

Outputs from the programme can be divided into several different categories including reports, scientific publications and training events. Overall, the programme has produced approximately 2,000 written outputs, not including media communications. These include:

- 200 conference presentations.
- 130 technical journal articles.
- Almost 400 training events.

Appendix 3: Table of outputs provides a breakdown of this across the 13 programme roadmaps, but given the number of outputs a complete list has not been included. Theme 2 – Capability – delivered the highest number of outputs, associated with the training activities undertaken, accounting for almost all the training events and many stakeholder workshops to co-develop materials with key stakeholders.

Patents and other intellectual property

Intellectual property developed from the TDVC programme takes many forms. The most easily recognised are patents. However, these are a relatively small portion of the programme outputs. More common are know-how: often held in the form of trade secrets and, in the case of the training and certification schemes, the content and materials for training sessions and courses.

As per the programme contract, all intellectual property developed within the programme is owned by the relevant industry investor, unless they have agreed to other assignments. This has ensured that there were no unnecessary barriers to the adoption of programme outputs. A large portion of the programme outputs have been publicly disclosed – e.g., scientific publications on the nutritional impacts of dairy protein – as part of securing the intended benefits.

Over the course of the programme there have been 16 patents filed *(see Appendix 2: Summary of IP (intellectual property))*. Of these, 11 relate to genetic variations and tests in dairy cattle *(see Resilient*

cows), and the remaining five are for dairy products or processes (i.e., Mozzarella, UHT Creams; Cognition ingredients, alternatives to traditional milk powders).

People and educational outputs

A large focus of the programme was the development of capabilities within the innovation system that supports the dairy value chain – whether in research organisations, the industry partners, rural professionals, or farmers themselves.

Delivery of the pre-farm gate projects:

- Involved 495 people across 18 projects over the seven years of the programme.
- One third of those contributors were DairyNZ staff (160), 60 percent (300) were from other organisations and 9 percent were students (14 PhD students, 18 master's candidates, 15 student interns / Honours students).
- The 11 DairyNZ projects had considerable external engagement, with 50 percent of contributors being non-DairyNZ staff including scientists, developers from commercial organisations, collaborators, university staff, rural professionals and trainers.
- The seven projects delivered by external organisations involved 250 staff with high DairyNZ engagement (23 percent of contributors).
- Farmer leadership was strong in two projects - Smaller Milk and Supply Herds (SMASH) and Farmer Wellness and Wellbeing.

A considerable focus of Theme 2 was skill and capability development with several highlights:

- More than 4,200 trainers have been up-skilled in the provision of advice and training to farmers, through 32 new or updated training programmes.
- The Rural Business Network (RBN) provides professional development to over 1,500 rural business people.
- Innovation in farm business management has been assured through capability development at Lincoln and Massey Universities, with 22 scholars and 25 academics providing research and rural business connectivity and education.
- GoodYarn is being delivered by more than 20 organisations, providing over 3,700 people with skills to support the mental health of others in pastoral industry workplaces.
- The smaller dairy herd farmers SMASH network reaches nearly 3,000 farmers, providing support and capability development specifically "by farmers for farmers".

Delivery of the post-farm gate projects:

- Over 150 people were involved in the delivery of the programme over the seven-year period.
- This included: over 56 Fonterra staff, 4 professors, 30 university academic and research staff, 24 post-doctoral researchers, 19 PhD students, 11 master's candidates, 10 student interns.
- Fifteen organisations were involved, including students and staff from four New Zealand and eight international universities.

In total, across the programme:

- Young scientists gained 29 master's degrees; more than 30 PhD's; and completed more than 25 postdoctoral research assignments.

These scientists have had the opportunity to develop their research careers in a programme that combined industry-defined problems and high engagement with industry R&D staff, along with high standards of academic excellence. A number of these young scientists have continued to develop their careers within New Zealand. Others have been approached to apply for academic positions at a range of prestigious universities.

Summary of benefits

Key benefits of the programme include:

Improvements in the profitability of dairy farms

The overarching industry measure is profit from productivity (PFP). This measures the impact of productivity improvements on farm, against a base year. The TDVC ambition is to enable a $NZD 1 B annual benefit after 10 years, which corresponds to an increase of $610 /hectare (ha) over the base year. A five-year moving average is used to reduce the inherent volatility in the measure. The target is $1,090 /ha.

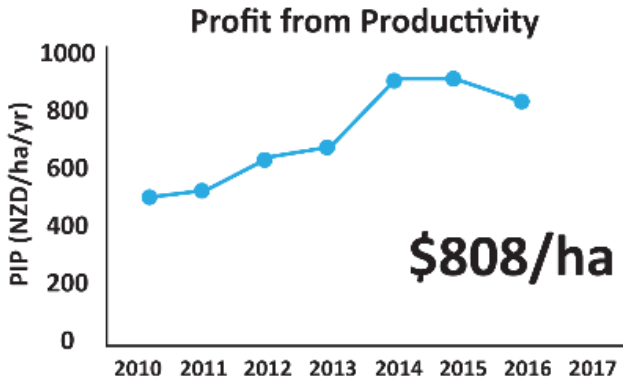

Figure 8 Five-year moving average value of PFP per hectare

Improvements in the sustainability of dairy farms

Rural professional certification schemes are providing farmers with trusted advice on nutrient, effluent and animal welfare management. Farming can grow and produce more milk within environmental limits and meet social and market demands. Outcomes enabled include retaining dairy farming in the Horizons region, reduced costs of meeting environmental constraints, reduction in non-compliant effluent systems, and improved animal welfare outcomes.

Improved rate of genetic gain in the national dairy herd

TDVC is contributing to an increased rate of genetic gain by improving the accuracy of algorithms that predict the genomic breeding value (BV) for traits of dairy cattle and accessing phenotypic data to provide new or improved BVs. Transfer of the Dairy Core Database to DairyNZ enabled increased accuracy of fertility and cow body condition score breeding values. The 0.3% improvement in gain seen between 2010 and 2016 is adding ~$NZD 60 M pa to the sector. Target is a 1.5% pa rate of gain.

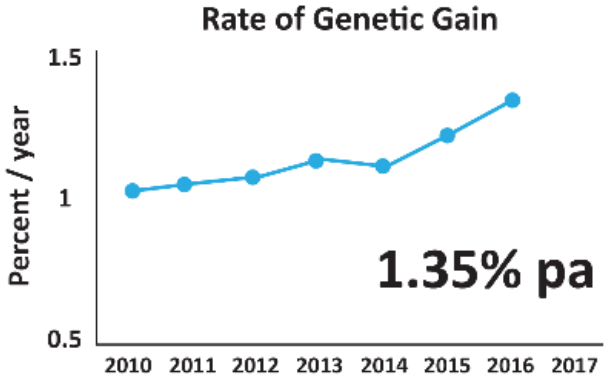

Figure 9 Rate of genetic gain in the national herd (5-year rolling average)

Increased per-hectare milk production

Detailed seven-year trials have determined the basis for loss of pasture persistence. This will address low farmer confidence in re-grassing using modern cultivars due to persistence concerns that has put at risk

New Zealand's productivity and milk solids production. Opportunities for improvements in farm management and plant breeding have been identified.

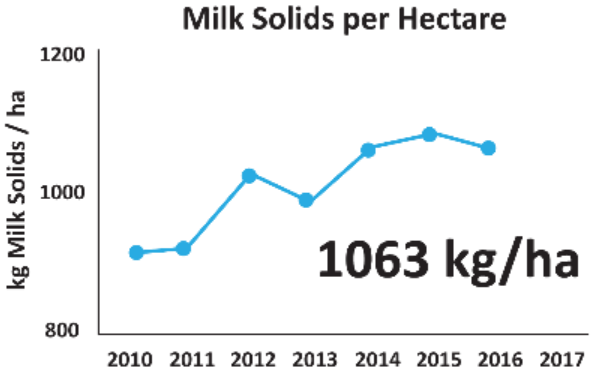

Figure 10 Milk solids production per effective hectares engaged in dairy production

Increased skills

TDVC has invested in multiple projects to attract, grow and retain people, and to build leadership and technology adoption capability in the dairy industry. Case studies have demonstrated that farms with healthy and skilled teams, strong farm business management skills, and access to competent advisory services are around $50,000 more profitable pa. For every 10% of dairy farms, this translates to $NZD 60 M pa.

Evidence to date shows an increase in ***primary ITO level 4 completions*** – a key indicator for the development of fully competent on-farm teams. Models of the impact of training and experience on farm performance suggest completion of a level 4 certificate is one of the most cost-effective training interventions for many farm staff.

Export revenue from new Mozzarella products

TDVC has enabled process improvements within the existing mozzarella plant and provided the technical basis for new mozzarella product development enabling profitable growth of the category. Fonterra invested $NZD 72 M to double the capacity of the Clandeboye mozzarella plant and a further $NZD 240 M investment has been approved by the Fonterra Board for the next-stage expansion.

Export revenue from UHT Creams

Technical insights on the impact of cream handling, processing and seasonal factors on the performance of UHT creams have been used as the basis for NPD projects and applied to improve existing products. In October 2016, Fonterra announced acceleration of plans to upgrade the Waitoa UHT facility to enable an additional 40,000 MT of UHT creams per year.

Mozzarella and UHT creams are key products within the Fonterra foodservice portfolio. As well as the individual contribution of the programme towards growth of these two product lines, the business confidence in a pipeline of future product options in both areas – enabled by the scientific and technical outputs of the TDVC programme – has been a key contributor to development of the foodservice strategy itself.

Sales of new infant formula products and ingredients

Nutritional science outputs have provided the evidence required to support adding milk gangliosides to infant formula. This has led to a complete refresh of the ANMUM™ product range, commencing with the NZ launch in 2016. Ongoing clinical trials are expected to provide additional evidence to support communications with healthcare professionals on the cognition benefits of gangliosides.

Repositioning of the ANLENE™ brand

The Fonterra brand ANLENE™ is moving from a bone expert position to move young. Early work provided evidence on the role of dairy protein in building and maintaining muscle, and was a key input into the brand repositioning decision. The full impact will come with the next major product refresh, which will deliver a level of protein proven to enhance muscle protein synthesis. Sensory targets for NPD have also been reset based on consumer preference research undertaken through TDVC.

Other significant benefits to New Zealand include:

- The train-the-trainer approach to the rural professional sector, and partnerships with regional councils on environmental matters, has multiplied the impact and reach of programme benefits beyond dairy. There has been a similar impact in academic and R&D circles by supporting more than 60 students and researchers in New Zealand and overseas, many of whom go on to work in dairy R&D and contribute directly to the industry and economy.
- TDVC-supported rural networks, including SMASH and RBN, and health and wellbeing initiatives such as the award-winning GoodYarn mental health initiative are impacting on thousands of farmers and rural professionals, giving them the tools to stay healthy, happy and productive, and the networks to communicate and share new innovations.
- The creation of data standards and other initiatives to enable data sharing *(*e.g., *DataLinker)* has set the industry on a path towards harnessing the value of big-data collection and analysis.
- Milk fingerprinting technology is being applied to select milk to meet specific market requirements, and new statistical approaches to process control and product grading are supporting significant reductions in the cost of quality failure.

Full realisation of these benefits requires additional investment by many organisations. Aspects of the capability development schemes are also being supported by the Red Meat Profit Partnership (RMPP). Realisation of other post-farm gate benefits requires product development, commercialisation, and capital investments by Fonterra.

Individual roadmap summaries

The following pages contain brief summaries of the achievements of each of the 13 roadmaps (or workstreams) within the programme, presented as the answers to five questions that address the goals, outputs, adoption, benefits and spill over benefits of each workstream.

1. What were we seeking to enable?
2. What was delivered?
3. How has this been applied?
4. What are the projected benefits?
5. What are the impacts beyond Dairy/Fonterra?

Resilient cows

What were we seeking to enable?

Genetic gain has been an important component of increased productivity in the sector over for several years. Traditional approaches were beginning to hit diminishing returns and there was an opportunity to reinvigorate improvements through innovation and new methods.

Targets included:

- Increasing the rate of genetic gain in the national herd from 1 percent to 1.5 percent.
- Improving prediction models for genomic breeding values (BV) for the National Breeding Objective from 55 percent to 60 percent reliability.
- Decreasing the time to prove sires from 5 to 2 years.
- Providing additional or revised BVs for additional traits potentially relevant to farmers e.g., fertility, facial eczema tolerance.

What was delivered?

In the first few years, the **gene sequencing** project developed significant bioinformatics capability to allow extraction of genomic information on important dairy animal traits. This required considerable whole genome sequencing (WGS) and extensive genetic mapping of several hundred bulls and cows. Genome Wide Association Studies (GWAS) with over 100,000 animals at 20M marker density was then completed using WGS, RNA-sequence, genotype, and phenotype data sets generated through the project. From this, LIC's genomic evaluation model was enhanced, improving the reliability for genomic predictions of young bulls from 0.55 to 0.60-0.65[3].

In addition, 19 markers for production, differentiated product, fertility and animal health were discovered. Findings have been implemented through the LIC Sire Proving Scheme, customised genotyping panels and mating management. Eleven *patents were lodged for 10 variants* (small calf syndrome, slick gene, 4 fertility variants and 4 production variants) and 'Slick' gene test. LIC will licence the test to interested parties, and the patents ensure LIC's ongoing freedom to operate.

Through the **phenotypic data** project, a breeding value (BV) for facial eczema (FE) tolerance, based on sire testing regime, was developed and is available to farmers through CRV Ambreed. Research into a lameness BV was also completed and it determined that implementation requires a significant increase in reliable phenotypic data.

Use of phenotypic data to improve fertility BV was achieved by using to a continuous trait for calving and heifer post-partum anoestrus trait. Implementation of the improvement re-ranks sires relative value for fertility due to improved estimates of between-breed effects.

Two residual feed intake (RFI) trials to assess the feasibility for implementing RFI were also completed. Point estimates of the heritability of RFI (~0.13) and the genetic correlation between young bulls and related heifers (~0.93) were encouraging, but the associated standard errors are too high (0.14 and 1.46) to allow implementation at this stage. Preliminary analysis found no evidence for significant differences between the Jersey and Friesian breeds.

How has this been applied?

The enhanced genomic evaluation model was used to evaluate young bulls for purchase in November 2017 and will be put into production in May 2018. Sires at LIC and other breeding companies are being screened for fertility variants to reduce prevalence and increase fertility of the national herd (valued at $2M pa). Similarly, it is expected that in 2018 all commercial New Zealand sires will be screened for the recently discovered production variants.

The improved fertility BV has been released to breeding companies on a trial basis so that they can, at their discretion, incorporate them into their breeding decisions. The official release is expected in February 2019.

DairyNZ continues work with the RFI BV, validating findings using an expanded dataset from other New Zealand and international trials using more sophisticated statistical approaches.

What are the projected benefits?

Work on a new genomic evaluation model is the culmination and commercialisation phase of the sequencing project. The improvement in predictive accuracy is 25 percent - this leads to a circa 5 percent improvement in the rate of genetic gain. LIC is now incorporating key markers into a genotyping panel.

FE costs the New Zealand dairy industry over $100 million a year in lost production, treatment costs and animal loss. Improving the FE tolerance in animals on FE-prone farms has positive animal welfare and production outcomes. Milk production of animals with subclinical FE can be depressed by up to 50 percent. It is estimated for every three in 100 cows showing clinical FE, about 70 percent of the herd may have subclinical FE. Economic evaluation of the improved fertility breeding value estimates the overall benefit is between $15-25M per year. (using $300M/yr with an increase in the value of genetic progress by 5 to 10

[3] Assessment of the benefits to LIC annual rates of genetic gain from use of genomics. Dorian Garrick. 2017.

percent). If an RFI BV could be implemented, benefits to industry are significant with an economic benefit of $20M per year.[4]

Increased rate of genetic gain is enabled by improving the accuracy of algorithms underpinning the genomic evaluation model and accessing phenotypic data to provide new or improved BVs. The 0.3 percent improvement in gain seen between 2010 and 2016 is adding circa $60M per year to the sector (see Summary of Benefits indicator - Rate of Genetic Gain).

What are the impacts beyond Dairy?

Capacity and processes are in place to rapidly identify the genomic cause of animal abnormalities found on farm (e.g., "hairy" genetic mutation; prolactin hormone). On the back of this discovery, the slick gene (prolactin receptor) was discovered in Senepol cattle that provide heat tolerance. LIC has a breeding programme to cross Senepol animals with New Zealand Holstein-Friesian dairy cattle, to create offspring with the prolactin receptor variation.

The **gene sequencing** project has identified the causative variants of bovine disorders, and these discoveries have the potential to shed light on mechanisms of analogous human diseases.

Collaboration with international communities has improved access to technologies and development of skills in New Zealand in the areas of genomics and bioinformatics.

On-farm technologies

What were we seeking to enable?

Two aspects of the on-farm technologies projects are covered below. The third – commercialisation by Synlait of specialty milk products arising from certain on-farm practises – is the subject of a separate report.

The two areas of science technology targeted by this part of the programme involved:

1. Understanding the causes of an apparent lack of persistence in pasture species, and
2. Understanding the benefits and role of an increasing range of so-called precision farming technologies when applied in the New Zealand pastoral environment.

Targeted goals include:

- Farmers use high-yielding pastures that maintain productivity between re-seeding, and plant breeders continue to develop more persistent cultivars.
- Increase in information used by dairy farmers and plant breeders that informs optimal ryegrass selection for different farm conditions.
- Farmers appropriately use precision technologies to improve farm management decision-making, take advantage of opportunities and improve the use of farm labour.
- Information derived from precision agriculture research enhances the process of technology development.

What was delivered?

The **pasture persistence** research programme monitored shoot and root trait responses to stress (2012), characteristics of ryegrass survivor populations (2014), and phenotypic-genotypic analysis of these (2016). Six seasons of longitudinal persistence experiments were undertaken, tracking genotypic and phenotypic structure changes as plants transition to unproductive states. Key findings include:

1. Poorly-adapted ryegrass plants are eliminated within six months of sowing. Underlying persistency traits are those that support vigorous plant growth (tiller density higher).
2. Genotype-by-sequencing analysis shows no evidence of genetic differentiation within perennial ryegrass populations over time, and

[4] Short paper: Residual Feed Intake PSG paper. Susanne Meier, Jeremy Bryant and Bruce Thorrold. July 2015.

3. Collapse of ryegrass populations after sequential droughts on soils prone to insect infestations revealed these as key risk factors contributing to poor pasture persistence.

Precision agriculture research on the benefit and requirements of technologies for heat detection, lameness, live-weight, paddock performance and mastitis detection were completed, with publications validating research and information put into protocols or technical notes for farmer decision-making, and to guide development of effective technologies. A steering committee with strong farmer involvement was used to establish the priority technologies for investigation, and regular communication with manufacturers to develop a relationship of trust.

Research defining opportunities for use of data and technology in **grazing management** and how rural professionals can support farmers using precision technologies was completed, filling a considerable gap in industry knowledge.

How has this been applied?

Findings from the **pasture persistence** research have been taken up by plant breeders and senior agronomists from major New Zealand plant breeding companies to identify implications for farmers, and for use in breeding programmes. Results and recommendations have been provided to the Forage Value Index (FVI) Technical Working Group. These provide a strong scientific foundation for future decisions on inclusion of persistence in the FVI. Plant resources have been provided for ongoing research (Pastoral Genomics research consortium) and further research continues into biologically- and economically-effective options for restoring perennial ryegrass density in run-out pastures, and investigation of alternative forage options that utilise either tolerance (e.g., relative summer dormancy or dormancy-like traits, and/or ability to resist grass grub attack) or avoidance (e.g., annual growth habit) mechanisms to reduce the total stress load on plants during critical periods, leading to improved profitability compared with continuing with the status quo.

The primary goal of the **precision agriculture** research was to enable farmers to appropriately use precision technologies to improve farm management decision-making, take advantage of opportunities, and improve the use of farm labour. Research in the first few years found that the technologies were not delivering the expected benefits. Therefore, guides and protocols were published to enhance the process of technology development and farmer decisions on their use.

With pasture being the cheapest feed source for New Zealand dairy farmers, measurement and decision support technologies have the potential to optimise their pasture growth and animal consumption. Key findings from the **grazing management** research have already influenced DairyNZ R&D through the delivery of farmer-orientated tools that are flexible enough to match the seasonal requirements of grazing decision-making, such as spring rotation planning and meeting target pasture covers prior to winter.

What are the projected benefits?

The **pasture persistence** research objective was achieved by systematically analysing the causes of loss of persistence of yield in perennial ryegrass and using the findings to support farmer use of high-yielding pastures that maintain productivity between re-seeding, and plant breeders continuing to develop of advanced cultivars. The key finding that supports both outcomes is that "*recent trends in ryegrass breeding (with the broad aims of increasing DM production and nutritive value) have not led to the 'persistence problem' – contrary to much popular anecdotal reporting that lays the blame on the plant".* Pasture renewal is a vital step in the introduction of improved plants and endophytes into farm systems. Business and Economic Research Limited and the Pasture Renewal Charitable Trust identified profitability lifts of $NZD 1 billion/year on New Zealand dairy farms if higher yielding pastures could be successfully introduced[5]. The findings from the research enables continued increase in milk-solids production per

[5] Economic Analysis of the value of pasture to the New Zealand Economy. Kel Sanderson and Michael Webster. BERL. September 2009. http://www.pasturerenewal.org.nz/assets/Uploads/economic-analysis-of-pasture-value-to-nz-economy.pdf

hectare (this Summary of Benefits indicator has moved from 912 to 1,063 kg/ha during the life of the project).

Industry involvement has been an important area of focus within the **precision agriculture** research with an impact report[6] noting *"A key positive of the project included 'the approach', which was open, transparent and promoted networking and collaboration. The 'quality of the research' was also praised, as demonstrative of best practice methods, which included refreshing and efficient engagement strategies"*. The work enables informed investment decision-making by verifying product capability and increased accountability for technology companies through direct farmer feedback. Findings continue to influence dairy industry research, development and extension activities.

What are the impacts beyond Dairy?

The **pasture persistence** research provides cross-pastoral sector benefits of increased grass production and increased sales and profit for plant breeders.

Precision agriculture research has supported technology development through protocols being used by manufacturers. The **grazing management** research has been extended to R&D and innovation managers at organisations such as Fonterra, Ravensdown, Ballance Agri-Nutrients, Tru-Test, LIC, and FarmIQ. They have noted the information on farmers needs around technology, and some have requested ongoing engagement.

Dairy data network

What were we seeking to enable?

The availability and quality of data is increasingly important to all forms of business, and dairying is no different. The overall goal of the **dairy data network** roadmap was an improved operational environment for maximising use of data in the industry. This included:

- Making the most of data available to drive quality decision-making across the industry and continuous improvement in breeding worth.
- Ensuring exchangeable data of high integrity is available to, and used by, all parties.
- Creating an environment where data from various sources can be shared and is used in new ways to drive innovation and productivity.

What was delivered?

In the first few years, significant gaps were closed to improve the operational environment for maximising use of data in the industry, including:

- Transition of Dairy Core Database to industry good management was completed (Dairy Industry Good Animal Database, DIGAD).
- Improvements were made to the Fertility Focus Report, Pasture Growth Forecaster and InfoVet, and
- Revised herd test standards, allowing data from new technologies (Distributed Milking Systems and Permanently Installed Milking Equipment) were submitted to DIGAD.

In later years, work focused on creating an environment where data from various sources can be shared and used in new ways to drive innovation and productivity.

- Nine data standards were published, as well as dynamic lists of livestock breeds and feeds to support interchange between systems.
- The Farm Data Code of Practice is in place with five organisations accredited and six more assessing readiness.

[6] Reviewing DairyNZ's Advanced Management Technologies Project: Where to from here? Penny Payne. May 2017

- *DataLinker*, a mechanism to support exchange of data, was established with 12 organisations implementing or commencing implementation of *DataLinker* APIs, and further nine organisations have provided an intent to participate.

How has this been applied?

All initiatives are operational with DIGAD, Fertility Focus Report, and Pasture Growth Forecaster being maintained by DairyNZ, InfoVet is primarily used by Zoetis and the revised herd test standards were published in 2015.

Two independent entities have also been set up and are managed by Rezare Ltd with industry shareholders.

- Farm Data Accreditation Limited manages the accreditation system and governance of data standards. An independent Review Panel assesses applications for accreditation and makes recommendations to the FDAL Board.
- DataLinker Limited manages the *DataLinker* system and supports adoption. The DataLinker Board and investors (RMPP and DairyNZ [previously TDVC]) are driving an increase on the use of *DataLinker* from its current very low base, to move *DataLinker* to a self-funding model (with a low-cost subscription).

What are the projected benefits?

The overall aim was to develop an integrated set of industry, government, and commercial databases that, by delivering improved data accuracy and accessibility, will assist dairy farmers with decision-making as well as innovations that increase value throughout the dairy value chain.

Improvements in the operational environment, particularly transfer of the Dairy Core Database into industry good ownership, was critical for ensuring ongoing herd genetic gain[7]. There has been a 0.3 percent improvement in the Summary of Benefits indicator – Rate of Genetic Gain since 2010, which is valued at $NZD 60M per annum to the sector.

In the minimum participation scenario for DataLinker, the value of farmer benefit is projected to be approximately $290,000 per year (time savings only) once full adoption is reached[8]. Time-cost savings were modelled for four industry tools, total gain ranges from $0.28M (minimum participation; from year 10) to $0.75M pa (widespread participation). The value of increased use of tools, improved data integrity and resulting innovation were unable to be valued.

What are the impacts beyond Dairy?

Farm Data Accreditation Ltd and DataLinker Ltd area collaborations between TDVC, RMPP and FarmIQ resulting in cross-sector benefit. While uptake of Farm Data Accreditation and *DataLink*er has been slow, there is a substantial change occurring with organisations willingness to share data across both dairy, sheep and beef sectors.

In addition, commercial organisations are reducing their protection of IP and increasing collaboration. This outcome is part of overall the TDVC programme synergies through increased engagement via other projects such as nutrient management.

More and better advisors and advice

What were we seeking to enable?

With the complexity involved in running a farming business in the modern environment, it is unreasonable to expect farmers to be experts in all the different areas that need to be managed. This challenge is magnified by the increasing rate of change in the regulatory, market and social environment surrounding

[7] New Zealand Dairy Herd Improvement Database Review. Robert Anderson et. A 2008.
[8] Objective 2.6: Dairy Data Networks - Data Linker TDVC briefing paper 9 June 2015.

farming. This roadmap sought to develop strong advisory capabilities to support farmers in key areas and had the following goals:

- Farmers have access to high standard 1:1 expert advice in key farm management areas, and advice is provided within a whole-farm systems context to ensure profitability of the farm business.
- Farming can grow and produce more milk within environmental limits and per public pressure.
- Development of the rural professional sector so dairying can respond to upcoming legislative changes and regional constraints.

What was delivered?

Fifteen rural professional certification and company accreditation (train-the-trainer) programmes have been co-developed with appropriate industry and commercial stakeholders, and have been implemented through service providers. The most significant programmes include:

- **Nutrient Management Advisor Certification** (NMAC) – operational since 2013 and administered by The Fertiliser Association of New Zealand Inc., on behalf of Nutrient Management Advisors Certification Programme Ltd with 160 certified rural professionals (RPs).[9]
- **Farm Dairy Effluent System Design** accreditation – operational since 2012, administered by IrrigationNZ and overseen by an industry governance group, with 22 companies accredited.
- A fit-for-purpose and 'ready to implement' industry **self-accreditation scheme for greenhouse gas** management that is being implemented alongside NMAC.
- **Body Condition Score Assessor Certification** (BCSAC) Programme – operational since 2012, administered by DairyNZ and overseen by a Technical Group with >300 certified RPs.
- **Dairy Farm Systems Certification** – operational since 2015, and administered by NZIPIM, with 15 certified RPs.

How has this been applied?

The train-the-trainer programmes include co-developed industry standards and training systems and were designed to fit the requirements of the different RP networks. These underwent testing, modification and engagement to drive supply of advice and to create farmer demand for the services. Business models were streamlined with most programmes transitioned to independent organisations. Competency development programmes are embedded into DairyNZ services (five programmes).

What are the projected benefits?

The train-the-trainer programmes increase the capability and capacity of RPs to provide farmers with specialised advice within a whole-farm context, enabling dairy farming to grow and produce more milk within environmental limits, and according to social expectations and market demands.

Underpinning the benefits is delivery of over 4,000 farm plans through the PGP train-the-trainer programmes. These numbers only account for plans tracked directly, and do not capture RPs delivery through integrating their own businesses. These plans include 470 effluent warrant of fitness plans, 38 people management gap assessments, 1,937 sustainable milk plans, 179 riparian management plans, 1,162 BCS management plans, 90 whole farm assessments, 27 seasonal management plans completed by RPs trained/working towards Dairy Farms Systems certification, and 270 whole farm assessments completed by DairyNZ Consulting Officers. The Early Response Service, made up of trained rural professionals and animal husbandry specialists, has supported more than 450 farms to develop, and implement, farm plans to address significant animal welfare risk.

Whole farm assessment (WFA) case studies have shown financial gains of more than $1,300/ha/year. These financial gains are difficult to scale up given the sample size, variation in the WFA recommendations, and resulting changes (systems changes are more likely to result in measurable financial gain compared to

[9] 2017 Progress Report: More and Better Advisors and Advice, Margaret Bowditch. Numbers as of 31 May 2017

business strategy, people management or compliance-related changes). They are consistent with other methodologies that estimated gains of $450-$980/ha/year[10].

The Summary of Benefits indicator - Aggregate Sustainability is valued at $282 M per annum by 2017 and is based on counterfactual economic assessment of the impact of NMAC and BCSAC programmes. The impact is expected to increase over the medium-term. The programmes have made significant contributions towards attaining the ***Sustainable Dairying Water Accord*** with delivery of >9,000 nutrient budgets, 13 regionally-tailored planting guidelines for waterways, and national significant effluent non-compliance statistics showing the lowest level on record (5.2 percent for 2016 from over 15 percent in 2010). The Accord also reported on the reduction in enforcement actions from regional councils with abatement and infringement notices and convictions all dropping significantly.

What are the impacts beyond Dairy?

The main spill over benefits have been in enhanced RP capability to support farmers in other sectors, and development of new business models by consultancy companies. Notably:

- NZIPIM reports that the strength of their organisation has increased significantly in terms of capability, capacity and scale. Resources and confidence to apply far-reaching strategies have led to a membership increase from 650 to 1,000 during the project. The capacity of NZIPIM has increased from 2 part-time staff (1.25 FTE) and revenue turnover of $208,400, to 4 staff (3 FTE) plus contractors, with revenue expected to exceed $400,000 in the year ending 2018, with minimal support from industry projects. NZIPIM membership covers all sectors and members such as farm management advisors, rural bankers, farm accountants, fertiliser consultants, rural valuers, representatives from industry good organisations, CRIs, universities, and agribusiness service providers.
- Nutrient management capability development has expanded into other organisations with staff from regional councils, sector organisations, professional services firms, farm consultancies, as well as the fertiliser industry, being trained and certified as Nutrient Management Advisors.
- On the back of success with Farm Dairy Effluent System Design accreditation, IrrigationNZ have set up a Certificate in Irrigation Management and New Zealand Milking and Pumping Trade Association-funded 'Farm Dairy Effluent Hydraulic Design' course.

Better farm decision-making

What were we seeking to enable?

The key goals of the **better farm decision-making** workstream were to:

- Build, and grow, a larger workforce that has the capability to do the right thing, at the right time.
- Work with farming networks to motivate members to participate in professional development opportunities, create a pipeline for the growth of new leaders and stimulate demand for farm education and training at every age and stage, starting with primary school.
- Address the wellbeing of farmers to minimise risks to the workforce and lower costs due to lost productivity and deliver programmes for large to smaller herd businesses.

What was delivered?

This programme has delivered a wide range of transformational initiatives that will attract and grow the pool of talent available to the dairy sector for the future.

The **leadership pipeline** has implemented networks to attract school students, grow capability, develop leadership and facilitate career progression through the successful AgriKids, TeenAg and Rural Business Network and Professional Land Managers (delivered by NZ Young Farmers (NZYF) and ASL). The pipeline ensures talent identification, leadership development and continuing education to raise capability across the dairy workforce. **SMASH** network and learning channels (conference, regional workshops and

[10] Pre-Farm Gate Impact Review, J Coutts, 2017.

media/website) are established with expanded reach and connectivity throughout industry initiatives. The farmer-to-farmer model provides low-cost extension to farmers with smaller farm businesses. **Large dairy businesses** governance training has transitioned to Business Torque Systems and Farm Supervisor Training to DairyNZ. The Māori strategy is implemented with establishment of partnerships and baseline models.

The **CEFBM** has met development of capability targets providing farm business capability for primary industries (23 scholars and 25 academics) with increased research (29 projects), rural business connectivity and education offerings (4 RP courses).

Farmer wellness and wellbeing GoodYarn and Health Pitstop programmes are well established and transitioned to sustainable models. There is strong industry and health sector support and collaboration, with progress measured through a wellness dashboard.

How has this been applied?

The seven-year TDVC PGP programme has allowed all initiatives to undergo development, refinement and become established as sustainable industry activities. Their legacy is maintained through alignment with industry training organisations (Primary ITO), commercial models, membership fees, sponsorship and contracted work. New Zealand capability in farm business management is positioned for future growth in capability and collaboration.

The farm networks have a reach of over 10,000 members from school kids to professional farmers with close to 400 training events provided. The networks have become aligned with industry priorities through connectivity with DairyNZ and provide integrated initiatives.

What are the projected benefits?

Farming networks are established and being used to motivate members to participate in professional development opportunities, develop new leaders and stimulate demand for farm education and training that is fit for purpose (age, career stage and distinct farmer groups). Building and growing workforce capability is essential for improving timely decision-making, accessing of RP advice and adoption of new farm business opportunities.

Case studies have demonstrated that farms with healthy and skilled teams, strong farm business management skills, and access to competent advisory services are around $50,000 more profitable per annum. Applied across 10 percent of dairy farms, this translates to $NZD 60 M per year. The benefits indicator for this programme is Primary ITO Level 4 completions and these have increased by 60 percent since 2013. This indicates that increased value is being placed on higher farm skills and knowledge.

Direct benefits realised through the projects that are ongoing include:

- A comprehensive dataset of dairy organisation financials, representing around 60 percent of Māori production, now held on DairyBase, providing benchmarks for Māori businesses.
- By attracting 500 farm workers with innate ability typical of the top third of farm workers per year, the industry has a potential gain of $NZD 20 M per annum (conservative; up to $200 M pa).
- 30 percent of participants from GoodYarn workshops were assisting those in need within 10 weeks of completing the course. Overall, the **farmer wellness and wellbeing** project reached over 8,000 people and provides at least $NZD 8 M in value through improved farm outcomes.
- Over 70 percent of farmers involved in SMASH training aim to improve farm systems decisions in their business.

What are the impacts beyond Dairy?

GrowingNZ (Primary Industry Capability Alliance (PICA)) was established out of this programme as an independent entity in 2014. As an industry, training and government alliance, it provides coordination of activities and resources to support career opportunities across New Zealand primary industries. The RMPP has been a collaborating partner through several projects, particularly the **leadership pipeline** with expanded reach, resources and assuring short-term ongoing support.

Growth and capacity of staff in all pastoral industries is enhanced through new initiatives delivered throughout the networks, with many of the capability-build events delivering to multiple sectors. Further, the enhanced agricultural education and research capability, as well as research outputs from Massey and Lincoln Universities, are being accessed by primary and non-primary industries.

By partnering with Business Torque Systems Ltd to deliver the Rural Governance Development Programme, it has been possible to open this programme to all rural businesses – not just dairy farms.

The Māori "fit for purpose" farm business governance and professional land manager programmes were delivered through the Extension 350 programme in Northland. The four-year scheme aims to lift on-farm performance, by improving farm systems and profitability through shared knowledge on 350 farms.

The Farmer Wellness and Wellbeing project has significantly increased strength of rural health advocacy through RHAANZ, Rural Support Trusts, Farmstrong and Health and Wellbeing Leader Network.

Endgame mozzarella

What were we seeking to enable?

Mozzarella is the fastest-growing global cheese category. **Endgame mozzarella** aimed to enable the growth of the foodservice mozzarella business by creating a sustainable product development pipeline. To do this required development of a fundamental understanding of the alternate make cheese process for mozzarella that connects the process to structure, material properties and functionality to improve the operation of the existing Clandeboye process and create a range of options for further mozzarella product development.

The "endgame" target was expressed as a challenge to produce a fully-functional all-dairy mozzarella with a moisture content of 60 percent (up from 48% for traditional make mozzarella). At the outset of the programme, this was considered "impossible".

What was delivered?

The TDVC programme has delivered a comprehensive technical base for future mozzarella product innovation that spans from the formulation and manufacture of the cheese, to the use on pizza and the final consumer experience. The programme has also provided technical knowledge and expertise to enable improvements in the pre-existing operations. Specific major outputs include:

- Scientific and technical insights on the effect of different process levers within the existing alternate make mozzarella process as installed at Clandeboye.
- Formulations for a high moisture mozzarella, achieved via manipulating structure property relations.
- Formulations for a very high moisture mozzarella, achieved via manipulating structure and/or including filler particles within the cheese. This mozzarella has been successfully demonstrated at pilot scale, and a patent application for high moisture mozzarella has been filed.
- A mozzarella process option that incorporates all the whey protein into the cheese, removing the need for a whey processing plant, lowering the complexity of new factories.
- Options for manufacture of a reduced fat cheese.

These outputs have been made possible by many discoveries and developments including:

- Proving a range of scientific tools for exploring and understanding the structure of cheese.
- Validated models of the pizza-baking process, and the links between cheese structure and the formation of blisters, bubbles and other consumer-observable features. This was coupled with machine vision applications to provide objective assessment of cheese performance.
- Development and design of unit operations for the critical mixing and cooking stages of cheese production, including establishing a relationship between mixing and final cheese performance.

As part of the high moisture prototype development, the team developed a novel technology with potential application across a wider range of dairy products. The potential for using this technology for fat, sugar and salt reduction in a range of dairy products is being explored for the purposes of IP protection.

How has this been applied?

- The formulation and process learnings saved the existing Clandeboye mozzarella plant, and Fonterra's reputation as a reliable business partner, by greatly reducing the amount of downgrade product. This supported the initial expansion of the Clandeboye facility.
- A high moisture formulation was the basis of a commercial product development, leading to the Clandeboye $NZD 240 M expansion, due to come on line in 2018.
- The formulation and processing knowledge is being used to diversify Fonterra's mozzarella and pizza cheese options via a range of commercial product development projects. Fonterra is also continuing to invest in science and technology development for mozzarella.

What are the projected benefits?

The greatest benefit has been that mozzarella is now a hero product that is central to the Fonterra foodservice growth strategy. This strategy will see the company build a $NZD 5 billion foodservice operation over the next decade. This is partly based on confidence in a future pipeline of mozzarella innovation, which will result in new product launches and factory construction beyond 2020.

The strong technical and intellectual property position will support deployment of the technology offshore, helping Fonterra to grow beyond the constraints of the New Zealand milk pool. Including the whey in the finished product reduces the capital cost, by eliminating the need for whey processing investment.

What are the impacts beyond Fonterra?

The family of mozzarella projects attracted several young scientists, both national and international, to the Manawatu region. Some of these scientists have been identified as world-class talent and five are now permanently employed by Fonterra.

The latest Clandeboye factory expansion will generate 26 new full-time positions and invests $NZD 240 M in the local region.

Endgame creams

What were we seeking to enable?

The overall objective of the endgame creams project was to aid in the design of future UHT cream products with new benefits by building a foundation of knowledge and expertise in cream. This will lead to expansion in UHT cream capability and capacity in New Zealand and offshore, to enable a volume increase.

UHT whipping and culinary creams provide clear benefits to chefs in Asian bakeries, foodservice operations and Italian-style restaurants. They are also potentially able to withstand the challenges of a variable quality supply chain, expanding Fonterra's distribution reach.

When the programme began, the UHT process was effective in preventing microbiological spoilage, but storage and shelf-life of products was limited due to physical stability of the creams. The "endgame" goal was to completely remove the need for chilled distribution for whipping creams (although these would still need chilling before use to enable them to whip).

What was delivered?

Early work provided insights on different aspects of the production of long shelf-life chilled creams and supported the development of creams capability and expertise within Fonterra, which was minimal at the time. Outputs included:

- Levers to extend chilled shelf-life and to manufacture UHT whipping and culinary creams with consistent functionality throughout the year.

- Increased understanding of how formulation, processing and storage factors drive changes in critical sensory attributes of UHT creams.
- Links between processing levers and UHT cream functionality such as whipping performance.
- Insights into the mechanisms behind the stability of UHT creams stored at ambient conditions over an extended shelf-life.

More recent work investigated a range of different technical options for temperature-robust and ambient-stable long shelf-life creams and has resulted in successful lab-scale demonstration of an ambient stable whipping cream. Options have included the use of Pickering stabilisation and understanding the roles of proteins, fat and different hydrocolloids in both the ambient stability and whipping performance of creams.

Novel microfluidic apparatus developed as part of the programme **(see Signature milks)** has enabled measurement of short-range interactions between individual fat globules within a cream. These individual particle force measurements enable the development of phase diagrams to help predict the stability of emulsions.

The programme has also delivered new understanding of the partial coalescence phenomenon through direct measurement of fat crystals and direct observation of morphology of fat droplets. Partial coalescence is one cause of instability on temperature cycling and is an important contributor to whipping properties of cream.

A patent application has been filed.

How has this been applied?

Expertise and insights related to key levers to extend chilled shelf-life and manage product functionality throughout the year have been applied to the manufacture of current UHT whipping and culinary creams, process trouble-shooting, and resolution of customer complaints.

Further work outside the TDVC programme on processing levers, scale-up and mechanisms to achieve ambient UHT whipping cream stability resulted in the production of fully recombined UHT whipping cream prototypes that are stable to temperature cycling.

Ten commercial product development projects have been initiated, of which four have launched and another is scheduled to launch in 2018. Three significant process efficiency projects have also used the outputs to unlock additional capacity within the existing factories.

What are the projected benefits?

UHT Creams are now a critical product within the foodservice portfolio. Fonterra has installed new processing capacity to enable the production of UHT creams.

Ambient-stable functional creams will enable Fonterra to sell UHT creams to second and third-tier cities in China and other countries where there isn't a reliable cold-chain.

What are the impacts beyond Fonterra?

As with the mozzarella work, the creams programme has attracted several young scientists to work alongside Fonterra. The work has also been strongly international in nature with projects in Australian and Canadian universities as well as New Zealand, and this has contributed to the growth of the supporting academic networks.

Signature milks

What were we seeking to enable?

- Consumer sensory preference for Fonterra beverages leading to sales growth and sustainable premiums for Fonterra products compared with competitor offerings.

- Scientific, technical and consumer insights to inform the development of future dairy beverages, accelerating the commercial product development process, and helping Fonterra to move an increased portion of the milk supply into consumer formats.
- The ability to deliver long shelf-life dairy beverages, with elevated levels of protein and minerals.

What was delivered?

Exploratory work by a PhD student on microparticulation resulted in Fonterra staff identifying a novel approach to making microparticulated whey protein ingredients. Pilot scale trials performed at FRDC suggest that this has potential as a future ingredient to carry high levels of protein into medical foods and sports nutrition products.

A novel microfluidics apparatus has been developed at Massey University that makes use of optical tweezers and mathematical modelling to take measurements of interactions between pairs or clusters of particles suspended in a fluid. These are used to predict the performance of the processing and storage of protein-rich, dairy-based beverages. The design of this equipment is world-leading, solving several technical challenges that make it possible to automatically and rapidly perform many experiments over a wide range of commercially relevant conditions. The application of the technology is just starting in earnest, with potential to substantially reduce technology risk in commercial product developments by allowing prediction of performance.

Consumer studies have identified previously-unknown sensory preference profiles for UHT and powdered milk in key markets. This led Fonterra to use mechanistic approaches to identify and develop a range of technologies to hit the preferred sensory profiles.

Professor Jason Stokes, and his team at University of Queensland, have applied their instrumental techniques (gap-dependent rheology and tribology) to model food systems containing particles, to better understand the modes of action for sensory properties of grittiness through to smoothness. This work has identified some key design principles that are important for delivering foods (including dairy beverages and yoghurt) with targeted texture profiles. An example would be designing an oat-containing milk. Combining this work with the consumer taste and texture preferences has enabled the development of approaches to deliver the consumer-preferred sensory characteristics.

A prototype computer model has been developed based on the equilibrium between the various mineral species present in milks. This mineral speciation approach will be used to predict the long-term stability of mineral fortified dairy beverages, avoiding or reducing the need for lengthy shelf trials at the early stages of product development.

Computer simulations were developed to predict the impact of post-harvest milk handling and transport on the quality of milk and creams intended for use in long shelf-life products such as UHT milks and creams.

How has this been applied?

The consumer preference work resulted in acceleration of two commercial product development projects – with prototypes for in-market testing being developed within two months of initiation – by having the understanding of which sensory profiles drive consumer preference and a range of suitable prototypes to hand.

The consumer preference work has also provided the sensory targets for a new version of ANLENE™ which was launched in early 2018. This product also provides a level of dairy protein that work in the **mobility and protein quality** roadmap proved to be sufficient to encourage muscle protein synthesis.

Work is continuing at the University of Queensland under an Australian Research Council grant to develop the gap-dependent rheology and tribology approaches.

The mineral speciation model and the sensory insights are the starting point for development of AI-based predictive approaches for development of future consumer beverages.

The models of milk quality have been used to inform milk and cream handling practises for new products, including UHT organic milk.

What are the projected benefits?

Greater consumer insight at the front end of the commercial product development process is helping to transition Fonterra from a dairy ingredients supplier to a strong consumer-oriented company. Specific benefits will include:

- Increased sales of ANCHOR™ and ANLENE™ products.
- Better targeting of consumer sensory properties in beverage product development, leading to greater commercial success.
- More rapid product development supporting faster innovation cycles and the ability to rapidly respond to competitor activity in market.
- Future development and sale of ambient-stable high-protein UHT beverages.

What are the impacts beyond Fonterra?

The microfluidics apparatus can be applied to fluids other than dairy to help predict the long-term stability of beverages and suspensions.

Fonterra R&D and Massey University have established an ongoing relationship with the research group at the University of Queensland.

ZESPRI / kiwifruit

What were we seeking to enable?

Zespri International Limited is the world's largest marketer of kiwifruit, "making life delicious" for consumers by delivering premium quality kiwifruit in more than 59 countries. Zespri manages 30 percent of the global volume, and has a goal to more than double global sales revenue to $4.5 billion by 2025. The implications of this growth path include investment and innovation in supply chain systems and processes to manage over 200 million trays of New Zealand kiwifruit, and over 50 million trays grown offshore. Innovation to extend the packing window and storage of SunGold™ is needed and an additional investment up to $1 billion is required by the post-harvest sector to keep pace with volume growth. Supporting this growth requires world-leading supply chain management, built on a deep understanding of the characteristics of the fruit. The Zespri component of the TDVC PGP programme sought to develop and apply knowledge of how the structure of kiwifruit changes over time - to improve post-harvest handling, and generate predictive models to support improved fruit selection and supply chain management.

What was delivered?

The projects improved prediction and segregation of kiwifruit in the Zespri supply chain - utilising post-harvest technologies is crucial not only to reduce fruit quality costs, but also to optimise fruit quality for consumers, and manage increased volumes as our industry grows.

- A PhD on developing a mathematical model for Hayward kiwifruit softening in the supply chain clarified the increased risk of chilling injury development associated with too-rapid cooling of kiwifruit, which has resulted in widespread industry change in cooling protocols.
- A PhD on the use of non-destructive near-infrared spectroscopy to predict storability of kiwifruit showed promise at laboratory-scale in the segregation of fruit. It was followed up with a Zespri-funded postdoctoral project to test this modelling approach at an industry-scale, where machine learning algorithms continuously optimise models to improve predictions of the storability of fruit.
- Post-doctoral research on a temperature and ethylene integrated fruit softening model accurately predicted the storage life of grower lines maturity areas at research-scale, so was followed up with Zespri-funded large-scale trial where over 36,000 individual fruit were measured from three packhouses.

How has this been applied?

- An ethylene and temperature-based fruit softening model for early season SunGold kiwifruit has been developed and is being applied during shipping to optimise conditioning regimes for improved fruit quality outcomes upon arrival in offshore markets.
- Implementation of the integrated fruit softening model has further progressed with a subsequent trial funded in the 2019 season, where four packhouses are conducting their own data collection on fruit softening to be used in the modelling and predictions.

What are the projected benefits?

- Improving the quality and consistency of early-season fruit arriving in offshore markets gives customers confidence in the Zespri brand and gives consumers a fantastic eating experience that encourages repeat purchase decisions.
- Predicting the storage life of grower lines, either at-harvest grading or by examining the softening curve early in storage, will enable post-harvest operators to optimise inventory management. Selling poor-storing fruit early, and keeping the right grower lines for long storage, significantly decreases fruit quality costs (over $100 million some years) resulting in a higher return to growers and an improvement in the consistency of fruit quality for customers and consumers all over the world.
- Learning about the skin properties of kiwifruit through a PhD on fringe projection technique is informing research on understanding condensation behaviour on kiwifruit and labelling failure.
- In addition to New Zealand-produced kiwifruit, Zespri sources premium quality kiwifruit from several countries in the northern hemisphere including Italy, France and South Korea. Building Zespri's global supply capability through a focus on lifting fruit quality and yield is a key element to achieving the company's 2025 goal to double sales revenue to $NZD 4.5 billion. Spill over benefits have included the investigation of using the measurement technologies from this PGP programme to detect brown marmorated stink bug damage in Zespri's SunGold™ kiwifruit in Italy. This pest is not yet in New Zealand, but is a serious biosecurity hazard and the New Zealand kiwifruit industry want to be as prepared as possible in case there is an incursion.

What are the impacts beyond ZESPRI?

A strong collaboration between Zespri and the Postharvest team at Massey University has been established through the programme, which will deliver benefits for the kiwifruit industry in the decade to come, as fruit volumes double, and supply chain innovation becomes more critical. Two post-doctoral researchers from the PGP programme have been identified by Zespri as key talent to retain at Massey University, working on kiwifruit supply chain research for Zespri. This talent has been secured through a four-year agreement with the Massey Agritech Partnership. Ongoing research relationships are critical for Zespri to outsource research and development.

Process analytical technology

What were we seeking to enable?

Milk powders provide a long-life, stable format for the storage and transport of dairy nutrition and form the backbone of Fonterra's operations. There are very few degrees of freedom for changing product formulations within the well-established commodity categories. However, there are quality premiums available from discerning customers for consistent and superior functional performance (e.g. solubility, dispersibility, powder appearance and flow properties). Many key properties of the final product cannot be measured during manufacture, limiting the ability to control the process.

Overall goals the **process analytical technology** project aimed to deliver were:

- Premiums from improved milk powder functionality.
- Reduced cost of quantity failure.
- Improved customer and consumer confidence.

Proving the value of the approach with milk powder is a first step to roll out to other Fonterra processes, such as cheese manufacturing.

The **process analytical technology** approach is a first step in the application of statistically predictive control of dairy processes, making use of large sets of data currently captured, but not used by process control systems, to gain additional insights about the quality of the product being manufactured.

What was delivered?

Accessing and combining data in new ways to derive process and product insights was a key component of this workstream. Many of the outputs are in the form of software tools and databases, including:

- A software tool that facilitates the automatic downloading and consolidation of processing and product quality data.
- A consolidated database that combines milk powder processing and associated product quality information from three factories across four years. This manually-assembled database has been analysed with a range of advanced statistical techniques.
- Software mini-tools that addressed specific processing issues in milk powder plants, including vitamin dosing and temperature optimisation in evaporator pre-heat systems.

Analysis of the multi-factory data set has provided a greater understanding of factors impacting on milk powder particle size, including the impact of processing and transport conditions. While some of these factors are inherent to factory construction, others can be controlled. Improved knowledge of how factory design impacts on particle quality helps to support product-factory alignment decisions.

As the team analysed the data sets, they identified limitations in the repeatability and accuracy of current milk powder functional tests, especially for use in computer model-based process improvement. This resulted in activities to improve the accuracy and resolution of test results. The programme also resulted in the development of a range of imaging technologies for assessing milk powder appearance.

How has this been applied?

As part of the development of the innovative cooperative aspect of the strategy, Fonterra is putting considerable focus on application of advanced analytics and machine learning technology.

- Fonterra is currently implementing a system for downloading and consolidation of processing and product quality data based on the software tools. The Automation and Operational Technology team within Fonterra will use this routinely for process control upgrades and process efficiency projects.
- Fonterra has strongly focused on improving milk powder functional grading tests as an outcome of the statistical analysis of process and product quality data.
- Milk powder imaging is currently a component of a significant research project. Aspects of this work use learnings from the previous research.

What are the projected benefits?

The benefits include improved quality premiums for milk powders and other dairy products, and improved production efficiency and reduced costs – including environmental impacts – associated with downgraded or off-specification product.

- Fonterra has launched a range of differentiated milk powders that attain a higher price based on superior quality attributes (**NZMP gold instant wholemilk powder**). The real-time quality work enables Fonterra to reliably and efficiently produce these products now and into the future.
- For the first time, Fonterra has access to a large database of linked process and quality data, along with the tools to readily create further such databases rapidly. This will lead to more efficient dairy processing – higher quality using less energy.

What are the impacts beyond Fonterra?

Through the **process analytical technology** work programme, Fonterra has developed a new way of working with the University of Auckland Industrial Information and Control Centre (I2C2), which has significant benefits for I2C2.

- I2C2 has developed a wealth of experience for application in dairy process control systems that provides a foundation for future industrial work by the Centre and supports delivery of industry-relevant teaching.
- The product quality and processing information database will be used as a teaching resource for future milk powder processing training, problem solving and academic collaborations.
- Fonterra and the I2C2 team have published 5 papers and presented material at 7 international conferences. This work is linked to Fonterra and shows clear leadership in the milk powder processing space.

Food safety and quality

What were we seeking to enable?

Prior to the programme, Fonterra – and other companies – had been rocked by the deliberate adulteration of milk in China through the addition of the industrial chemical melamine. This had led Fonterra, in partnership with Arla Foods and Foss Analytical, to develop a Fourier transform infrared spectroscopy (FTIR)-based method to detect suspicious milk – the beginnings of milk fingerprinting.

The **food safety and quality** workstream sought to expand the use of the milk fingerprinting approach through:

- Developing the necessary business processes to support the use of the existing abnormal spectrum module developed with Arla and Foss.
- Expanding the range of calibrations available to enable measurement of additional milk quality parameters, at virtually no additional operational cost. This would provide the ability to make predictive quality and milk allocation decisions in real time.

The other major goal was to improve the statistical basis for product sampling and testing, including the frequency and timing of samples within a batch, and the treatment of uncertainties in the analytical measurements. Improvement here would lead to:

- Improved customer and consumer confidence in results.
- Improved value from testing without an increase in costs.
- Reduced cost of quality failure.

What was delivered?

The **milk fingerprinting** work programme has resulted in development of a core of expertise in managing, understanding and analysing Fourier transform infrared spectral data that is routinely collected from every farm every day. This has resulted in calibrations, business rules and processes for detecting and managing the following:

- Abnormal spectra as an indicator of potential adulteration.
- Titratable acidity (TA) to address regulatory constraints.
- Fat evaluation index (FEI) to prevent processing issues with milkfat products.

In addition, preliminary evaluation of a range of further calibration options has been completed, including looking at “outlier samples” to understand sources of variation that potentially include the impact of on-farm practises.

The **industrial statistics** work has delivered statistically more robust approaches for specific areas including:

- Assessment of measurement uncertainty.
- In-process determination of quality attributes.

- More efficient product inspection and sampling protocols, and,
- Process diversion and re-inspection plans.

This covers all product composition and certain microbiological test parameters. Nine papers in peer-reviewed journals will provide a basis for considerable additional improvements in the use of industrial statistics.

How has this been applied?

Milk fingerprinting has become a standard analysis tool within Fonterra.

- Milk for use in UHT products destined for China is selected based on milk fingerprinting TA results.
- FEI has been included in the milk compositional information provided to farmers.
- The on-farm R&D team is actively looking to deploy milk fingerprinting in three other applications.

To continue development of the milk fingerprinting platform, we have appointed a position in conjunction with the University of Auckland as a chemometrician, focusing on FTIR data.

The **industrial statistics** work has been applied to reduce the costs and risks associated with product testing and grading. Fonterra has implemented the proportion non-confirming (PNC) statistic as part of the routine on-line grading assessment process.

Aspects of the work on statistical sampling has been taken to Codex Alimentarius by the NZ delegation (led by MPI).

What are the projected benefits?

The economic benefits are primarily a reduction in costs and risks associated with product quality problems.

Based on milk fingerprinting:

- Fonterra has been able to grow its white (unflavoured) UHT milk business in China without incurring the cost of wet-chemistry-based measurements. Over two million samples were analysed over a four-month period, with the cost of the equivalent wet-chemistry estimated at $30 million, which would have limited the ability to develop this business opportunity.
- Fonterra farmers have rapid feedback on the quality of their milk fat and can manage their supplementary feeding to maintain product quality within acceptable limits.

Implementation of the proportion non-conforming approach to product grading has seen Fonterra identify batches of product for further investigation, rather than directly shipping to customers, eliminating several potential complaints.

Non-financial benefits include:

- Fonterra being seen as a world leader in application of milk fingerprinting to support milk processing.
- Fonterra has strengthened its relationship with the University of Auckland and MilktestNZ.

What are the impacts beyond Fonterra?

The publications in statistical journals has shown that New Zealand is leading thinking in the application of advanced statistics to processing industries.

Mobility and protein quality

What were we seeking to enable?

The aim of the **mobility and protein quality** programme was to deliver robust science to support the growth ambitions for ANLENE™, and to provide scientific evidence to support international recognition of the superior quality of dairy proteins compared to plant-based alternatives.

To enable this, the programme aimed to provide dossiers of credible scientific evidence to support the regulatory approval and marketing of a pipeline of new options for nutritional products that help improve functional mobility outcomes in the context of a healthy lifestyle including proven ingredients, components and final consumer products.

What was delivered?

Through a combination of animal and human clinical studies the programme has:

- Demonstrated the value of dairy protein in terms of amino acid appearance in the blood, stimulation of muscle protein synthesis and benefits to the impacts of exercise.
- Provided evidence that milk protein (including both casein and whey proteins) is as effective as whey protein for muscle benefits.
- Delivered a coherent benefit story for the value of dairy protein to middle-aged adults through a programme of interlinked studies (the target market for Fonterra's branded products with mobility benefits, an age group hitherto largely ignored by nutrition science).
- Demonstrated ancillary benefits of dairy protein consumption on makers of joint and bone health, providing a "total package" for mobility benefits.
- Provided initial evidence and support for an improved measure of protein quality (Digestible Indispensable Amino Acid Score: DIAAS*)* that will allow the superior nature of dairy protein amino acid composition to become evident, as opposed to current methods.

This has supported development of a portfolio of dairy protein ingredients with a range of function properties (e.g., fast appearance of amino acids in the blood) that can be tailored to customer needs.

The programme has also developed non-diagnostic, consumer-focused, tools to measure lean muscle mass in specific ethnic groups (this supports the development of new consumer-activation tools to drive proof-of-need in the same manner as Fonterra's partnership with GE for the ANLENE™ bone-scan).

How has this been applied?

A multi-national consortium of research providers is developing the evidence required to drive acceptance of DIAAS as the new standard method of determining protein quality. Leadership of this work has been taken up by the Global Dairy Platform.

There have also been changes to Fonterra's ANLENE™ brand:

- The market positioning of ANLENE™ has moved from a focus solely on bone towards a more complete mobility position.
- New generation ANLENE™ products have been developed and launched with a "clinically proven" level of dairy protein shown to support mobility benefits. These products have also been designed using the sensory preference insights from the **signature milks** workstream.

NZMP have launched the "Sure Protein™" range of ingredients, backed by a portfolio of scientific evidence. There has also been significant improvement in the NZMP marketing strategies for innovative dairy protein products.

The dairy protein knowledge base provided the confidence to Fonterra to develop two new business units under NZMP to drive ingredient sales: Medical Nutrition and Sports Nutrition. Understanding the functional properties and benefits of different milk protein ingredients was key in being able to provide a suite of tailored products.

What are the projected benefits?

- Increased revenue from both incremental growth in Fonterra-branded consumer products (e.g., ANLENE™) and growth in returns from high-value protein ingredient offerings to customers, from purified functional proteins through to providing white-label formulations for other brand owners.
- Leverage of functional protein expertise and the role of dairy protein in mobility from healthy middle-aged populations to more specific nutritional needs of specialist (e.g., sports and active

lifestyles) or at-risk (e.g., hospitalised or elderly) populations leading to growth of the new medical and sports nutrition businesses.

What are the impacts beyond Fonterra?

- An expanded local and international network of engaged researchers in nutrition and mobility.
- Support for the "holistic" approach to mobility, with emphasis of the role of both high-quality protein in the diet and exercise to drive health benefits.
- Acceptance of the DIAAS measure of protein quality will allow much more accurate formulation of foods for nutritionally vulnerable or at-risk populations. The change to DIAAS from the previous PDCAAS method will also favour other animal sources proteins (meat, egg, fish) in comparison with plant-based alternatives.

Paediatrics

What were we seeking to enable?

The aim of the **paediatric** programme was deliver robust science to support the growth ambitions for ANMUM™ - Fonterra's maternal and infant nutrition product range that is positioned around cognitive development.

To enable this, the programme will provide a dossier of credible scientific evidence to support the regulatory approval and marketing of a pipeline of new options for maternal and paediatric nutrition including proven ingredients, components and final products for delivering brain development benefits.

Where relevant, the science will be leveraged across other benefit platforms and brands.

What was delivered?

The programme has provided the scientific evidence to support the development and commercialisation of a complex milk lipid ingredient – Milkfat Globule Membrane (MFGM). This includes:

- An improved method of analysis for measuring the levels of MFGM components in blood and other fluids.
- Data to support the use of MFGM in maternal milk powders and infant formulae, including better data on the levels of these components in the normal diet (including breast milk) across different geographies.
- Evidence of health benefits from dietary consumption of MFGM components in a human population with a genetic inability to synthesise key components.
- A body of peer-reviewed publications, conference presentations, and expert-led presentations to medical key opinion leaders building a robust and coherent benefit story for the role of MFGM and MFGM components in paediatric cognitive development.
- Two large clinical studies on the impact of MFGM supplementation during pregnancy, and in infant formula, are still underway, with results expected later in 2018.

The workstream has also demonstrated potential cognition benefits of a new dairy-based ingredient as the basis for a next generation of products, with opportunities for proprietary IP capture.

How has this been applied?

Starting in 2016, the MFGM ingredient has been launched throughout the ANMUM™ range in many key markets (China, Hong Kong, Malaysia, Indonesia, Vietnam, Thailand). ANMUM™ infant formula was also launched in New Zealand for the first time.

NZMP have launched the "SureStart™ Lipid 100" ingredient, backed by a portfolio of science evidence.

Fonterra is seeking to leverage MFGM benefits outside paediatrics, including a study of the role of MFGM in improving brain function in children, targeting the ANCHOR™ brand.

Patent protection for a new cognitive benefit has been sought, the proof-of-efficacy data been used to drive improvements and scale-up manufacture, and the next stages of product commercialisation.

What are the projected benefits?

- Increased revenue from growth in ANMUM™ consumer products and new returns as high-value ingredient offerings to paediatrics customers.
- Successful regulatory approvals to allow the use of MFGM in paediatric powders, as required for each geography. Approvals are contingent on the ability to provide a portfolio of MFGM evidence (efficacy, proof-of-need, safety, etc.).
- Until recently, MFGM was not found in infant formulae, even though it is naturally present in breast milk. MFGM is now increasingly recognised as a premium bio-active component for paediatric nutrition, with high demand for MFGM ingredients – driven from a strong science base.
- Recognition of Fonterra as a credible provider of high-quality research with award recognition of conference presentations and ingredient offerings.

What are the impacts beyond Fonterra?

The analytical method developed to measure gangliosides, ceramides and phospholipids in MFGM represent a major advance in the field and have been applied to a wide variety of food substances.

Workplan changes

In addition to the "roadmaps" described above, the programme included workstream that did not progress as originally intended.

Gene sequencing

The history	Fonterra underwent a strategy refresh in 2012 and, as a result, bovine genomics was removed from VLB's core business objectives. It was deemed that the market now required more milk and differentiated milk products (derived from naturally-occurring genetic variants) were no longer desired by the industry. As such, VLB disestablished their bovine genomics team, and withdrew from the PGP project by terminating the increased genetic gain subcontract.
Key learnings and changes	Results from the first few years of the project far surpassed expectations of the original proposal and, after only two years, bioinformatic capability was developed, analysis pipelines and data generation were in place and genetic markers were identified and integrated into predictive tools. Preliminary results indicated that a significant improvement in the accuracy of genomic selection could be achieved and thus increase the rate of genetic gain. These data sets, infrastructure and skill sets were pivotal to the identification, test development and removal of the de novo mutation found in a sire called 'Holcyon' (commonly known as Hairy) and a subset of his daughters that had deleterious effect on milk production. Due to the proven benefits already achieved, the LIC Executive Team decided LIC would significantly increase investment for the PGP project, to replace the previous ViaLactia contributions and maintain the level of industry investment. The work delivered in the project was expanded and delivered a large-scale gene expression study of lactating mammary tissue (RNA-Seq), developed a New Zealand dairy-specific genome reference, and investigated the emerging science of metabolomics for its potential to enhance the ability of sequence data to predict phenotypes that have only a small genetic component.

The future	Because of the PGP project, LIC, alongside their collaborators, are now world-leaders in gene discovery and animal breeding, having collectively discovered more causative genes for dairy cattle traits than any other group.

Precision agriculture

The history	The hypothesis linking autumn-applied N fertiliser to increased N leaching via pasture composition changes was investigated, including analysis of field data and modelling studies. The work provided relevant knowledge for the industry, which will be incorporated into current industry guidelines and made available to researchers. New approaches using real-time measures of feed status, animal N balance and weather data were then scoped and were found to be more complex than initially thought. In 2013, at the time the scoping was being completed, the MBIE-funded programme – OPTIMUM N, led by the New Zealand Centre for Precision Agriculture (Massey University and Lincoln University) – was initiated, delivering research that would duplicate and expand upon this part of the project.
Key learnings and changes	It was essential during the project delivery to maintain linkages with complementary groups within New Zealand and internationally and utilise a Steering Group to keep abreast of developments as well as provide direction. Because technologies are commercial developments, a Technology Supplier Group was also used. Work investigating development of precision agriculture tools to manage nitrogen use was discontinued and the Precision Agriculture Team remained in consultation with Lincoln Agritech to keep informed of developments within the OPTIMUM N programme. Based on a 2012 strategy and work programme, developed through a Trans-Tasman Precision Dairy Workshop, direction was reprioritised to investigate use of information technology and precision approaches in feeding strategies.
The future	The final review of the MBIE OPTIMUM N programme (Lincoln Agritech; 2016) identified that the technology was still in a concept phase and no additional work could be integrated into the PGP project. Areas requiring further work were identified and reported to appropriate industry groups.

MACO

The history	The MACO software (My achievements and career opportunities) was developed through the Leadership Pipeline project as a tool for farm staff to navigate their career development. The core software was developed in 2014, incorporating pastoral farming careers information. A review of MACO was undertaken as there was concern around its limited functionality (compared to the pace of technology change) and questionable long-term sustainability. In addition, over previous years there were several developments that could supersede MACO (for example, formation of the Primary Industry Capability Alliance [PICA]; Ministry of Education Vocational Pathways approach and new portal for teachers; Careers NZ new strategy including new digital approach).

Key learnings and changes	When the project was initiated, the concept of a cross-sector product was not envisaged and therefore it was a smaller project specifically for the dairy industry. With increased cross-sector engagement, the development scope grew, and, in hindsight, there was insufficient planning and consideration of resource needed for successful delivery. Furthermore, the raw data computational requirements grew exponentially during pilot testing and development of career search functionality. Launch of MACO was halted and the resource was transferred to PICA for coordination of implementation with other initiatives.
The future	The MACO project did result in a strong foundational product that has been delivered as a navigation tool – "Open a door into our innovative primary industries" – via the PICA website - www.growingnz.org.nz. This provides videos and links to CareersNZ and FutureTech career opportunities, as well as network and scholarship opportunities.

Restructuring lactose

The history	The original scope for Theme 3 – Food structure design – included a workstream aimed at providing a scientific foundation for adding value to lactose by-product streams. This reflected a strong expectation of growth in the production of milk protein concentrates and other protein rich dairy streams, creating the potential for increased volumes of lactose rich by-product streams. Providing high-value applications for the resulting solids would support the profitability of the value-add proteins. Technical areas identified in the original business plan included work on: • Phase transition kinetics in lactose solutions and impacts on solubility and crystallisation. • Mechanisms to enable stable supersaturated lactose solutions. • Physics approaches to produce micro-crystallised and nano-crystallised lactose. • Inducing insolubility in crystalline lactose through manipulating particle surface properties. The restructuring lactose workstream was terminated in June 2011 – prior to any programme investment – due to a large permanent change in market demand for lactose. It became clear that, for the foreseeable future, the demand for lactose and lactose-rich milk permeates for milk protein standardisation would exceed the growth in milk protein concentrates (MPCs), resulting in Fonterra being a net importer of lactose.

Natural cheese slices

The history	Very early in the life of the PGP programme, the concept was proposed for natural cheese slices (NCS), prepared using the alternate make mozzarella process. The characteristics of this type of cheese meant that a significant change to the mozzarella process would be required to reach the target and this would necessitate considerable research activity. The proposal aligned well with market insights reported by the category team and aligned well with the foodservice strategy. The new process would be used to

	make sliced cheese for sandwich and burger manufacturers. Market insights indicated favourable cheese volumes and price, and the project was approved at gating. The project was initiated, and a considerable body of work was completed and reported in the first phase. However, unfortunately the original market insights were not robustly proven, and the work was stopped.
Key learnings and changes	There were limitations in the methodology used for gathering the consumer and market insights that informed this work. Since then, Fonterra has developed specialty consumer and market insights teams in Auckland and at FRDC, with the teams working closely together. At the time of the NCS project development, Fonterra was primarily a foodservice and ingredients business. This has now evolved, with a much greater emphasis on consumer brands. As part of the TDVC programme, Fonterra has run workshops to develop an awareness of the need for a consumer-centric approach to consumer and market insights. The TDVC PGP programme has also invested in consumer and market research, with the application, testing and eventual adoption of new methodologies that better predict the consumer response to new products and processes. These methodologies have also identified (unoccupied) 'white space' on the consumer-preferred landscape for white milks. Fonterra is now using these methodologies at the beginning of most new research programmes, improving the ability to predict the return on investment.
The future	The original NCS research is not wasted effort – it is likely that the technology developed during the NCS project will be used soon to make cheese slices using extrusion processes. The new consumer-centric approach means that market and consumer research is undertaken early in the life-cycle of new programmes. Fonterra has co-funded the Fonterra–Riddet Chair in Consumer and Sensory Science held by Professor Joanne Hort. She is working with Fonterra's own experts to provide robust market and consumer research.

Process redesign

The history	The manufacturing processes for the core dairy commodities have a long history, with limited innovation in the fundamental process design. Productivity innovation has instead focused on improving the efficiency of individual unit operations and increased scale of operations (e.g., the 30 t/hr WMP drier at Darfield). By the start of the TDVC programme, this had reached the point of diminishing returns and there was a risk an entirely new approach to production of long-life intermediate dairy products could disrupt the base of Fonterra's business. Rather than wait for disruption to occur, the decision was made to invest in developing radically different processes. Technically, the work resulted in the development of a system of four key processes to produce two initial concentrates – a high-density skim milk powder and a milkfat paste – a transport-efficient whole milk concentrate brick, and the use of the resulting brick in an industrial recombining and UHT process. A patent has been granted for aspects of this process, and Fonterra has also developed new hygienic designs for two of the unit operations. Sufficient bricks were

	manufactured in the FRDC pilot plant to enable a successful commercial trial with a NZMP recombining customer in Saudi Arabia. Commercial implementation of the technology did not progress, and the process redesign workstream was terminated during FY13, after completing all the initially scoped projects.
Key learnings and changes	There was no customer need or pull for a change in technology. The programme was driven by a desire to reduce processing and supply chain costs, but the outcomes required customers to make changes in their own factories to accommodate a new product format and potentially to lock themselves to NZMP as a supplier. To secure this change would have necessitated passing on a significant portion of the cost savings to customers, which undermined the business case for implementation. This need for stronger consumer/customer insight echoes the NCS experience above. The potential capital investment and manufacturing footprint implications were not developed early enough. Consideration of this may have resulted in an earlier decision to terminate the work. The process redesign workstream experience has resulted in a change in Fonterra's internal ways of working for large-scale innovation, driving much better cross-functional integration (e.g., between R&D and capital projects) in the early phases of programmes. Staff on the project were fully dedicated and co-located for the duration of the work, which created a fantastic team environment and work ethic.
The future	Stronger emphasis on outlining the possible full implementation scenarios at the outset of new technology programmes will lead to a higher success rate in the future. Aspects of the technical knowledge gained have been applied in other areas. The milkfat paste ingredient has been explored as a potential creaminess enhancer in consumer beverages. Co-location of core project teams along with use of "agile" project management practices has been applied to Fonterra's larger research and technology development programmes.

Appendix 1: Table of abbreviations

The following abbreviations have been used in this report.

Abbreviation	Meaning
ASL	Agricultural Services Limited.
BCSAC	Body Condition Score Assessor Certification - certification programme to maintain standards for body condition scoring.
BV	Breeding value - measure of the economic value of certain animal traits.
CEFBM	Centre of Excellence in Farm Business Management - joint venture between Massey University and Lincoln University, also known as OneFarm or AgriOne.
DIAAS	Digestible Indispensable Amino Acid Score - a measure of protein quality that considers the digestibility and absorption of indispensable amino acids and provides improved accuracy over the previous method (PDCAAS).
DIGAD	Dairy Industry Good Animal Database - industry good database created by TDVC to hold core animal information.
FDAL	Farm Data Accreditation Limited - organisation established to provide governance of farm data standards.
FE	Facial eczema - disease caused by fungal spores that produces a toxin which attacks the liver of sheep and cattle.
FEI	Fat valuation Index - a measure of the quality of milkfat in a milk sample.
FTE	Fulltime equivalent - measure of labour inputs.
FTIR	Fourier Transform Infrared Spectroscopy.
FVI	Forage Value Index - a rating system for ryegrass that helps farmers with cultivar selection and provides direction for plant breeders.
FWW	Farmer Wellness and Wellbeing - project area within the *Better Farm decision-making roadmap* (Theme 2).
FY	Financial year - a financial year ended 30 June of the stated *year* (aligning with the government calendar and midway between the DairyNZ and Fonterra calendars).
GWAS	Genome Wide Association Study - an observational study of a genome-wide set of genetic variants in different individuals to see if any variant is associated with a trait.
I2C2	Industrial Information and Control Centre.
IF/FO	Infant formula / follow-on formula - specially designed products to provide either complete (IF) or partial (FO) nutrition for infants.
IP	Intellectual property.
ITO	Industry Training Organisation.
LIC	Company formerly known as Livestock Improvement Corporation.
LME	Liquid milk equivalent - also known as fat and protein corrected milk (FPCM) - a measure of equivalent milk volume in litres at a global standard level of milk protein and fat.
MACO	My Achievements and Career Opportunities - discontinued software project to support career development for farm staff.

MBIE	Ministry of Business Innovation and Employment.
MFGM	Milk fat globule membrane - the biological membrane that surrounds the fat in milk.
MPC	Milk protein concentrate
MPI	Ministry for Primary Industries.
N	Nitrogen.
NCS	Natural cheese slices.
NeSI	New Zealand e-Science Infrastructure - partnership between MBIE, universities and CRIs to provide high-performance computing capability.
NMAC	Nutrient Management Advisor Certification - certification programme to maintain standards for nutrient management advisors.
NPD	New product development - process for commercialisation of new products and services.
NZD	New Zealand dollars
NZIPIM	New Zealand Institute of Primary Industry Management - organisation dedicated to building the capability and capacity of rural professionals operating within New Zealand's primary industries.
NZMP	Formerly New Zealand Milk Products - brand for Fonterra's ingredient sales business.
NZYF	New Zealand Young Farmers organisation.
PDCAAS	Protein digestibility corrected amino acid score - historical measure of protein quality based on amino acid composition.
PGgRC	Pastoral Greenhouse Gas Research Consortium.
PGP	Primary Growth Partnership - industry-government innovation partnership scheme operated by MPI.
PICA	Primary Industry Capability Alliance.
PSG	Programme Steering Group.
R&D	Research and development
RBN	Rural Business Network.
RFI	Residual feed intake.
RHAANZ	Rural Health Alliance Aotearoa New Zealand.
RMPP	Red Meat Profit Partnership PGP programme.
RNA	Ribonucleic acid.
RP	Rural professional - providers of specialist professional advice to farmers.
RS&T	Research, science and technology.
SIL	DairyNZ Strategy and Investment Leaders
SL	Sialyl-lactose - a carbohydrate found at differing levels in bovine and human milk.
SMASH	Smaller Milk and Supply Herds - farmer driven organisation dedicated to the information needs of smaller herd farmers.

TA	Titratable acidity - a milk quality measure.
TDVC	Transforming the Dairy Value Chain.
UHT	Ultra-high temperature - Commercial sterilisation process for production of long-life ambient liquids.
VLB	ViaLactia Biosciences – former Fonterra on-farm bio-technology research organisation.
WFA	Whole farm assessment.
WGS	Whole genome sequencing - the process of determining the complete DNA sequence of an organism's genome at a single time.
WMP	Whole milk powder.

Appendix 2: Summary of IP (intellectual property)

The following patents applications have been filed or completed because of the programme:

Application no	Title	Inventors	Filing date
WO2018/020473	Dairy Product and Process	Alan Welman, Geoffrey Stevens, Paul McJarrow, Bertram Fong, Bing Wang	28 July 2017
NZ738516	Dairy Product and Process	Thomas Fuller, Sayed Hosseinipavar, Skelte Anema, Mitaben Lad, Therese Considine, Alexandra Legg, Hemang Bhatt, Aurelie Cucheval	19 Dec 2017
NZ715584 **NZ716956**	Dairy Product and Process	Graeme Gillies, Palatasa Havea, Christina Coker and Steve Taylor	24 Dec 2016
US61/319817 **US61/319801**	Production of concentrated milk fat compositions and unitized high-density compositions	Antony Mackereth, Alan Baldwin, Frank Van De Ven	31 March 2010
NZ625688	Genetic markers and uses therefor	Chad Harland, Kathryn Sanders and Richard Spelman	30 May 2014
NZ630540	Genetic markers and uses therefor	Mathew Littlejohn and Stephen Davis	12 Sept 2014
NZ717877	Genetic markers and uses therefor	Mathew Littlejohn and Stephen Davis	23 March 2016
NZ722031	Genetic markers and uses therefor	Mathew Littlejohn and Stephen Davis	11 July 2016
NZ717870	Genetic markers and uses therefor	Mathew Littlejohn and Stephen Davis	23 March 2016
NZ719236	Genetic markers and uses therefor	Carole Charlier, Mathew Littlejohn, Michel Georges and Richard Spelman	20 April 2016
NZ724061	Genetic markers and uses therefor	Carole Charlier, Mathew Littlejohn, Michel Georges and Richard Spelman	09 Sept 2016
NZ724066	Genetic markers and uses therefor	Carole Charlier, Mathew Littlejohn, Michel Georges and Richard Spelman	09 Sept 2016
NZ724056	Genetic markers and uses therefor	Carole Charlier, Mathew Littlejohn, Michel Georges and Richard Spelman	09 Sept 2016
NZ738338	Genetic markers and uses therefor	Mathew Littlejohn and Michael Keehan	21 Dec 2017
NZ738350	Genetic markers and uses therefor	Mathew Littlejohn and Michael Keehan	21 Dec 2017
NZ738354	Genetic markers and uses therefor	Mathew Littlejohn, Thomas Lopdell and Michael Keehan	21 Dec 2017
NZ738356	Genetic markers and uses therefor	Mathew Littlejohn	21 Dec 2017

Appendix 3: Table of outputs

The following table shows the various outputs from the programme by roadmap and output type (excluding media articles, webpage announcements, *Inside Dairy* or *FarmSource* articles, or other forms of external communications activity).

Programme roadmap	Conference papers	Published papers	Internal reports	Training events	Other Outputs[11]	TOTAL
Resilient cows	9	18	36	0	22	**85**
On-farm technologies	21	21	38	0	22	**102**
Dairy data network	5	3	65	1	84	**158**
More and better advisors and advice	24	3	222	186	190	**625**
Better farm decisions	69	6	237	202	189	**703**
Endgame mozzarella	21	15	44	0	7	**87**
Endgame creams	1	0	40	0	1	**42**
Signature milks	14	7	10	2	3	**36**
Zespri	10	4	0	5	2	**21**
Process analytical technology	9	11	18	0	0	**38**
Food safety and quality	9	18	22	0	0	**49**
Mobility and protein quality	1	19	5	6	0	**31**
Paediatrics	5	11	14	0	1	**31**
TOTAL	**198**	**136**	**751**	**402**	**521**	2008

[11] Includes patents and student theses.

Appendix 4: Benefit model

Figure 11 below is a modification on a figure used in the original business plan to illustrate the position of the programme within the innovation system and how outputs generate benefits. The programme sits towards the front-end of the innovation system, generating a range of outputs including solutions to *technical challenges, qualified people, and technical publications that form the starting point for downstream activities and investments by industry investors* (e.g., dairy farmers, milk processing and marketing companies).

The large "$" on the right-hand side represents the economic benefits delivered via the industry co-investors. The "Other $" represents the additional downstream investment made by these investors to realise the benefits and includes capital and implementation costs, which are significantly greater than the original programme investment (small $ at left).

The diagram also indicates two of the mechanisms by which the programme generates spill-over benefits for other industries: through use of the capabilities and use of the published technical results.

The one change from the original version is the addition of the line connecting the capabilities generated by the programme to the downstream activities of the industry investors. This represents the key role that qualified people have in supporting the commercial implementation of innovation and is particularly relevant to the capability development work undertaken as part of Theme 2.

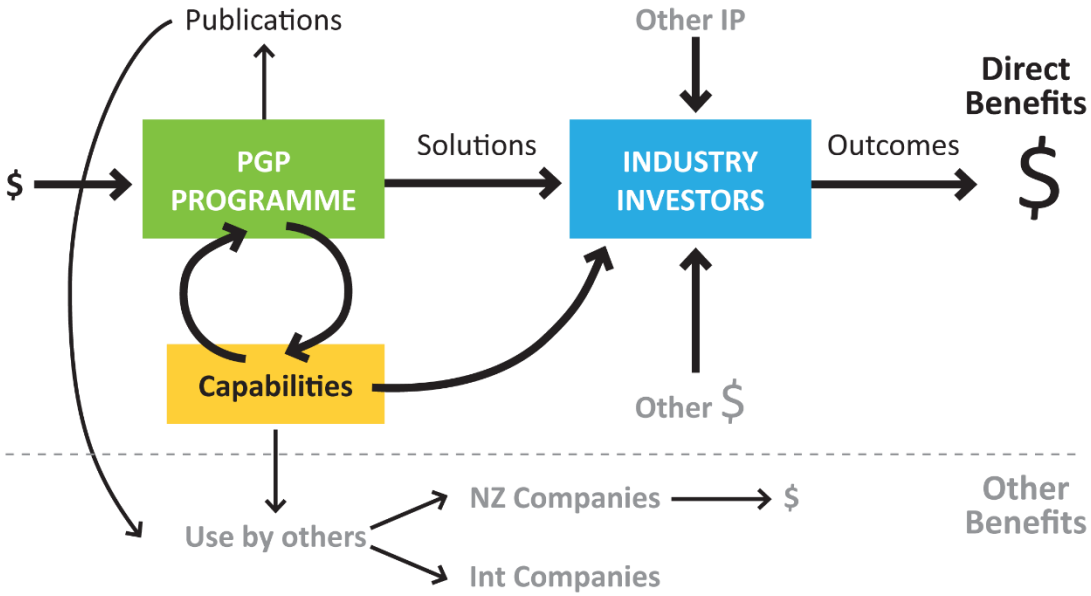

Figure 11: Benefits from the programme will arise from the downstream investment and activities of the industry investors


Ministry for Primary Industries
Manatu Ahu Matua


Fonterra
Dairy for life


DairyNZ


LIC


asl
A Primary ITO Business


NZ YOUNG FARMERS


Zespri


synlait