Reducing New Zealand's Livestock Methane Emissions

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Executive Summary

Climate change is a global issue with local influence. It will both impact New Zealand's agricultural systems and be impacted by them. New Zealand farmers face significant agricultural emissions reduction targets. Achieving these will be heavily influenced by how agricultural methane emissions can be reduced. The methane from farmed livestock in New Zealand accounts for 76 per cent of all of the biogenic methane New Zealand produces.

This report seeks to understand the potential options for New Zealand livestock farmers to decrease their methane emissions. It considers the unique circumstances faced in New Zealand and assesses some of the drivers and impacts which should be considered in their uptake.

To understand the potential options for New Zealand farmers and the impacts they may have, several questions needed to be answered:

- What are the drivers pushing New Zealand farmers to decrease methane emissions?
- Where New Zealand agriculture has got to on reducing methane, and how it got to this point?
- What are the reduction options for New Zealand farmers to consider?

The methodology comprises of a conducting a stocktake of emission reduction targets faced by farmers to understand how the timing and intensity of these targets have changed.   Datasets from peer reviewed, government, and industry, published sources were extracted to produce a time-series view of the livestock sector and enable interlinkages to be explored. Finally, a review of existing peer-reviewed and grey literature and a thematic analysis was conducted. This both identified possible options for New Zealand farmers and considered the implications for New Zealand farming systems of the options. Each themed option was explored to understand:

- What the option is.
- The methane emissions reduction impact.
- How applicable the option is for New Zealand farmers.
- The cost of implementing the option on a farm.
- When the option will be available for New Zealand farmers.

While government targets have historically been the main driver for agricultural emissions reduction, industry and businesses are now bringing in commitments. These will need to be met by farmers or they may face challenges selling their products.

New Zealand's agricultural sector is a dynamic mosaic. It is constantly changing to adjust to outside pressures and its methane emissions have grown and shrunk over time. It's mosaic nature also means different parts of the sector are further through realising methane reductions than others. Beef, sheep and dairy all face the same challenge, but are at different stages of responding to it. Not all options can be applied equally.

Farmers already have some tools to hand which can be used to reduce methane emissions. These need to be embraced early if methane is to be reduced in time. Some technologies are under development for the future, which may be easier to implement, have lower costs, or achieve greater reductions, but they are also still unproven. Significant research is still required for these to become useable options for New Zealand farmers.

It is recommended that:

- All groups work together to ensure methane reduction options are adopted on farm as early as possible.
- Farmers consider the full impact of methane reduction options on all emissions and the wider environment, how the different options may fit with their farm, and how they will operate in a changing operating environment.
- Government and industry work together to encourage and enable farmers to reduce their methane emissions as rapidly as feasible.

There is still significant progress to be made on reducing methane, but some change has already occurred. Each year, new ideas and technologies become a reality, so the options for farmers needs to be regularly reviewed. There is a low methane future for New Zealand's farmers.

Acknowledgements

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1. Introduction – the scene setting

Climate change is a global issue. Human activities are understood to have had a significant impact on global average temperatures. The drivers for this are many, covering all sectors of human lives, including energy, industry, transport, buildings, waste management, and agriculture. It is estimated the global surface temperature for 2011-2020 was 1.09 degrees Celsius higher than for 1850-1950 (Intergovernmental Panel on Climate Change, 2023). Further heating will compound the consequences already being seen on water availability and food production, health and wellbeing, settlements and infrastructure, and biodiversity and ecosystems.

New Zealand is directly experiencing the impacts of climate change. While weather event-based incidents, like Cyclone Gabrielle, raise the profile of how climate impacts people, property and livelihoods, there are a range of chronic and far-reaching impacts. Glavinovic et al (2023) predict climate change will impact rural communities earlier and more severely. It will exacerbate existing poor access to health care and other goods and services, as well as pre-existing urban–rural socioeconomic inequalities.

New Zealand has the highest proportion of national emissions contributed by agriculture, more than any other developed country. This is influenced by food and fibre products making up more than 80 per cent of New Zealand's exports. The high level of decarbonisation of the energy sector is unusual globally and causes agriculture to become a larger proportion. Figure 1 shows that while agriculture is about 50 per cent of New Zealand's greenhouse gas emissions, in absolute terms, it is comparable or smaller than many of the major trading partners.

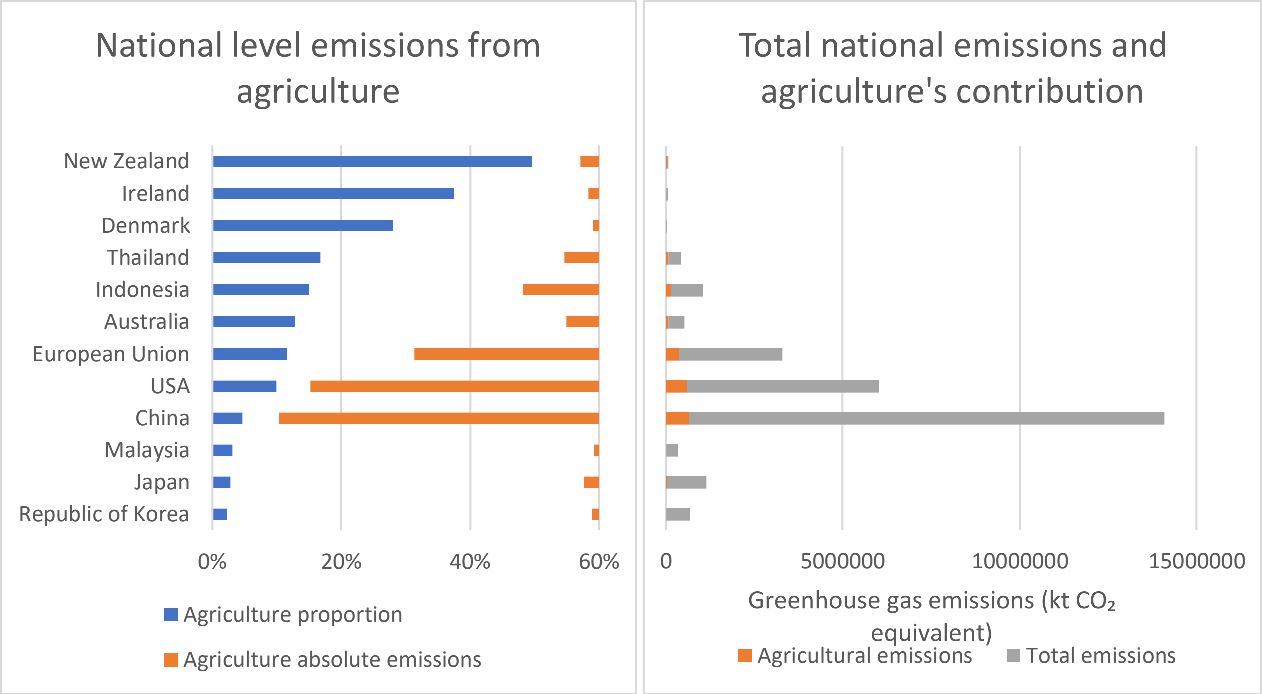


Figure 1. *Two graphs representing of the proportion of agricultural emissions to national emissions, a comparison of absolute agricultural emissions, and how agricultural emissions relate to the total absolute national emissions* (calculated from UNFCCC, 2023 and FAO, 2023)

Commitments to reduce global warming by mitigating greenhouse gases are being made by all countries and increasingly global businesses. New Zealand has made commitments to decrease emissions, including ones which heavily rely on contributions from the agricultural sector. Methane emissions from livestock are the dominant component of New Zealand's agricultural emissions. Realising these reduction commitments will rely on farmers reducing these emissions.

Ruminant livestock (e.g. sheep, cattle and goats) digest feed through a multichambered digestion system. Plant material is broken down during a process called enteric fermentation. It takes place in the rumen and enables these animals to extract nutrition from plant matter other animals may be unable to digest. Micro-organisms in the rumen break-down and ferment feed, extracting more of the nutrients. One by-product of this process is the production of methane. The more food they eat, the more methane they produce. A training resource produced by the Food and Agriculture Organization of the United Nations (FAO) and the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) estimated approximately 30 per cent of global methane emissions come from ruminants (FAO & NZAGRC, 2016).

This report looks at how New Zealand agriculture is changing to meet the climate change challenge and provides a lens across the options for livestock farmers in New Zealand, highlighting some of the impacts these choices could have.

What are agricultural greenhouse gases?

"Greenhouse gases" means those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation (United Nations, 1992). Reduction in greenhouse gases and national commitments generally focus on the anthropogenic emissions. This is the emissions caused by human activity, as separated from those caused by natural processes (such as volcanic eruptions, unmanaged forests and animals, the oceans, etc).

In New Zealand agriculture, the dominant gases are methane, nitrous oxide and carbon dioxide. Each of these gases have different potential for warming the climate. The potential for warming from carbon dioxide is the standard which other gases are measured against. This is referred to as the carbon dioxide equivalent (CO_2e). There is debate over how this equivalent should be calculated and how strong the warming potential of other gases are. This is influenced by the timeframe you calculate against. Carbon dioxide remains in the atmosphere for centuries, nitrous oxide breaks down over about 100 years, while methane largely breaks down within 12 years.

While they are in the atmosphere, nitrous oxide and methane have the potential to warm the climate by more than carbon dioxide. Nitrous oxide is about 300 times more effective at warming the atmosphere than carbon dioxide. The short lifespan of methane by comparison to carbon dioxide has caused debate over the exact amount of greater warming methane contributes. Over a 100-year period, it is estimated to be approximately 25-30 times stronger than carbon dioxide, even though it breaks down in just the first 12 years.

Methane's stronger ability to warm the atmosphere is the reason livestock farming is not inherently climate neutral. Plants take carbon dioxide out of the air to grow. These are eaten by animals and turned into either animal products, waste, or gases (like methane). While the methane exists, it warms the air more than if it had remained as carbon dioxide. Eventually, the methane breaks down to form carbon dioxide again and the cycle continues.

2. Purpose

This report seeks to understand the potential options for New Zealand livestock farmers to decrease their methane emissions. It considers the unique circumstances faced in New Zealand and assesses some of the drivers and impacts which should be considered in their uptake.

This report addresses:

- The drivers pushing New Zealand farmers to decrease methane emissions;
- Where New Zealand agriculture has got to on reducing methane, and how it got to this point; and
- Possible reduction options for New Zealand farmers to consider.

3. Literature review – what has been done before

The greenhouse gas challenge for New Zealand's agricultural sector is well documented. Numerous peer-reviewed publications, government and industry reports, grey literature, and media pieces refer to agriculture's high proportion of emissions in New Zealand. The challenge is clear.

3.1 The operating environment

The national and global operating environments for farmers are evolving. There are national level targets and international commitments made by New Zealand. Businesses are increasingly adding requirements to their supply chains. These are on top of the existing international trade pressures and competition for markets.

Reports generally focus on one of these drivers at a time. The most common being how can the national and international commitments be met. Costa Jr et at (2022), Woodbury (2018), Breton Richards et al (2018) and Amjath-Babu et al (2019) focus on how national level changes in agricultural greenhouse gases could help prevent global warming. These all rely on national level targets and exclude the role multinational business commitments could play in driving the changes sought. There is little published information quantifying the impact of these drivers.

Bozzola et al (2023) outlined how climate change could have significant impacts to agri-food trade. However, while they took a long-term holistic view on the impact climate change adaptation would have on production trade, there are shorter term impacts. Due to the recent rapid evolution of drivers in the trade system, there has not been an examination of how the inclusion of mitigation options into New Zealand farming systems may influence trade flows.

Data breaking down contributions to greenhouse gas emissions is regularly published (Ministry for the Environment, 2023b). It is disaggregated by farming type when considered at one year snapshot levels (Ministry for the Environment, 2023a). However, it is not common to see the data broken into farm types when tracking agricultural emissions over time. Over time, the sector is generally considered as a whole. This misses some of the nuance that can be observed as different farming pressures cause varying impacts across the sector. Industry bodies produce research specific to their component of the agricultural sector. A report by Case and Ryan (2020) was commissioned by Beef + Lamb New Zealand and showed New Zealand sheep and beef farms were close to being carbon neutral. However, these are often viewed critically by the wider public. Beyond the mention of the role of livestock, there is often little quantification of the differentiation between farm types. The challenge is faced equally by the sector as a whole.

3.2 The options

Many analyses have been carried out on potential mitigation options. They range in scope and often provide generic potential options without considering the circumstances of those who may use them. Arndt et al (2021), Arndt et al (2022), and Costa Jr et al (2022) have conducted analyses globally of how agriculture can reduce greenhouse gas emissions. These outline several categories of potential options which could be utilised.

New Zealand farming systems share similarities with many international systems. However, between geography, farm system and regulatory drivers, the systems in New Zealand are unique. This means solutions which could operate effectively for other countries may not be applicable in the same manner in New Zealand. There has been instances of putting options into the New Zealand context. The national level reports by the Biological Emissions Reference Group (2018), Reisinger et al (2018), and the Biological

Emissions Reduction Science and Mātauranga Plan Leadership Group (2023) provide a New Zealand context view across potential options. These looked at the impact at the national scale. Some solutions that were considered to have a low potential national impact, may be relevant for individual farmers.

The development of greenhouse gas mitigation technologies for livestock farming is a rapidly evolving space, with many options being explored. Reported potentials change over time as new research is conducted, generating higher degrees of certainty on impact. Much of the research conducted to date focusing on the potential emissions reductions are calculated off lab-based trials. Some options have made it to field trials. Very few are at the commercial scale with proven impact. Meta-analyses like those conducted by Hegarty et al (2021) provide a way to better understand what the most likely impact will be.

The New Zealand research sector is actively pursuing viable options for New Zealand. This is rapidly changing how potential reduction technologies for New Zealand farmers are understood. Fact sheets providing updates by the NZAGRC and the Pastoral Greenhouse Gas Research Consortium (PGgRc) are good sources of information on individual technologies. However, there is limited documentation pulling the options together into one place and enabling comparisons.

Although agricultural mitigation options is a space undergoing significant levels of study, there are no recent reports looking specifically for options for New Zealand farmers to decrease methane from various agricultural livestock systems.

4. Methodology – how this was done

To understand the potential options for New Zealand farmers, and the impacts they may have, several questions needed to be answered. A mixed method of qualitative and quantitative analysis was used, drawing from publicly available data from government, industry, and independent peer reviewed sources.

To understand the operating environment New Zealand farmers are in, an examination of the greenhouse gas reduction drivers took place. A stocktake of emission reduction targets faced by farmers was conducted to understand how the timing and intensity of these targets have changed. This looked at the governmental drivers of change in agricultural climate change, including international and nationally legislated commitments, drawing out the key impacts for New Zealand farmers. The stocktake also explored climate commitments by companies and financial institutions. When reference was also made toward actions put in place to support the achievement of these targets, these were collated.

To understand how emissions on New Zealand farms are changing, relevant datasets were extracted from peer reviewed, government, and industry, published sources. These include supplementary tables submitted as part of New Zealand's greenhouse gas inventory, agricultural production data published by industry bodies, and from Statistics New Zealand databases. To examine the dependencies between key criteria, datasets covering the years 1990 to 2021 were combined and graphically assessed to identify individual effects of different parameters. Parameters included quantity of emissions (of varying types), livestock type, output produced, and intensity of emissions. The absolute values for these were examined. To better compare between different systems or product type, datasets were converted to percentage variation across the timeframe to observe relative changes. Time series data was baselined against 2017 and 2005 to align with national policy timeframes. The yearly variations were analysed to identify trends in changes related to emissions and production.

To understand the possible options for farmers to meet the obligations they are under, a review of existing literature and a thematic analysis was conducted. This both identified possible options for New Zealand farmers and considered the implications for New Zealand farming systems of the options. Sources of data included global meta-analyses, industry publications, government reports, company product claims, peer-reviewed publications and research presentations. These identified a wide range of potential options at different scales. Where possible, New Zealand specific information on each option was extracted. The options were themed up into categories representing potential classes of option. These option classes were examined to inform:

- What the option is;
- The methane emissions reduction impact;
- How applicable the option is for New Zealand farmers;
- The cost of implementing the option on a farm; and
- When the option will be available for New Zealand farmers.

5. Analysis – what was discovered

5.1 There are many targets set to drive emissions reduction

The exploration of greenhouse gas reduction drivers identified three main sources driving change. These have come to prominence in different stages. Governmental targets at the national and international level were first, recently industry targets have come to the fore, and trade flow drivers are currently expected to become more prominent as the deadlines for action get closer.

5.1.1 New Zealand has made commitments to reduce emissions

What are they?

In 2015, 196 parties adopted a legally binding international agreement, commonly referred to as the Paris Agreement. The Paris Agreement acknowledged "that climate change is a common concern of humankind" and signatory parties agreed to take actions to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels (United Nations Framework Convention on Climate Change, 2016). It also outlined the processes for countries to present how they intended to achieve this target and the reporting required to demonstrate action.

New Zealand is required to make international commitments, called Nationally Determined Commitments (NDC), to demonstrate how temperature increases will be limited. In 2021, New Zealand updated their target to be a 50 percent reduction of net emissions below the gross 2005 level, by 2030 (Ministry for the Environment, 2022). The original commitment, in 2016, had been a 30 percent reduction. This is an economy wide target and corresponds to a 41 percent reduction in greenhouse gas emissions. The updated NDC submission notes:

> *"Given our existing high proportion of renewable electricity generation (80 to 85 percent), this means New Zealand has a challenging task ahead. We are mindful, however, that a successful transition to a low-emissions, climate-resilient future will require us to overcome these challenges and to capitalise on opportunities."* (New Zealand Government, 2021)

To meet the challenge of the NDC, New Zealand has established legislated targets for emissions reduction. The Climate Change Response (Zero Carbon) Amendment Act (2019), set targets for achieving by 2030 and 2050:

- 2030 target of a 10 percent reduction of biogenic methane (from 2017 levels); and
- 2050 target of a 24 to 47 percent reduction of biogenic methane (from 2017 levels) and a net zero accounting for all other gases.

These targets are different to the NDC. Both a split gas approach and a different 'base' year used in the domestic legislation. These enable the profile of New Zealand's greenhouse gas emissions to be considered when designing actions to achieve the targets. It also removes the need to use an agreed metric to convert methane effects into equivalents of carbon dioxide.

New Zealand has a legislated emissions trading scheme. This currently excludes emissions from agriculture. The Climate Change Response (Emissions Trading Reform) Amendment Act (2020) outlines the requirement for a pricing scheme for agricultural emission to be established. Under this legislation, all New Zealand farms needed to know what their greenhouse gas emissions were by the end of 2022.

Understanding a farm's greenhouse gas emissions is crucial to understanding how they can be reduced. The pricing scheme will also take a split gas approach with a different price for methane compared to other gases.

What support is there to address this?

The He Waka Eke Noa partnership brought together groups from across the agricultural sector, with government and Māori representatives. A series of calculators were developed for farmers to use to calculate their emissions. These ranged in complexity and sophistication depending on the amount of data available. Another calculator is currently under development by central government for farmers to be able to report their emissions into a future agricultural pricing scheme.

Government and industry have invested significantly in the development of mitigation options for New Zealand farmers. For more than 20 years, New Zealand has been researching options to decrease agricultural greenhouse gases (PGgRc, 2017). New Zealand is recognised as a world leader in livestock mitigation research and has been at the cutting edge of new developments.

Industry bodies and research institutes have developed large numbers of guidance documents and run in person training sessions for farmers (DairyNZ Limited, 2023a; Beef + Lamb NZ, 2023). To support their sectors, industry bodies have both developed training material for farmers, while providing research and advocating for a decrease to the impact of commitments to farmers (Beef + Lamb, 2020a).

Government has been increasing investment into extension services and rural professional development. Building on and with existing support mechanisms for rural New Zealand, the Ministry for Primary Industries has added to programmes supporting farmers. These include support for catchment groups in 2020, integrated advisory services for Māori agribusinesses in 2022 and on-farm support advisers in 2022. These provide further channels for farmers to seek information and guidance on understanding both the requirements they face and the research results.

5.1.2 Industry players are now making their own targets

What are they?

Many of the world's largest agri-food companies and New Zealand processors are making climate pledges. These directly impact purchasing patterns and global food product process. Table 1, shows some of these pledges. The commitments relate not only to the emissions generated within their operational footprint ("scope 1 and 2 emissions"), but also to those emissions which occur elsewhere in their supply chain ("scope 3"). The emissions on New Zealand farms are part of these scope 3 commitments.

Table 1. *Corporate emissions reduction pledges*

Who	Commitment	Scope
Fonterra (2023)	Scope 1 and 2 - 50% reduction by 2030 and net zero by 2050. Farming emissions – 30% reduction per kilogram of milk solids by 2028	Scope 1 and 2 targets are reductions in absolute emissions against 2003 levels. The farming target is an intensity target and against 2018 levels.
Synlait (2023)	Scope 1 and 2 – 45% reduction by 2028. Scope 3 – 30% reduction per kilogram of milk solids by 2028	Scope 1 and 2 targets are reductions in absolute emissions against 2018 levels. The scope 3 target is an intensity target and against 2018 levels.
Rabobank (2022)	12% reduction per kilogram of milk solids by 2030	This is a New Zealand dairy specific target covering all greenhouse gases.
Nestle (2023)	20% reduction by 2025 and 50% by 2050, net zero by 2050	Absolute reduction in emissions based on 2018 emissions,

		including emissions from their supply chain.
JBS Foods (2023)	Become net zero by 2040	Across global operations and full supply chain
Cargill (Ragaller, 2022)	Scope 1 and 2 – 10% reduction by 2025. Scope 3 – 30% reduction per ton of product by 2030	Scope 1 and 2 targets are reductions in absolute emissions against 2017 levels. The scope 3 target is an intensity target.
Danone (2023)	Scope 1 and 2 – 47.2% reduction by 2030. Scope 3 – 42% reduction by 2030, including a fresh milk specific commitment of 30% reduction	Absolute reductions in emissions based on 2020 emissions, with additional specific agricultural production and deforestation targets.

What support is there to address this?

There are a range of activities being supported by these companies to support change within their supply chains, including:

- Six of New Zealand's largest agribusinesses have partnered with the government to scale up the efforts around creating tools to rapidly reduce on-farm emissions (AgriZero^{NZ}, 2023).
- JBS Foods (2023) is investing in both research and the infrastructure to enable greater levels of research at the farm level.
- Danone (2023) are investing in research and a knowledge centre for sharing information on regenerative agriculture.
- Fonterra (2023) are investing both with others in research, but also doing additional research to develop methane inhibitors for their farmers.
- Nestle (2023) are investing in research and innovation, while also supporting farmers to improve practices and piloting "net zero" farms. These farms will demonstrate the research in practice for farmers.

5.1.3 Trade pressures will influence farmer action

What are they?

New Zealand's food and fibre exports returned revenue of $57.2 billion in the year to March 2023 (Ministry for Primary Industries, 2023a). This was nearly 82 per cent of New Zealand's export trade. Dairy was $25.4 billion of this, while meat and wool were another $12.4 billion. The international trade of agricultural products is a significant driver of New Zealand's economy.

Other countries compete to sell their products into the same markets. Each country seeks to extract a competitive edge, enabling better returns for their farmers. All countries are faced with the same challenges around climate change and a need to reduce emissions, although reduction targets vary.

International trade also relies on consistency and safety. With the use of new production or mitigation technologies, there is a need to ensure destination markets are comfortable with changes. Organisations, such as the World Trade Organisation and Codex Alimentarius help to provide consistency across the rules and clarity around what standards need to be met for a product. Changes to agricultural practice to meet climate challenges raises new approaches. These need to be acceptable in international markets.

What support is there to address this?

There are teams within several government Ministries, industry groups and companies, all working on ensuring the access and competitiveness of New Zealand agricultural products. The activities include selling New Zealand's story, helping other countries shape their approach to agricultural emissions, building understanding of each other's circumstances, sharing learnings, collaborating to generate benefits for both sides, and helping to ensure the trading system enables both trade and a healthy environment. Recently, there has been work happening with partner countries at Codex Alimentarius to enable the setting of standards for residues from environmental inhibitors. The Codex Committee on Pesticide Residues has accepted environmental inhibitors as within their scope and will now consider requests for maximum residue limits (Ministry for Primary Industries, 2022). This is a significant achievement both from a trade and food safety perspective.

5.2 The New Zealand agricultural sector is dynamic

The New Zealand agricultural sector is continually changing. Weather, climate, prices, policy and availability of supply are all applying force to the sector. In the last 30 years, the face of the sector has changed, along with it's emissions.

5.2.1 The current situation for agriculture

Across all sectors, New Zealand still has significant progress to make in achieving the legislated targets.

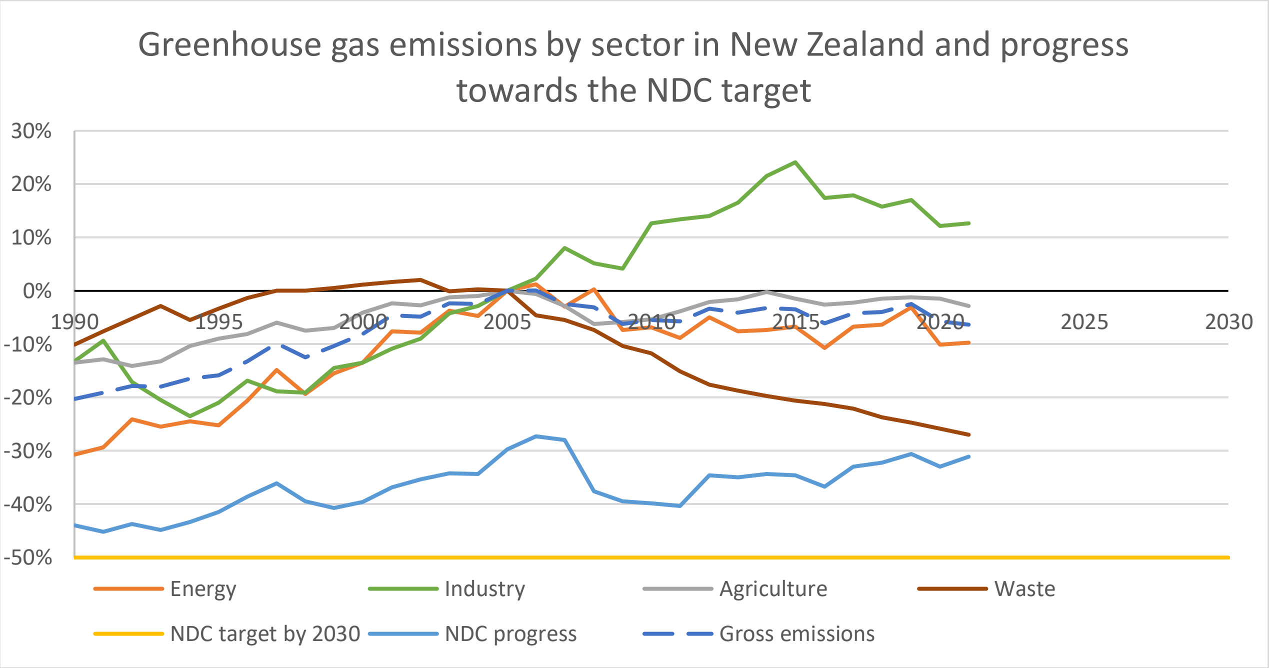


Figure 2. *Time series graph demonstrating progress per sector towards New Zealand's 2030 NDC target* (calculated from Ministry for the Environment, 2023b)

Figure 2 demonstrates the progress on reducing emissions New Zealand is yet to make, across all sectors. Since 2010, progress has been trending away from the NDC target. Emissions from waste have made substantial progress towards contributing to meeting the NDC. Industrial process and product use emissions rose substantially until 2015, but have trended down since then. Agricultural emissions in 2021 are slightly lower, by 2.8 per cent, than 2005 levels. There has been little change in these emissions since 2015.

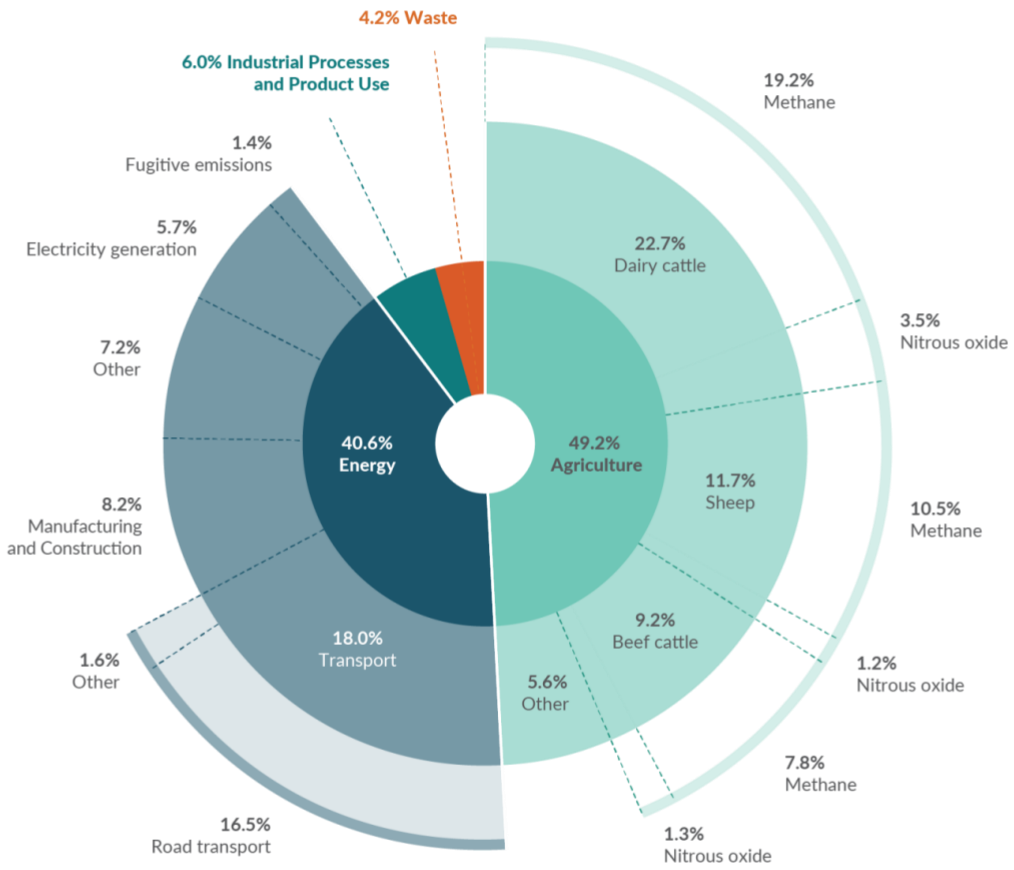


Figure 3. *Gross greenhouse gas emissions in 2021 by sector, sub-category and gas type* (Ministry for the Environment, 2023a)

Figure 3 shows how New Zealand's emissions profile is dominated by agriculture and energy. These are the two sectors who will need to make the majority of reductions for New Zealand to achieve reduction targets. With a large proportion of the electricity generation already produced from renewables and the agriculture sector a strong contributor to food systems, this is not a simple challenge.

There were just under 37 million ruminants farmed in New Zealand in 2021 (Ministry for the Environment, 2023b). The dominant farming systems are dairy, sheep and beef. These account for 97 per cent of the farmed ruminants. Livestock Improvement Corporation Limited and DairyNZ Limited (2022) estimate there are just under 11,000 dairy herds in New Zealand, milking on average 450 cows each. Beef + Lamb New Zealand (2023b) estimates there are approximately 9,165 commercial sheep and beef farms in NZ.

From a financial perspective, the Ministry for Primary Industries (2023a) predicted the average farm profit before tax for the 2022/23 season for all classes of sheep and beef farms is expected to fall 31 percent from a record high achieved in 2021/22 to $146,300 per farm. The inflation adjusted profit remains below the four-year average.

Brunsdon (2023) shows that since 2005, the break-even milk price for dairy farmers has more than doubled. It has risen from $3.72 per kilogram of milk solids in the 2005/06 season to $8.16 for the 2022/23 season. While on average the pay-out farmers received for their milk has remained above this line, the value received has fluctuated from $9.30 in 2021/22 to $3.85 in 2005/06. Some years the pay-out has been below the breakeven mark. Between 2005 and 2023, the average difference between the pay-out and breakeven values has been $0.64 per kilogram of milk solids. At 2021/22 season production levels, this works out to be approximately $110,000 pre-tax profit per farm (calculated from Livestock Improvement Corporation Limited & DairyNZ Limited 2022).

5.2.2 Agricultural methane emissions have decreased

Looking at just the current state of emissions does not provide an accurate view of how the evolution of New Zealand's agricultural sector. The sector is continuing to change, and with it it's emissions. Livestock methane is heavily impacted by the stock numbers, types of stock and levels of production achieved.

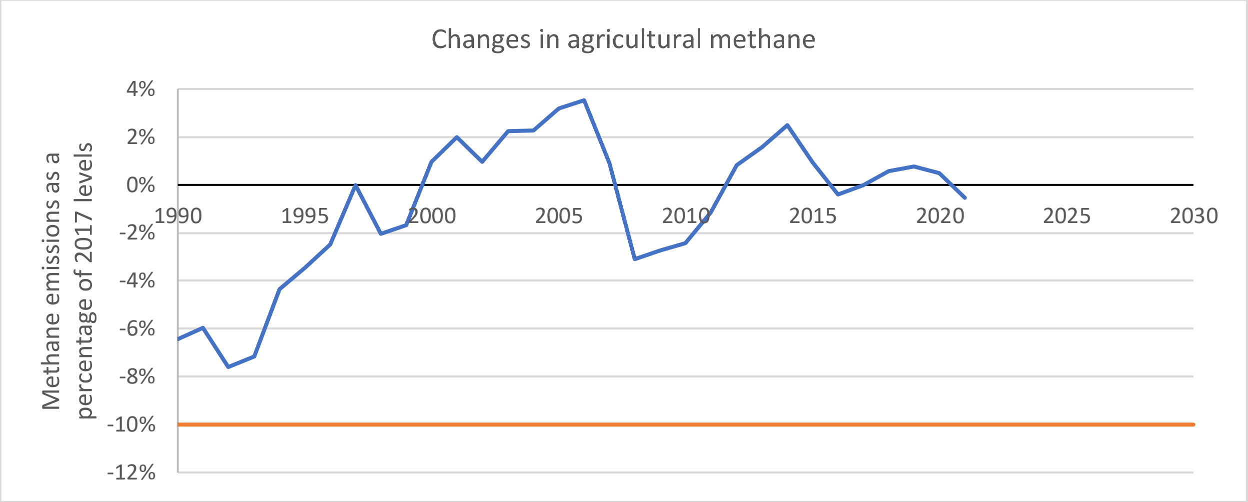


Figure 4. *Time series graph of agricultural methane emissions from 1990-2021, baselined on 2017 emissions, and the 2023 methane reduction target* (calculated from Ministry for the Environment, 2023b)

For agriculture to play its part in meeting the challenge of preventing global temperature rise, the sector needs to reduce its methane emissions. Figure 4 illustrates New Zealand's limited reduction in agricultural methane emissions since 2017. With the 2030 reduction target, and further reductions needed by 2050, there is still significant change needed. While agricultural methane emissions are no longer rising, they need to fall more rapidly if the 2030 target is to be achieved.

5.2.3 Changes vary within the sector

Figure 5 shows that since 1990, the populations of livestock in New Zealand have changed dramatically. National sheep flock numbers have progressively decreased by over 55%, from nearly 58 million in 1990 to just under 26 million animals in 2021. The national dairy herd rose to a peak around 2015 and have decreased to current levels, and after dipping to a low near 2015, beef cattle numbers started to rise again.

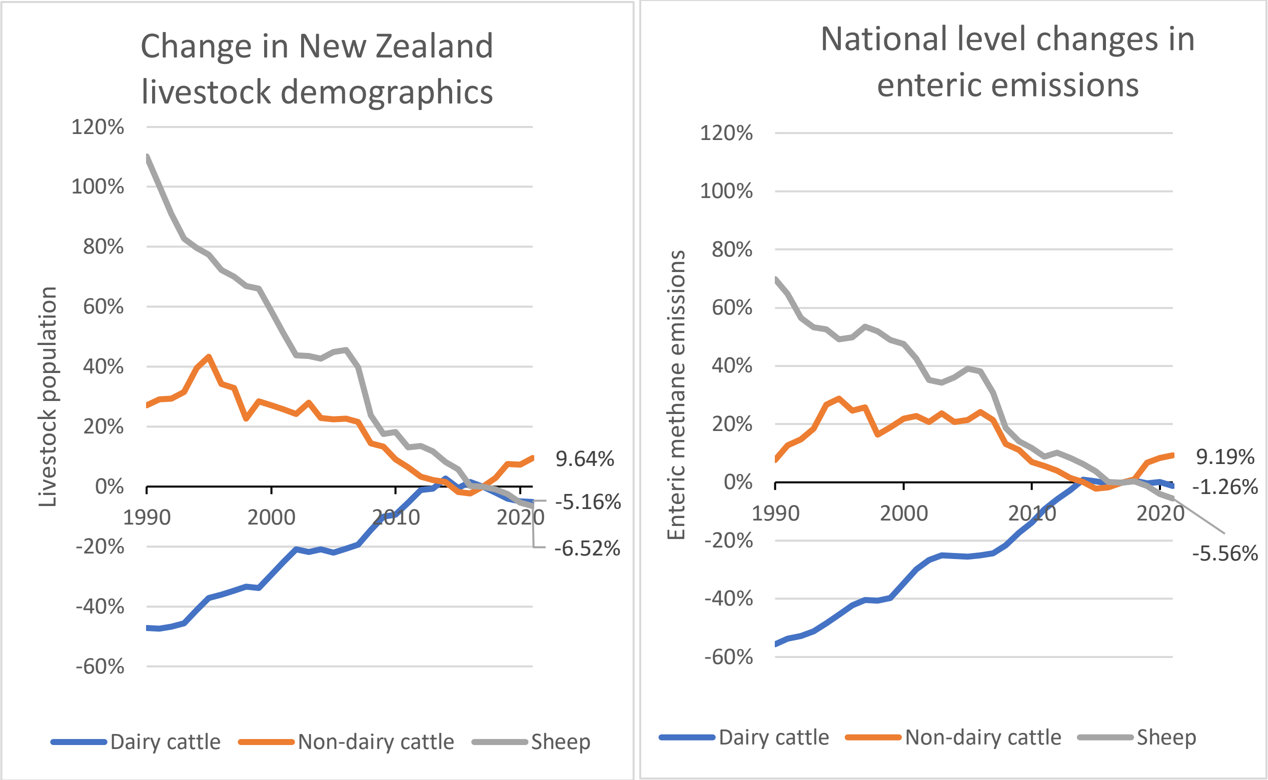


Figure 5. *Time series graphs displaying the changes in both national livestock population and enteric fermentation for dairy, beef cattle and sheep, as a percentage baselined against 2017 values* (calculated from Ministry for the Environment, 2023b).

Methane emissions from enteric fermentation followed a similar pattern to livestock numbers. Sheep enteric methane emissions have progressively decreased since 1990, dairy emissions peaked around 2015, and beef cattle emissions hit their lowest point in 2015.

The size of the sheep flock, and the emissions from it, both follow the same pattern of decrease. However, the decrease in enteric methane emissions has seen a lower rate of change than is accounted for just by population change. For beef cattle, shape and rate of change of methane emissions is similar to that of population change.

Dairy enteric emissions follow a different pattern. Enteric methane emissions grew at a faster rate than population. In addition, while population peaked and then decreased since 2015, emissions peaked and plateaued.

Against the 2030 methane reduction targets in the Zero Carbon Act, sheep farming has reduced its contribution of emissions by 5.5 per cent, from 2017 levels. This leaves another 4.5 per cent reduction to be found before 2030. Emissions from beef have risen by nine per cent rather than falling to the 10 per cent reduction target. Dairy emissions have fallen slightly, but still have the majority of the required 10 per cent reduction still to realise.

5.2.4 New Zealand is producing more per animal

With changing populations, production of milk, beef and sheep meat have all undergone significant change. However, the changes in production are not completely consistent with changes to livestock population, indicating changes to per animal production.

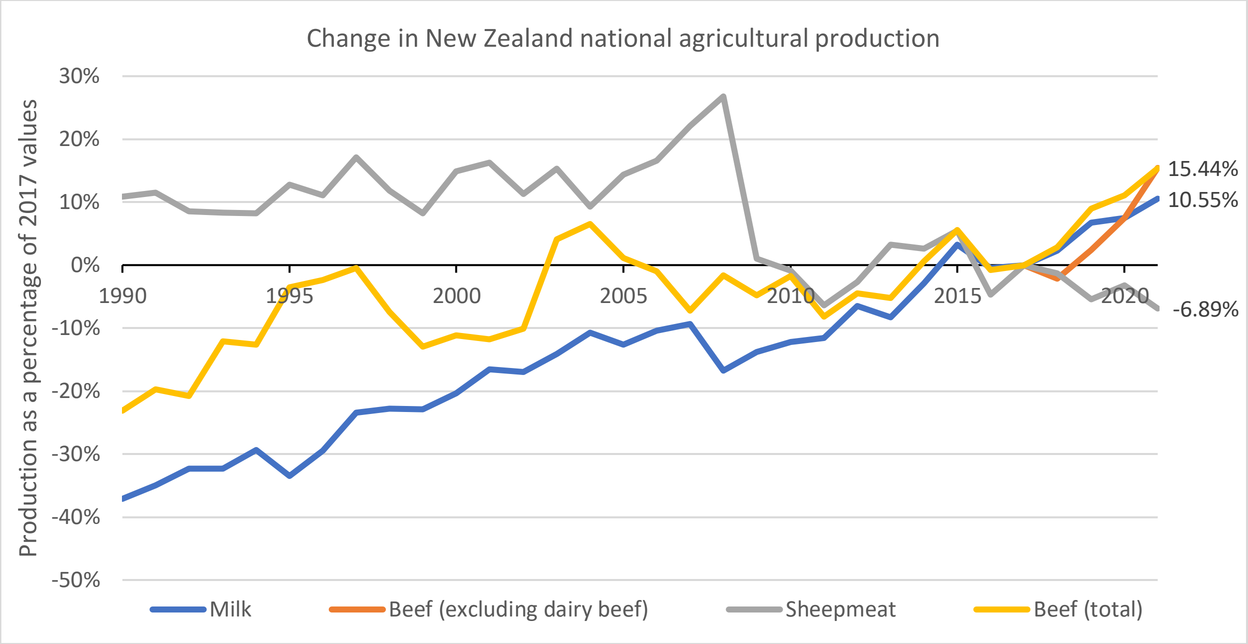


Figure 6. *Time series graph of percentage changes in New Zealand agricultural production, segregated by sector and baselined against 2017 levels* (calculated from Livestock Improvement Corporation Limited & DairyNZ Limited, 2022; Statistics New Zealand, 2023)

Overall, sheep meat production has decreased since 1990. Against a backdrop of decreasing population, kilograms sheep meat produced per year actually increased slightly until 2007/2008. Between 2007 and 2010, significant change occurred to sheep meat production levels. Large drivers of this were significant droughts and the 2008 economic crisis. These resulted in a substantial destocking of sheep and a spike in meat production (as seen in Figure 6). Since 2010, sheep meat production has remained lower, but while animal numbers have continued to decrease, production has not decreased in the same manner.

Dairy production has grown significantly. Nationally, the number of litres of milk processed has more than tripled, from about 6.8 billion litres in the 1989/90 season to nearly 21.7 billion litres in the 2020/21 season (Livestock Improvement Corporation Limited & DairyNZ Limited, 2022) . Since the peak in dairy cattle numbers, milk produced has continued to increase, while animal numbers decreased.

Beef production has shown some volatility, but overall production has increased. The non-dairy cattle population peak around 1995 is likely to have influenced the peak in beef production in 1995 and 1996. Over a 20-year period of non-dairy cattle population decreases, kilograms of beef produced increased by about 14 per cent between 1994 and 2017. With populations increasing again, production increased by a further 14 per cent in the seven years between 2014 and 2021.

5.3 There are promising options for New Zealand farmers

Technologies and practices both exist and are under development for farmers to reduce methane emissions. From existing literature, a wide variety of options has been identified. They have been themed into the following categories.

5.3.1 Progress through genetic gain

What is the option?

Farmer's use of genetic improvement is a key component of their existing toolbox. It is used for increasing production, improving pest and disease resistance, and improving fertility. Breeding stock is carefully selected to ensure desired traits are past into future generations. By choosing stock with desirable and heritable traits, these are then bred into future generations. It has been discovered that lower emission of greenhouse gases can be bred for.

How much impact could it have on emissions?

AgResearch have been selectively breeding high or low emitting sheep. Two flocks have been established. After three generations there was an average 11 per cent difference in their methane emissions, with a more than 20 per cent difference in emissions value between the highest and lowest emitting rams (Rowe, 2020). It is predicted a 1 per cent reduction in emissions per year is achievable (NZAGRC, 2023).

LIC and CRV-Ambreed are currently researching this effect in dairy cattle. Evidence to date indicates a heritability of 0.1. By 2050, the aim is to have a 10 to 20 per cent reduction in methane emissions through breeding (McNaughton, 2023). This may be impacted by the weighting of this trait against other production linked traits during breeding selection.

How widely can this be used in New Zealand?

There is potential for this solution to be used by any farmer in New Zealand. In sheep production, there is already a programme underway to identify low emission rams. Beef and Lamb New Zealand's "Cool Sheep Programme" is measuring 5000 stud rams per year (Beef + Lamb New Zealand Genetics, 2023). These rams are then able to be classed as higher or lower emitting, with farmers able to use this information when selecting breeding options.

LIC and CRV-Ambreed are measuring around 350 of the elite bulls per year. Working with Pāmu, they inseminated a herd of cows and expected 400 daughters to be born in the spring of 2023, with a 50:50 split between high and low emissions. These will be tested to see what the impact is on production and the level of methane impact.

For dairy cattle, more than 80 per cent of the dairy herd are artificially bred (Livestock Improvement Corporation Limited & DairyNZ Limited, 2022). For the number of cows bred each year, very few bulls are used. If the breeding worth of these bulls includes attribution for greenhouse gas emissions, there can be a very wide reach across the national herd very quickly. The national dairy herd has a longer average lifespan than the beef herd or sheep flock. While breadth of reach is high, it may take longer per farm for animals to have been replaced with low emission descendants.

Since the change in regulations around dairy bobby calves since 2016, more dairy calves are becoming part of the national beef herd. Any genetic gains around emissions made in the dairy herd will also transfer through to the beef herd.

What is the cost to implement the technology on a farm?

This solution requires limited new systems for most farmers. There will be a cost for stud farmers to test their stock. For ram breeders this is currently subsidised.

A breeding value balances and puts a value on desirable traits. In some cases, desirable traits come at the expense of others. Existing research programmes are looking at if there may be a cost in terms of forgoing aspects of potential future production gains, to realise emissions gains.

As a farmer, when can I use this?

The underlying principles of genetic gain are well understood and have no barriers for use. For sheep farmers, this is one of the few "new" technologies able to be used now. Some ram breeders are measuring and ranking their stock in terms of high or low emissions. Work is underway to scale up the use of this technology, and to develop more methods to estimate high or low emission animals in the national flock.

For New Zealand dairy cattle, the intent is to develop breeding values related to methane emission by 2025. How rapidly this is expected to be taken up will depend on how traits interact and are weighted in the breeding values.

5.3.2 A methane vaccine

What is the option?

Methane from enteric fermentation is the largest challenge for reducing agricultural emissions in New Zealand. The microorganisms in the rumen produce methane as they break down feed. The concept behind the idea of a vaccine is based on causing an animal's body to produce an ongoing reaction to these microorganisms. If the digestion process in the animal can be modified to produce less methane, less greenhouse gases will be produced.

By 2015, the research had progressed to a level that a vaccine programme was established in New Zealand with the intent of commercialising a potential vaccine (PGgRc, 2017). This programme has been designing and testing the components needed to develop a prototype. There are other programmes underway around the world using a range of possible options.

How much impact could it have on emissions?

There is not currently a working methane vaccine in commercial production. The expectation is that a vaccine could reduce an animal's methane emissions by about 20 per cent. Current lab trials have achieved reductions of up to 26 per cent (Baca-González et al, 2020). However, in animals there has been less than a 13 per cent response and the response has been inconsistent under repeated testing.

Research is continuing on a number of components of a vaccine to refine what is achievable. This will enable a vaccine to achieve minimum thresholds around uptake by the animal, methane reduction potential, and longevity of effect.

How widely can this be used in New Zealand?

The vaccine would work in sheep and cattle. With the intended reapplication rate being low, it would work in extensive systems where animals are only handled infrequently. It could be combined with existing drenching or other animal health plans.

The applicability of a vaccine to a range of production systems, in a wide range of environments, is one of the big attractions. Should a vaccine be successfully developed, it could be used in all ruminant livestock around the world. The intention is that the vaccine would have a lasting impact and reapplication (if needed) would not need to be frequent.

What is the cost to implement the technology on a farm?

Until a working vaccine is developed, costs remain unknown. Other widely used animal vaccines are generally low cost per dose.

As a farmer, when can I use this?

Timeframes are unclear for when a commercially produced vaccine will be available. The Biological Reduction Science and Mātauranga Plan (2023) estimated a timeframe of 3-5 years before a proof of concept would be developed. From there, the product needs to undergo a range of trials and certification processes before it can be commercially produced and distributed. It is unlikely a vaccine will be available for New Zealand farmers before 2030.

5.3.3 Changing the diet of animals

What is the option?

One of the basic factors impacting enteric fermentation levels is the diet. In New Zealand, the amount of dry matter eaten has a substantial role in the level of enteric fermentation produced. The New Zealand greenhouse gas inventory uses a methane yield value (Ym value) to calculate enteric methane emissions. The Ym value predicts the grams of methane produced for each kilogram of dry matter consumed. Research has shown that the Ym value varies depending on the feed used (NZAGRC, 2019).

While the predominant diet of New Zealand livestock is pasture, other feeds are used. Supplementary feeds are used to "smooth" the pasture growth curve. These include maize silage, fodder beet, palm kernel expeller and brassicas. These all produce methane at different rates.

How much impact could it have on emissions?

Experiments in New Zealand have shown a range of Ym values ranging from 11.4 grams of methane per kilogram of dry matter from radishes, to 25.9 for a combination of pasture and maize silage. This significant difference raises opportunities for farmers to vary the diet of their stock to decrease emissions.

The level of inclusion of different feeds can impact how they affect emissions. Della Rosa et al (2022) showed that while substituting ryegrass for forage rape reduced emissions, the relationship was not linear. Feeding forage rape as 100 per cent of the diet, methane emissions were reduced by approximately 45 per cent (per kilogram of digested dry matter). At a 75 per cent inclusion rate the reduction was about 25 per cent. At both 50 and 25 per cent inclusion, approximately 15 per cent reductions in methane were observed. Therefore, just including other feeds as a component in the full diet being fed, may not have the expected impact on emissions.

Care needs to be taken to ensure additional emissions from the production of these feeds does not exceed the emissions mitigated. While methane emissions may be lessened (contributing to progress against methane targets) there may be additional nitrous oxide and carbon dioxide emissions used in growing, harvesting, and feeding out these feeds. There may also be impacts to soil carbon stocks. Ledgard and Falconer (2015) estimated that per kilogram of dry matter, the carbon footprint of palm kernel expeller fed out in New Zealand to be 506 grams of CO_2 equivalents. Therefore, the overall production emissions are likely to exceed any methane reduction.

How widely can this be used in New Zealand?

The applicability of this option for the majority of New Zealand farmers is where there are challenges. These challenges include that the basic unit of feed for most farms is pasture, ensuring a complete diet is feed to livestock, and the impact over the lifespan of the animal.

The majority of farms in New Zealand grow pasture to feed their stock. It grows on most land classes, is available year-round, is the crop farmers have the most knowledge about, occurs in many varieties, is not competed for with human food supply chains, and is generally resistant to weather and climate variability. These factors make it an efficient crop to grow for feeding livestock.

Many farm systems employ supplementary feeds to provide additional nutrition in times when pasture is unable to fulfil all needs. Some are produced on farm, while others may be bought in. However, they only comprise a small part of an animal's lifetime diet. So, emissions reductions from them are generally minor.

There are several farms or farming systems in New Zealand which have full control over the diet. This is particularly true of feedlot systems. This solution is more likely to be relevant to these types of systems.

Changes to diet need to be carefully managed to ensure the full nutritional needs of the animals is being met. Not all feeds will provide nutrients in the optimal balance for production. While methane emissions may be lower, production or animal welfare may be impacted too.

What is the cost to implement the technology on a farm?

The growth or purchase of other feeds comes with a cost. To a certain extent, this is an existing cost for some farms. The scaling up of this solution will progressively increase this cost. Table XX demonstrates the costs of different supplementary feeds. These costs vary and may be different if produced on farm, do not include costs associated with storage, transport, or feeding out, and do not take into account any other nutritional requirements. It is clear that the cost of pasture to provide nutrition for livestock is significantly lower than that of buying in other feeds.

Table 2. *Average cost of buting in different supplementary feed types, per unit of dry matter and metabolisable energy content* (calculated from Beef + Lamb New Zealand, 2020b)

Feed type	% Dry matter	MJME/kgDM	Price in cents/kgDM	Price in cents/MJME
Pasture	18%	10.5	9-13	81-119
Hay	85%	8.	27-35	343-441
Baleage	37%	10	48-63	480-630
Grass silage	35%	10.5	30-36	286-340
Maize silage	35%	10.8	31-37	291-344
Lucerne	24%	11	19-27	173-245
Greenfeed oats	17%	13	17-25	131-192
Swede	11%	13.5	24-30	178-222
PKE	90%	11	44-49	404-444
Molasses	75%	11.8	49-53	418-452
Sheep nuts	94%	12	86-92	714-767

As a farmer, when can I use this?

This option is currently available to farmers and is already an active part of many farming systems. However, the impact of changing management to utilise this effect is poorly reflected in farm emissions calculators and models. For simplicity, most calculators and models assume an average diet over the lifespan of the animal. This is generally pasture based with an inbuilt allowance for the comparatively small amount of supplement used.

The realistic potential for large scale change of animal diets is limited on most New Zealand farms. For those who feed a controlled diet (e.g. feedlots) large scale manipulation of diet is possible. It is also likely that the current methane emissions from livestock in these systems are inaccurately estimated.

To implement this solution in other farm systems would require the production and distribution of larger quantities and types of feed. This is a movement away from the existing dominant farming practice. Converting pasture to animal product is the basis of the New Zealand farming system. Aspects of both New Zealand's comparative advantage and trading system are built on this. Changes to the diet may impact both the taste and perception of New Zealand produced product when traded.

Finally, care must be taken to ensure livestock receive a complete diet. Significant changes to diet will need to balance potential methane reductions with ensuring animal health and production is maintained.

5.3.4 Using methane inhibitors

What is the option?

Methane inhibitors are the option discussed most regularly in the media. This is due to their wide variety, the variations in the way they can be delivered, and that they can be added to existing systems, rather than requiring significant change in practice.

Inhibitors are generally provided as feed additives. They differ from diet change by being included at less than five per cent of the diet and are not generally delivered as part of meeting the animal's nutritional needs. They are added to the diet specifically to cause a change in the rumen, reducing the methane produced.

The variety of inhibitors reflects the many parts of the methane production process which can be targeted. The pathway of reactions in the rumen, resulting in methane production, is complex. There are many possible intervention points.

How much impact could it have on emissions?

There is a range of inhibition potential. Reductions are generally less than 30 per cent when tested in animals, but there are experimental results indicating a more than 90 per cent reduction in some products. Numerous experiments and meta-analysis have taken place to look at the methane reduction potential of different treatments, including those by Jafari et al (2019), Almeida et al (2021), Hegarty et al (2021), Honan et al (2021), Michalak et al (2021), and Sun et al (2021). All agree that while there are treatments which show potential, there are also often questions yet to be answered. This is a field undergoing rapid development and testing of options. New products and ideas frequently undergo exploration.

Possible inhibitors include nitrogenous compounds (e.g. nitrate and Bovaer), pre- and pro-biotics (e.g. lactic acid bacteria and yeast), and plant based products (including those containing saponins, tannins, halogens and essential oils). There are large variations in the reported mitigation potentials. The observed level of methane reduction is impacted by the way the testing is done (i.e. lab based or in animals), consistency of the product used, levels of inclusion in the diet, and possible impacts on production.

Table 3 contains some of the most well-known current options and their potential methane reduction benefits.

Table 3. *Methane inhibitor options and potential mitigation impact* (extracted from Hegarty et al, 2021).

Product	Active	Approximate mitigation potential in livestock	Other considerations
Bovaer	3-NOP	29%	No known production issues
Asparagopsis seaweed	Bromoform	49%	Some evidence of improved feed conversion. Investigation is underway regarding safety concerns related to the probable carcinogen status of bromoform. However, there do not appear to be residues in the animal product.

Nitrates	Nitrate	11%	Potential animal health impacts of nitrate absorption.
Agolin	Essential oils	8%	Limited published information regarding methane reduction. Sold for improving feed intake.
Mootral	Various plant extracts	Unclear	Limited published information
Monensin	Antibiotic	5%	Banned in EU. Already used in many feedlot systems as has wide ranging production and animal health impacts.

There are a number of other products coming on the market which suggest they may have methane reducing properties. Many of these are based on providing bacteria or yeast microorganisms. While some have documented production improvement capability, there is currently limited published evidence of methane reducing potential. Improvements in the selection of strains for these products are underway and likely to result in products being developed in the future.

How widely can this be used in New Zealand?

Most inhibitors need to be regularly consumed by the animal. This is an issue in New Zealand systems where most animals are fed on pasture, with no control by farmers over the level of intake. The small number of feedlot systems in New Zealand will be best able to use this solution under current circumstances. Many of these products are being developed under total mixed ration (TMR) circumstances. While TMR systems are common in housed animal systems, they are less applicable to New Zealand.

It may be possible for some level of inhibition to be observed through the use of in shed feeding systems for the dairy sector. While the full effect may not be realised, a level of impact may still be present. Iqbal et al (2023) showed that dairy cows generally ingest feed during the day, particularly following the milking period, while time at night is more often spent ruminating. Therefore, if cows consumed an inhibitor at milking time, it is likely to still be present in the rumen while they ingested most of their diet. This would enable the inhibitor to have an impact.

While direct supplementation of feed is the main method being tested, other delivery methods are being explored. These include:

- Providing a direct dose of the inhibitor. Options for this technique includes the use of a slow-release bolus. Due to the size, it is more likely a bolus for cattle will be available before that of smaller ruminants. In April 2023, AgriZero^{NZ} invested $1.8 million into the slow-release, biodegradable methane-inhibiting bolus, under development by Ruminant biotech (Ministry for Primary Industries, 2023b). If successful, a payload of inhibitor will be delivered to the animal and released over time. This will mean it is always present while the animal is eating.
- Modification of drinking water. If the inhibitor is water soluble, stable, and palatable, it could be added to stock water supply. This would enable the use of an inhibitor in pastural systems. Currently none of the inhibitors nearing commercial availability are suitable for this.
- The use of dietary supplement products (e.g. salt licks). This is an option which is already used to provide additional minerals into the diet of animals and can be used in all farming systems. Urea-molasses-mineral blocks are available in New Zealand from some suppliers. A limitation to this delivery mechanism is the ability to control the amount and timing of when the animal ingests the product. Quantifying and verifying any methane reduction will be challenging in a farming system.
- Modifying the pasture to provide the inhibitor. This would make the inhibitor an option on any farm who resows their pasture. It has been demonstrated that it is possible to modify a grass endophyte to produce some simple methane inhibiting compounds (NZAGRC, 2020). Currently, genetically bioengineered plants are not able to be commercially grown in New Zealand. Until the public and political approach to genetic modification changes, this technology will not be able to

be used in New Zealand. Ongoing work will also need to be done to understand if more complex inhibitors can be produced in this way.

What is the cost to implement the technology on a farm?

No products certified as methane inhibitors have yet been registered for sale in New Zealand. Without the market existing, no price has been set. The cost per dose or per kilogram of methane avoided is unable to be calculated. Due to the inputs and production methods across the range of inhibitors, it is highly likely there will be significant variation in the cost of different inhibitors.

There will also be costs associated with getting the inhibitor into animals. DairyNZ Limited (2023b) have observed that as dairy sheds are being modernised, more sheds are including in shed feeding systems. In their 2023 survey, more than half of respondents now have in shed feeding systems, compared to 40 per cent in 2018. There are significant capital costs with installing these systems, which will need to be met by the other half of farms if they are also to be able to feed inhibitors.

As a farmer, when can I use this?

Some of these products are currently available (e.g. nitrates), but not for the purpose of methane reduction. The first commercial methane inhibitor products with a high reduction potential are expected to be Bovaer and a seaweed-based product. Both still have significant regulatory hurdles to overcome. It is unclear what the timeline for getting these available on the market for farmers will be.

In July 2023, the active ingredient in Bovaer (3-NOP) was approved by the New Zealand Environmental Protection Authority for import and manufacture (Environmental Protection Authority, 2023). This shows it has passed the tests for wider environmental impact. Before it will be able to be used by farmers the Bovaer product will also need to be approved for sale and receive approval under the Agricultural Compounds and Veterinary Medicines Act 1997. These largely relate to managing risks around food safety, animal welfare, trade, and proving levels of efficacy. The timelines for achieving this are unclear. Bovaer is already registered in in some markets, including having been provided food safety approval in the European Union in 2021. Development of Bovaer has been occurring for more than 10 years to get to this point.

Other inhibitors are also under development. Some of these are being developed by commercialisation partners, so have limited information in the public arena on their potential. In New Zealand there is:

- Kowbucha being developed by Fonterra. This is a probiotic treatment based on their collection of dairy microbial strains. At the New Zealand Agricultural Climate Change Conference in 2023, Dr Bassett (2023) presented that in their studies Kowbucha had reduced methane in claves by up to 20 per cent.
- The PGgRc have been running a methane inhibitor programme. In 2022, they announced a collaboration with a global animal health company to collaborate on turning their research into products for farmers. At the New Zealand Agricultural Climate Change Conference in 2023, Dr Ronimus (2023) presented that in their studies they had seen an 11 per cent reduction in methane from sheep.

Biochar is emerging as an area of interest for potential methane reductions in animals, in addition to its impact in soils. Honan et al (2021) identified several studies where biochar was fed to animals. The methane reductions ranged from none to 22 per cent. They concluded “the wide variation in effectiveness precludes biochar as proven feed additive to reduce CH_4 production at present”. This is partly due to the variation in biochar as they are significantly impacted by the temperature they are produced at and what they are made from. There is no “standard” biochar.

5.3.5 Influencing animal development as they grow

What is the option?

Some studies have shown that it is possible to influence the microbial populations of adult ruminants through actions when they were young (Kelly and Waghorn, 2020), although many do not. When young ruminants are born, their digestive system is not yet fully developed. The theory behind early life interventions is that is could be possible to influence the development of this digestive system in a way resulting in less methane production. To date, there has been limited success in achieving this.

How much impact could it have on emissions?

It is unclear yet what level of impact this could have over the life of the animal. Meale et al (2021) treated calves with 3-NOP from birth until three weeks post-weaning. They saw a reduction in methane produced from the treated calves. This reduction was still present nearly a year after the treatments had concluded.

Other examples of impacting the microbial populations in a developing rumen, such as Huuki et al (2022), showed no change in methane production once the treatment stopped.

There are several research projects being undertaken around the world to explore this possible solution. Once complete there will be a better understanding of the mechanisms and limitations of this sort of treatment.

How widely can this be used in New Zealand?

Due to the nature of most of New Zealand's farming systems, young animals normally have limited human interaction. In sheep and beef systems they are generally raised on their mothers. This limits the potential for regular early life interventions.

In the dairy herd, however, calves are normally reared off their mothers. This raises the potential for this technique to be used in the rearing of replacements in the dairy herd. It could also feed into New Zealand's beef production. Large numbers of dairy calves end up being raised for beef. In 2022, approximately 30% of the beef produced in New Zealand came from dairy beef (Statistics New Zealand, 2023).

What is the cost to implement the technology on a farm?

As with the use of methane inhibitors, it is too early to have a clear understanding of the costs. The costs could be as little as the cost of the inhibitor, for mixing into calf feed.

There would, however, be long term cost savings. If treatment up until three weeks post weaning was enough to have an impact for the first year (or longer) of life, there would be savings in terms of methane and inhibitor over these weeks. Most inhibitors base the quantity needed on the amount of food eaten. Calves consume less than grown cattle, so there could also be savings there.

As a farmer, when can I use this?

This solution is still under development. Research is being undertaken in parallel to the development of inhibitors. Should the research be successful, it is likely three to five years before the evidence exists to a level where farmers can be clear on the practice.

5.3.6 Decreasing stock numbers

What is the option?

The biggest driver of emissions from agriculture in New Zealand remains animal numbers. The more animals, the higher the emissions. This is particularly true for large animals. Reducing stock numbers remains an option for farmers. However, it is unpalatable to many farmers due to an expected reduction in net profit for the farm. At a national or global scale, fewer animals would also result in less overall food produced.

How much impact could it have on emissions?

As can be seen in Figure 5, the level of methane emissions per animal has increased since 1990. The Ministry for the Environment (2023b) calculated that in 2021, the kilograms of methane produced per head per year for different stock types was:

- 86.54 for dairy cattle;
- 59.97 for beef cattle;
- 23.01 for deer;
- 12.45 for sheep; and
- 8.96 for goats.

How widely can this be used in New Zealand?

This is an option for all farmers. Stock numbers fluctuate annually in response to the need for replacement breeding stock, availability of feed, in response to regulations, and depending on the value each year of stock. By including emissions levels in the decision about how many head of stock to carry, farmers can modify their emissions.

What is the cost to implement the technology on a farm?

The cost per farm for this can vary. On more intensive farms, there are more costs per animal than in more extensive systems. Extra feed bought and higher management costs partially offset the increase in production. For each farm the breakeven point will be different. This is commonly seen in the argument for once-per-day milking. Lopez-Villalobos et al (2023) explain that the decreased production intensity for once-per-day milking systems can be more than offset by the decrease in labour, feed and animal health costs. However, this is individual farm specific.

As a farmer, when can I use this?

This is currently available to farmers. Management decisions around stocking rate are part of every farm system. The numbers of animals vary depending on the expected season ahead.

5.3.7 Modification of feeds

What is the option?

This option is related to the earlier options around changing the animal's diet and methane inhibitors. Modifying the chemical composition of the feed can impact emissions. There is potential to decrease methane production in animals through increasing the digestibility, fat content, and sugar content of feeds (Beauchemin et al, 2022). They each achieve this through different methods. Some of them result in higher total emissions, but at a lower intensity when balanced with the increased production.

How much impact could it have on emissions?

These vary considerably over the broad range of possible conditions.

- For supplementing with fats, the impact can range from 3.8 to 5.6 per cent reductions in methane. This is impacted by the level of fat included and the type of fats used. Vegetable oils are considered some of the most effective.
- For high sugar grasses the impact on methane depends on the concentrations of water soluble carbohydrates (WSC). For every 10 grams of WSC per kilogram of dry matter increase, methane yield decreases by 0.311 grams per kilogram of dry matter eaten. However, this decreases if the grass is turned in to hay or silage.
- Increased feed digestibility normally increases feed intake and production. While this increases overall methane production, it is at a lower intensity per unit of production (i.e. kilogram of milk solids).

How widely can this be used in New Zealand?

Increased digestibility is the most applicable for New Zealand farms. When considering feed options for livestock, more digestible feed generally results in better production. By managing pasture production farmers can ensure stock consume less mature (and more digestible) pasture. The same holds for supplementary feeds. The digestibility of the hay or silage used will have both production and methane impacts.

Supplementing with fats is more complicated. The availability of vegetable oils has many competing audiences. In some regions, cracked oilseeds may be an option at certain times of the year. Particularly as a way of utilising waste streams from other industries. However, care should be taken to ensure the emissions cost of producing oil specifically for stock consumption does not exceed the emission reductions from its use.

Pasture type selection is an important factor in some farm systems. There are many factors impacting which grass is selected, including lifespan, growth pattern, persistence, and pest resistance. The sugar content is starting to be included for some farmers in selection criteria.

What is the cost to implement the technology on a farm?

Costs for these options are already part of the decision-making process for many farmers. More digestible feed is considered higher quality, and has higher costs. Buying in oils to supplement feed will likely incur additional costs, unless they are considered a waste stream elsewhere.

As a farmer, when can I use this?

These are generally options which are currently available to farmers in New Zealand. They relate more to decision making and balancing across different decision drivers. For example, high sugar ryegrasses are currently available from several seed suppliers in New Zealand.

There is research underway on developing high metabolizable energy (HME) ryegrasses. These have higher fat contents. Field trials are underway in the USA on HME grasses developed in New Zealand (Beechey-Gradwell, 2021). These have been modified to produce higher fats, but are currently unable to be grown at field level in New Zealand. There are also conventional breeding trials underway seeking to achieve the same benefit.

5.3.8 Changing the way manure is managed

What is the option?

How manure is collected, stored, treated, and disposed of can have large impacts on emissions. There are many manure management methods in practice globally. Manure is used as a source of nutrients, which can be returned back into the paddock, and as a fuel source in some places. Many New Zealand dairy farms collect manure in effluent ponds. There are now treatments available for effluent ponds to reduce methane generated.

How much impact could it have on emissions?

In 2021, methane from manure management accounted for 5.3 per cent of all of the methane produced in agriculture (Ministry for the Environment, 2023b). Of this, more than 85 per cent is produced from dairy systems, largely from effluent ponds. Recent technology developed in New Zealand is demonstrated to be able to reduce methane from dairy farm effluent by up to 99 per cent (Cameron and Di, 2021). This could significantly reduce methane from the sector.

How widely can this be used in New Zealand?

Ravensdown's EcoPond product can be retrofitted into most effluent ponds. This makes the technology available to most dairy farmers and some feedlot farmers.

What is the cost to implement the technology on a farm?

EcoPond is estimated to cost $45,000 to $49,000 (Malhus, 2021). There are also associated running costs.

As a farmer, when can I use this?

Improvements to manure management is something farmers can do now.

5.3.9 Wearable devices which capture emissions

What is the option?

Technologies are under development to capture emissions from the breath of animals. The idea is that a portion of the methane belched out by livestock is captured. The methane is passed through a catalyst, which breaks down the methane into carbon dioxide and water.

Companies like Zelp (2023) are developing devices which can be worn by animals. These halter type devices are being designed to capture gases. In addition to this, a range of animal monitoring sensors can be built in. This could enable better monitoring of health issues, fertility, and behaviour.

How much impact could it have on emissions?

The technologies are still under development. Marketing material from Zelp (2023) indicates they expect their technology could reduce methane emissions by 60 per cent per animal. Depending on the final designs, changes to the amount of breath captured, size of the device, and other factors may result in different emissions reductions.

How widely can this be used in New Zealand?

This technology could be particularly useful for New Zealand farmers, where pasture-based systems make some methane reduction options challenging. The device is worn continually by the animal, ensuring it is able to capture emissions through time.

Due to the size of the current prototypes, the technology is most suited to cattle. The model tested by Buijs et al (2023) weighed in excess of four kilograms and exceeded 30 centimetres at its widest point. This makes it unlikely at this stage for the product to be suitable for smaller livestock such as sheep, deer, and goats.

The animal monitoring aspects of the technology are targeted toward production systems where larger quantities of animal specific data are monitored. This makes it more useful in a high production dairy system compared to an extensive beef system.

What is the cost to implement the technology on a farm?

No information currently exists. Until a product gets closer to commercial availability, pricing schemes and ownership models have not been released.

As a farmer, when can I use this?

This is unclear. The methane reduction component has been demonstrated to work. However, Buijs et al (2023) found that existing prototypes had detrimental impacts on animal welfare and production. They recommended further product development before a product is released.

5.3.10 Improving animal health outcomes

What is the option?

Improvements to animal health can result in lower emissions from the farm system. By reducing the incidence of animal health issues, there is less loss in production. Therefore, fewer animals are required to produce the same amount of product. This reduced production efficiency is referred to as “unproductive emissions” (Ozkan et al, 2022).

There is currently a limited amount of evidence to show that some health impacts may also directly contribute to higher emissions from an animal (e.g. the research by Fox et al, 2018). However, this is not currently well researched. Possible animal health issues include parasites, infertility, mastitis, infections, and lameness.

How much impact could it have on emissions?

Enzenwa et al (2020) estimate that “pathogen-induced changes in livestock methane emissions have the potential to increase methane inputs to the atmosphere by up to 50 per cent”. This can be through a combination of increasing methane yield, reducing production efficiency, and lengthening time to achieve production targets.

The research by Fox et al (2018) showed that lambs with parasitic worm infections, consumed less, grew slower, and produced less methane. However, while they consumed 30 per cent less feed, they only produced 20 per cent less methane. They produced 33 per cent more methane per unit of feed intake than those without infections.

How widely can this be used in New Zealand?

This is an option which can be used in any farming system in New Zealand. All farming systems in New Zealand carry some level of “acceptable” animal health issue and have plans to manage and mitigate their impacts. Most systems carry some extra stock as an unofficial insurance policy to account for some animals likely to be impacted by health issues and a decrease in production.

What is the cost to implement the technology on a farm?

There are costs associated with improving animal health. However, there are well known economic gains for reducing animal health incidents, in terms of increased productivity. In a report for the Global Research Alliance on Agricultural Greenhouse Gases, the Global Dairy Platform and the Dairy Sustainability Framework, Statham et al (2020) found that the cost of prevention of many common animal health issues was a fraction of the cost of managing the issue when it arose and production loss. They looked at mastitis, infertility and bovine viral diarrhoea, in Kenya, Chile and the UK, finding similar challenges and impacts. Even before the cost of any emissions, it is more economical to prevent animal health issues than to treat them.

As a farmer, when can I use this?

Practices to reduce animal health issues are widely available and used to varying degrees around New Zealand.

6. Discussion – what it means

6.1 The operating environment for New Zealand farmers is complex

Farmers face many external drivers influencing how they operate. Most of these are complex and comprised of many smaller interacting aspects. There are economic, environmental, social, and cultural aspects of these drivers. While environmental aspects are a major driver related to responding to climate change, it is intertwined with social, economic, and cultural issues. At the high level, some of these influences are:

- Commitments New Zealand has made to reduce greenhouse gas emissions.
- Commitments being made in other parts of the global food supply chain
- International trade balance and competition

The role of each of these is different, working at different levels and at different time scales. National and international emission reduction targets have been in place for New Zealand since 2002, with the Kyoto Protocol, but have become more specific and stringent as the target deadlines have got closer. Industry player commitments are becoming more common, with the majority of them appearing in the past couple of years. These are closer to the level of the farm business and do more to drive change than national targets. Moving forward, trade pressures are going to play a larger role again and directly impact farming businesses.

What national level targets mean for New Zealand farmers?

National and sector level targets impact all farmers. They are national level, so set across all farming enterprises. This is irrespective of livestock type or how efficient an individual property may be. A dairy farmer and a deer farmer have the same targets to contribute toward. While this means that parts of the sector where emissions reductions may be easier to achieve can offset where they are harder, it also means those with less potential reductions face the same pressure to contribute.

To achieve the 2030 methane target (10 per cent reduction), at least a further 8.5 per cent reduction in biogenic methane will be required over the seven years (calculated from Ministry for the Environment, 2023b). With agriculture responsible for 89 per cent of the biogenic methane produced, the majority of this reduction could be expected to come from there. Approximately 76 per cent of those agricultural emissions come from livestock farming. So, New Zealand farmers are facing significant pressure to decrease methane emissions.

What industry commitments mean for New Zealand farmers?

In order to meet their pledges, companies are going to be looking at the emissions footprint of the products they buy. To meet their targets, they will need to purchase more product from farmers with lower emissions, moving away from those with higher emissions. This provides a strong incentive to be producing with emissions as low as possible.

A key challenge with this is how emissions are measured. There are many ways to measure emissions and many assumptions built into those calculations (Mazzetto et al, 2023). There are also questions around how they are reported and the contribution of different greenhouse gases to the equation. For dairy, should emissions be based on the weight of whole milk, milk solids, energy or protein level, or contribution of mineral (such as calcium)? Each of these change the way products can be compared against each other. There is not a single globally agreed method.

Depending on how you quantify the emission of a product, New Zealand products are among the lowest emissions in the world, or have significant room to improve. Mazzetto et al (2023) found New Zealand beef and sheep meat supplied to international markets have a full life-cycle carbon footprint at the lower end of other published estimates, including lower than reported in other studies of New Zealand product. Ledgard et al (2020) calculated the emissions footprint of New Zealand milk at a level approximately 12 per cent lower than that reported by the Food and Agriculture Organization of the United Nations (2022).

While New Zealand can successfully claim to have among the lowest emissions for agricultural product, companies will buy from New Zealand farmers. Once that claim is lost, accessing markets for product will become more difficult.

What trade pressures mean for New Zealand farmers?

Policies and practices are being put in place to enable countries to meet their greenhouse gas targets. Some of these make products from their market more internationally competitive, some have the potential to harm New Zealand trade access, and some could be beneficial to New Zealand farmers.

It is likely some countries will subsidise the use and uptake of options to reduce emissions. After leaving the European Union, the United Kingdom has been reviewing their farmer subsidy schemes. Moving forward the UK Secretary of State for Environment, Food and Rural Affairs said they intend to "pay farmers for delivering climate and environmental benefits while producing the nation's food" (UK Parliament, 2023). This could change the economic balance for farmers, making some mitigation options more viable. There is not a similar mechanism in New Zealand.

A range of overseas domestic environmental protection policies are under development. The challenge for New Zealand farmers is, if these come into effect, products entering their market must meet the same standards. This is being seen for industrial products in the European market, with the establishment of their Carbon Border Adjustments Mechanism. This is a border tax on products to ensure they are paying a similar cost for the carbon emitted during the product's development. The scope does not currently include agricultural products (Ministry of Foreign Affairs and Trade, 2021).

Similarly, the overall challenge of agriculture needing to reduce emissions is the same around the world. Investment in other countries into new technologies, testing and commercialisation of products, and guidance for farmers are all potentially relevant for New Zealand farmers. The marginal abatement cost curves produced by Lanigan et al (2023) for the Irish agriculture sector provide valuable insights into the potential for farmers. Although the specifics of what can be achieved may be different in Ireland, the options explored and way they have been considered can provide insights for New Zealand.

Finally, the consistency and safety of internationally traded products means there are approvals and regulations needed before changes can be made to traded products. New Zealand experienced first hand the impacts of a residue being detected in milk when dicyandiamide (DCD) had been used on pastures to reduce nitrate leaching. In 2012 and 2013 there were recalls of milk powder after residues of DCD were thought to be detected in traded product. Even though there was limited food safety concern, there were no international residue standards for DCD in food (Lee-Jones, 2013). Government, Fonterra and the fertiliser companies all took part in re-assuring markets that DCD had been removed from use in New Zealand.

6.2 New Zealand farms are constantly adapting

Farming is a dynamic business. The ability for these farmers to adapt to changing external drivers is impacted by both the support they receive and the economics of the returns they receive. Economic challenges felt across New Zealand have had similar and in some cases more severe impacts in the agricultural sector. Rising costs for energy (electricity and fuel), rising interest rates on debt, inflation on food and living costs, all impact farmers. Farmers get caught between calls for food to cost less, while the cost of producing it rises. These restrict the ability for farms to change to meet new governmental and consumer demands.

Livestock at the largest contributor to New Zealand's methane emissions. Livestock emissions come predominantly from enteric fermentation (94.4 per cent) and manure management (5.6 per cent). This is why the Zero Carbon Act's split gas approach is of such importance to agriculture. For New Zealand to meet the 2030 and 2050 methane targets, agriculture will need to make significant emissions reductions.

The underlying pattern of agricultural methane emission change is a progressive reduction since about 2005. However, this reduction over the last 15 years is approximately half of the reduction yet to be made over the next seven years.

The price returns for dairy have seen the number of animals increase, while the lower returns for sheep meat and wool have seen a reduction in the size of the national flock. These changes have included a combination of increased stocking on some farms, changes in land use, and farmers reacting to the price driver by seeking increased productivity. Productivity increases have meant that fewer animals are needed to produce the same amount of product. With higher productivity, fewer animals are needed to produce the same amount of product and there is a reduction in methane emissions intensity. If production was to be held constant, while productivity continues to increase, a reduction in methane emissions would result. However, there is currently limited economic gain from making these emission gains and forfeiting the potential increased production.

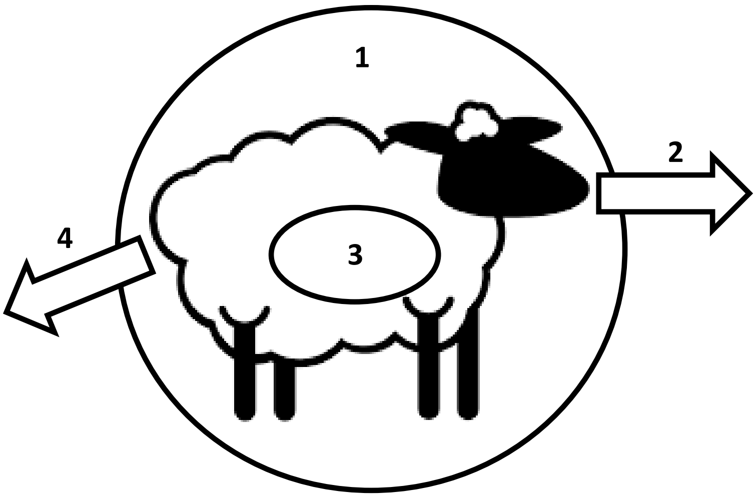
The historical trend seen in the decrease of the size of the sheep flock, provides a similar shaped reduction in methane emissions from it. If current reductions continue at the same rate as seen since 2017, methane emissions from sheep farming would meet the national 2030 reduction target. However, many farms carrying sheep, also carry some cattle. There is a chance the gains being seen in sheep are more than offset by increases to beef emissions. At the national level, beef emissions have progressed in the wrong direction and now face a 100 per cent increase in the challenge by 2030, than they faced in 2017.

Dairy is seen as one of the largest challenges. Methane from dairy cattle is more than the total from the sheep and beef sectors combined. While the size of the dairy herd has decreased slightly since about 2014, production has continued to increase, while methane emissions have remained constant. In 2021, Fonterra claimed New Zealand has reached "peak milk" (Hancock, 2021). If production efficiencies can continue to be made and targeted emission reduction technologies implemented, methane reductions can be realised. However, while the emissions curve has been 'flattened', it is yet to actually reduce.

External events can have a sizable impact on the level of agricultural methane emissions. Over the 2007-2009 period New Zealand's agricultural sector saw some large changes. There was a significant decrease in both the sheep and cattle numbers. For sheep it was a 16 per cent decrease in head count, while for beef it was a seven per cent drop. At the same time dairy numbers continued to grow and grew by more than 10 per cent. However, the effect on methane production was a 6.6 per cent reduction in methane (calculated on a 2017 baseline level). Over these two years, about two thirds of the reduction needed between now and 2030 occurred. Similar wider economic and climatic events in the future could have emissions impacts moving forward. The extent of the effect on New Zealand's food, fuel and finance systems of the recent cyclones, outbreaks of war, and changes to policies of trading partners, is yet to be reflected in New Zealand's emissions accounting.

6.3 What New Zealand farmers can do

In exploring possible technologies for agricultural methane mitigation, it is clear there are multiple factors which need considering. Both the option and how you deliver it to the animal are important considerations for farmers. To make a difference, you need the right solution in the right place, at the right time.



1. *Lower overall emission animals*
2. *Changes to the emissions released by animals*
3. *Changes to the rumen so that fewer emissions are produced*
4. *Changes to how waste is managed*

Figure 7. *Diagram of intervention points for emissions from ruminant livestock*.

There are four points of intervention for the reduction of methane emissions from livestock, as illustrated in Figure 7. For wider agricultural emissions (including nitrous oxide and carbon dioxide), there are two other intervention points - being direct capture from air and emissions from soils. They are outside the scope of this report.

It is possible to make changes:

1. At the whole animal level to reduce the level of methane (and other greenhouse gases) they produce. These are through changes to the animal's physiology.
2. To the inputs to the animal which impact the methane released.
3. To the rumen environment which can influence chemical reactions and cause less methane to be produced.
4. To the conditions around how manure is managed and the chemical reactions it undertakes.

Across these intervention points are a number of possible options. Some are available to farmers now, while others are still being researched and developed. Options relying on the modification of current practice can be implemented to an extent on farm now. These include:

- Changing the number and type of animals farmed
- Improving overall animal health and decreasing the need for replacements
- Changing the diet of animals to lower emission feeds
- To a more limited extent, modification of the animal's diet

Some options are currently available but are being further researched, or are just coming on to the market. These will continue to develop and expand their potential over time.

- Including selection for low emission genetics in breeding programmes
- Improving the management of manure

Other options are still under development, but may become options in the future. Further knowledge is needed before methane inhibitors, a vaccine, wearable technology, and early-life intervention stage can be used on New Zealand farms. As farmers consider their options to reduce emissions, they should keep an eye on what future technology they may need to plan for.

Cost is often the major driver for farm decision making. Methane reduction options will come at a cost to the business. For the options which involve modification to existing farm practice, there is often a potential production cost. This could be foregoing future production gains by using different weighting in genetic selection, foregoing current production by changing stock, or purely a financial cost for buying in or growing other feeds. The technologies under development will all have costs associated with getting it to the methane source and purchase costs. When farms are already facing financial pressures impacting existing purchasing patterns, further costs will be hard to address.

Not all options will suit all farms and farm types. While this can be seen based on the livestock type, there are other factors which should be considered as well. Location and topology of the farm may impact factors such as what can be grown. Some customer certifications, such as "organic", will need to be considered based on the options available for methane reduction.

For many options, how well they can operate together in a "stacked" manner is yet to be fully explored. Due to the modes of action, it is expected they will not all be able to have a pure additive function. Just because on its own option A can have a 5 per cent reduction and option B a 7 per cent effect, does not mean that together they have a 12 per cent impact. Depending on the modes of action and the impact they have on the animal, they may be stackable, may lessen each option's impact, or enhance it. The research has not yet progressed to a stage of being able to accurately determine this stack-ability. Care should be taken to understand how different options will react together.

Many of the options identified are still in various stages of development. These will need to progress through multiple stages of regulation at both the national and international level. This is a complex process and can take varying lengths of time. Any products applied to the land or animals will need to be approved and certified before they are commercially available. Without this, there could be impacts on trade and with getting recognition of the actions taken to reduce methane emission.

New Zealand has experienced how greenhouse gas mitigation options can impact trade in the past. Care must be taken to ensure that the reduction options used meet with international approval. Otherwise, there can be significant impacts on trade of agricultural products. As illustrated by the earlier DCD example.

Finally, the full footprint of the option must be considered. There are two parts to this.

- Does the methane reduction impact other greenhouse gas emissions or carbon sequestration; and
- What are the emissions generated in the production and use of the option.

The systems within a farm and within animals are very complex. Modifying one thing will often have impacts on other parts of the system. For example, moving to a diet which produces less methane may result in more nitrous oxide emissions caused by the animal. There will also be emissions from the production, transport and storage of that feed. If additional cropping needs to take place, there may be soil carbon losses as well. For it to be a good decision, the methane emissions reduced must outweigh any other emissions generated.

7. Conclusions – what you should remember

Reducing agricultural methane emissions will be a major step towards preventing climate change. Without reductions, New Zealand will struggle to meet both domestic and international targets. However, it is not just government targets driving action. The climate commitments by purchasers of agricultural products provide significant drivers of practice change, which will reduce emissions. Progress towards achieving these targets will play out under the spotlight of international trade concerns.

Different parts of New Zealand's agricultural sector are further through realising methane reductions than others. Beef, sheep and dairy all face the same challenge, but are at different stages of responding to it. They also have different opportunities and support available to them to make changes. A farmer informed approach which considers these differences is crucial for extracting the best result for the New Zealand agriculture sector.

Farmers already have some tools to hand which can be used to reduce methane emissions. These need to be embraced early if methane is to be reduced in time. Some technologies are under development for the future, which may be easier to implement, have lower costs, or achieve greater reductions, they are also still unproven. Significant research is still required for these to become useable options for New Zealand farmers. However, early action is needed due to the time required to implement an option and make reductions to methane emissions.

New Zealand farmers should be proud of the changes they have already achieved. There is still significant progress to be made, but some change has already occurred. Moving forward, it can be expected further options will become possible. Methane reductions can be made and the market advantage of New Zealand's agricultural products maintained.

8. Recommendations – what you should do

It is recommended that farmers:

- Stay alert to changes to targets, especially those being set by the purchasers of their product.
- Consider how wider industry action in response to other policy, environmental, and economic drivers has shaped the trajectory of change. Within this, farmers should take note of whether they are travelling in the right direction on emissions and at the right speed.
- Carefully explore the emission reduction options available to them, to take into account the full life-cycle of all greenhouse emissions from a technology, including wider environmental impacts.
- Critically examine methane reduction options to understand the fit with their farming system. Not all options will be suitable for all farms, and while at the national level an option may have limited impact, for some farmers it may be very applicable.

It is recommended that policy makers in government and industry:

- Agree to standard methodologies for reduction claims. This will instil greater trust with farmers and enable comparisons to be accurately made.
- Work together to encourage change in the sector. Government targets are being superseded by industry ones. This should be seen as a positive and not competition.
- Consider options to positively incentivise change, and penalise not changing. New Zealand's approach to agricultural subsidies means incentivisation is most likely to be able to come from the industry. While the government is more likely to be in a position to penalise any lack in progress. Government and industry should work in sync on these.
- Reflect on the change that has already occurred in the industry and why those emissions changes occurred.
- Continue to invest in the research and development of more, and cheaper, options for farmers to use.

Finally, it is recommended that methane reduction options are adopted on farm early. This will require action from farmers, rural professionals, industry, researchers, and government. Without early action change will not be able to be made in time.

9. Limitations – what couldn't be done

There are a series of assumptions built into the analysis of this report. They impact how the report should be considered.

- This report only looked at methane and excluded other greenhouse gases. The discussion notes the importance of also considering nitrous oxide and carbon emissions. These are also part of the emissions from agriculture and subject to legislated 2050 targets. Some industry targets also include these gases in their targets.
- Agricultural emissions come from more than just livestock, however this report only considered livestock emissions. For example, emission from agricultural soils are about 16 per cent of agricultural emissions.
- Biogenic methane is emitted from more than just livestock. Livestock account for about 76 per cent of biogenic methane emissions. A further 24 per cent is emitted elsewhere.
- The report is neutral on whether the targets are appropriate. It addresses how the targets can be worked towards with them as they stand.
- By focusing on methane levels the report is silent on the level of warming attributed to the atmosphere by each gas. There is ongoing debate about how each gas is accounted for in terms of contribution to global warming. By focussing on reductions to methane, the report avoids comparisons between greenhouse gases.
- Potential changes in emissions from changing land use were out of scope of this report. Some of the potential options would require changes in land use. These were not included in this report.

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