

Chapter 7:

Reducing emissions from agriculture

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Agriculture contributes significantly to the Aotearoa economy, communities and culture. Farming livestock makes up the majority of agricultural emissions, with smaller contributions from horticulture and cropping. Agriculture emits the majority of biogenic methane emissions in Aotearoa and also makes a significant contribution to long-lived gas emissions.

This chapter explores the sources of livestock emissions and opportunities for reducing emissions, including farm management and new technologies, along with the opportunities and challenges for each option. Emissions from farm vehicles and machinery are covered in Chapter 5: Reducing emission from energy and industry and Chapter 6: Reducing emissions from transport, buildings and urban from.

7.1 Agricultural emissions

Agriculture makes a significant contribution to the Aotearoa economy, and has helped to shape our landscapes, communities and culture for generations. The different ways that land is used also impacts greenhouse gas emissions. Agricultural emissions in Aotearoa come primarily from livestock farms, but also fertiliser use, horticulture, and arable cropping (Figure 7.1). Farming of ruminant livestock makes up the majority of agricultural emissions and leads to the release of biogenic methane (CH₄) and nitrous oxide (N₂O). Aotearoa farms have changed significantly over time, as has their overall contribution to climate change.

Aotearoa has a total land area of 26.8 million hectares. Almost 40%, about 10 million hectares, is used for pastoral agriculture – predominantly dairy, sheep and beef farms. A relatively small area of land is used for horticulture and arable cropping – about 270,000 h or 1%. In Aotearoa, most emissions (90%) from the agriculture sector come from livestock farming, and the biogenic methane and nitrous oxide emitted are the result of complex biological processes. Agriculture emits 1.22 MtCH₄ of biogenic methane (91% of the total), and 9.02 MtCO₂e long-lived greenhouse gases (19% of the gross total).¹ Emissions from removing trees and changing to a different land use (deforestation) is covered in *Chapter 9: Removing carbon from our atmosphere*.

¹ (Ministry for the Environment, 2020)

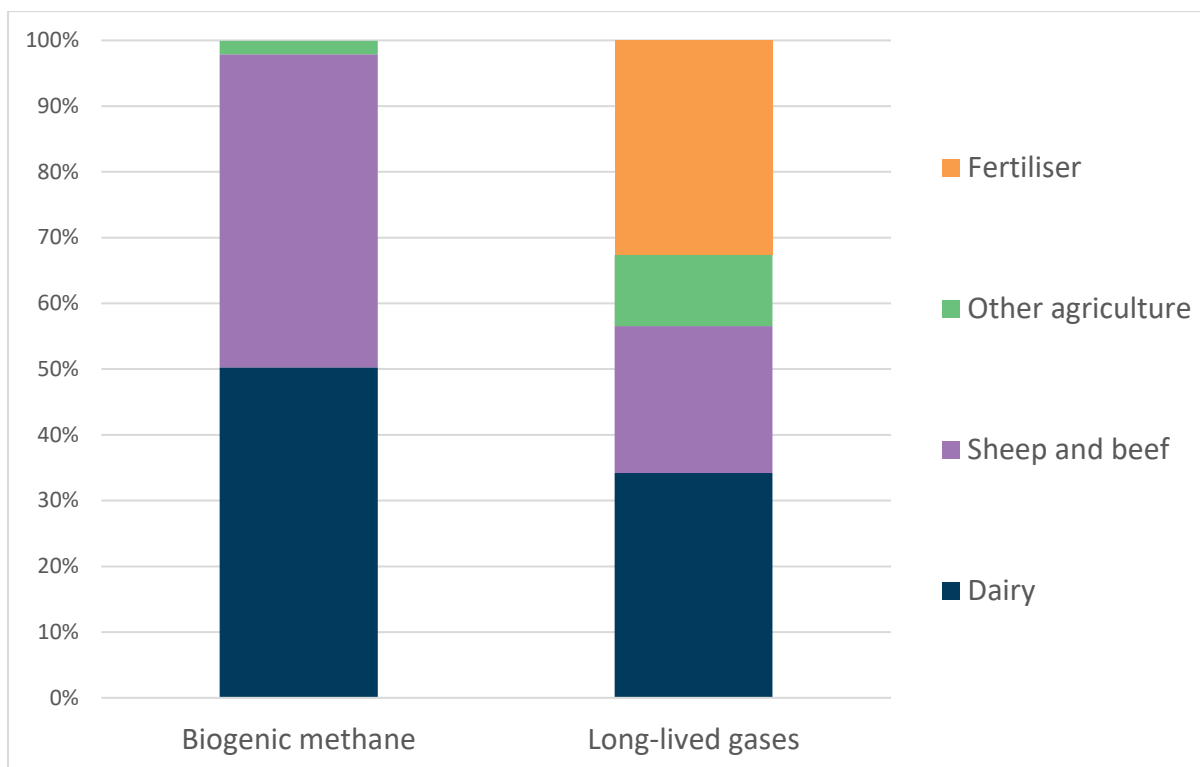


Figure 7.1: The breakdown of Aotearoa agricultural emissions in 2019²

The profile of agricultural emissions in Aotearoa has changed since 1990. Since the 1980s, many sheep and beef farms have converted all or portions of their land to dairy farming, forestry, or have retired the land. This is reflected in animal populations and emissions,³ see *Chapter 11: Where are we currently heading?*

In 2019, emissions of both agricultural biogenic methane and nitrous oxide in Aotearoa had increased by about 17.1% since 1990.⁴ Yet, large improvements in productivity mean that the sector's emissions intensity – greenhouse gases produced per unit of product – has fallen by about 20% over the same period.⁵

This gain in emissions efficiency has come about through a range of productivity improvements and farmer innovation. Selective breeding has resulted in more productive animals with the potential to grow faster, produce more milk and have more offspring. Improved pasture and feed management, improved animal health and more effective use of fertiliser have also enabled farmers to improve efficiency. Without these changes, current emissions would have been 40% higher.⁶

² Commission analysis based on (Ministry for the Environment, 2021)

³ (Ministry for the Environment, 2020)

⁴ (Ministry for the Environment, 2020)

⁵ (Interim Climate Change Committee, 2019)

⁶ (NZAGRC, 2015)

Improvements in productivity are expected to continue, though at a declining rate.⁷ This means there could likely be ongoing improvements in average emissions intensity on farms for some time, even without the introduction and uptake of additional emissions reduction actions.

There are new farming techniques that could incrementally (and perhaps cumulatively) accelerate the increase in efficiencies and reduce overall emissions.⁸ There are also promising technologies under development which, if successfully brought to market, could lead to substantial emissions reductions.⁹

Practices and technologies that lead to further reductions in biological emissions are likely to have co-benefits for other environmental outcomes, such as supporting biodiversity and continued improvements to water quality.¹⁰ They also likely align with and support the wellbeing dimensions and the tikanga outlined in He Ara Waiora (HAW) framework as they apply to the realms of Te Taiao and the Ira Tangata - refer to *Chapter 10: Perspectives from Tangata Whenua: Considering emissions reductions and removals from a Te Ao Māori* for further explanation of the HAW framework.

Box 7.1: Sources of livestock emissions¹¹

Cattle, sheep and other ruminant livestock produce biogenic **methane** as part of their digestive process. Billions of microbes inside the rumen break down grass and other feed through a process of fermentation. Some of these microbes produce biogenic methane, which the animals then burp out.¹² Biogenic methane emissions are largely a function of the amount of feed an animal eats, with about 21 grams of biogenic methane produced for each kilogram of pasture consumed. Each additional kilogram of pasture consumed adds about the same additional amount of biogenic methane emissions.¹³ This biogenic methane (termed 'enteric methane') makes up 95% of biogenic methane with almost all the remaining 5% from the microbial breakdown of manure (Figure 7.2).

Nitrous oxide emissions are largely a function of the amount of nitrogen added to the land through urine, dung and fertiliser. The nitrogen deposited on the ground is broken down by microbes in the soil. Some of the nitrogen is taken up by plants, some is converted into nitrate, and a small amount is converted into nitrous oxide and emitted into the atmosphere. Because excess nitrogen is excreted in urine, nitrous oxide emissions are directly related to the amount of nitrogen animals consume. The quantity of nitrous oxide that is released also depends on other factors such as soil and weather conditions.¹⁴

Nitrous oxide is also generated from nitrogen in synthetic fertiliser through the same process noted above. This makes up 25% of direct agricultural nitrous oxide emissions.

⁷ Emissions intensity declined at a rate of about 1% per annum between 1990 and 2012, but the rate is expected to reduce over subsequent periods – to 0.3-0.6% between 2015 and 2030, and 0.3-0.5% between 2030 and 2050 (Reisinger & Clark, 2016)

⁸ (Reisinger et al., 2017)

⁹ (NZAGRC, 2020)

¹⁰ (Primary Sector Council, 2020)

¹¹ (Ministry for the Environment, 2020)

¹² These methane producing microbes are called methanogens, and the methane produced via this process is known as 'enteric methane.'

¹³ At about 21 grams of methane for each kilogram of pasture consumed.

¹⁴ For example, if soil is heavily compacted it is harder for plants to take up nitrogen, and the microbes that produce nitrous oxide thrive in waterlogged conditions.

There are also small amounts of **carbon dioxide** emissions from agriculture arising from the application of lime and urea. Changes in land use (and sometimes management) can also impact on soil carbon. On-farm emissions and removals of carbon dioxide from the use of fossil fuels, planting, harvesting and deforestation are included in *Chapter 5: Reducing emissions from energy and industry*, *Chapter 6: Reducing emissions from transport, buildings and urban form*, and *Chapter 9: Removing carbon from our atmosphere*.

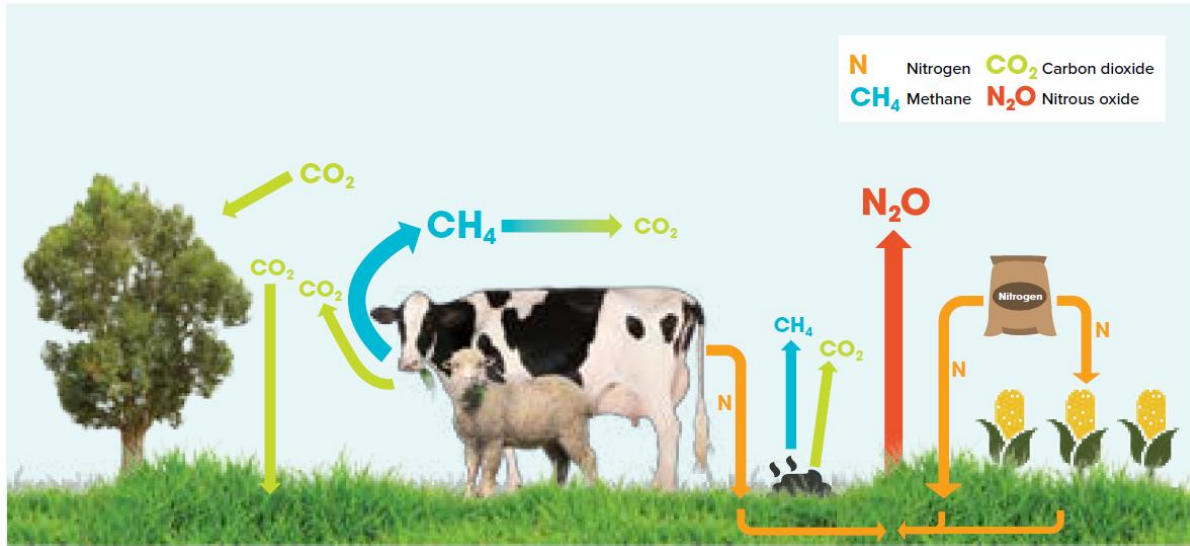


Figure 7.2: Sources and sinks of greenhouse gas emissions on a farm¹⁵

Box 7.3: Why is there concern over methane, but no recognition of the carbon sequestered by grass?¹⁶

People often ask why the methane emitted by ruminant livestock is counted, but not the carbon dioxide removed by grasses as they grow. This is because the carbon has markedly different impacts on the climate depending on whether it cycles in and out of the grass as carbon dioxide or is eaten by a ruminant and is converted into methane.

The natural process of grass growth uses photosynthesis to take up carbon dioxide from the atmosphere and converts it into plant tissues. The reverse process happens when the plant respire, or dies and breaks down, and carbon dioxide is released back into the atmosphere. Some of the grass will be eaten by animals and ultimately returned to the atmosphere either rapidly (through respiration and urine or dung) or over a few years (as products and carcasses eventually decay). None of these processes contribute to sustained change in the concentration of carbon dioxide in the atmosphere or to global temperatures. They are effectively balanced over time and can be thought of as carbon neutral.

¹⁵ (Interim Climate Change Committee, 2019)

¹⁶ (AgMatters, 2020c)

However, when the grass is eaten by ruminants some of the carbon is converted to methane by microbes in rumen and expelled to the atmosphere. This methane eventually decays back to carbon dioxide after 12-20 years.¹⁷

While the methane is in the atmosphere, it has a warming effect far greater than if the same amount of carbon dioxide were emitted – 84 times greater if the warming over 20 years is considered, or 25 times greater if the warming over 100 years is considered. See *Chapter 1: The science of climate change* for more information on the temperature effects of different greenhouse gases.

In summary, there is a focus on reducing methane from livestock because of its additional effect on global temperatures. The sequestration of grass on farms is not a focus because it is part of a climate-neutral carbon cycle.

7.2 Options for reducing emissions

Agricultural emissions can be reduced through either adjusting on-farm management or the use of emissions reduction technologies.^{18,19}

Agricultural emissions on-farm can be reduced using farm management practices such as reducing stocking rates, reducing total feed being produced or purchased and then consumed by animals, as well as reducing nitrogen being deposited onto land. The Biological Emissions Reference Group (BERG)²⁰ estimated that changing practice on farms with existing technologies could reduce emissions by up to 10%.²¹

There are a range of new technologies under development or working towards commercialisation and licencing that have the potential to reduce on-farm emissions. These technologies are likely to include a mix of vaccines, inhibitors, novel feeds, breeding and biogenic methane capture. There can be limits on the effectiveness of these technologies, due to the relevance of the approach to Aotearoa farming systems and rates of adoption. Collectively these could reduce emissions by up to 30%.²² However, not all of these technologies are additive. For example, a biogenic methane inhibitor and a biogenic methane vaccine would likely target the same biogenic methane producing microbes.

The government has developed an Agritech Industry Transformation Plan to accelerate the growth of agricultural technology in Aotearoa to make the sector more productive, sustainable and inclusive as part of a low-emissions economy.²³ Agritech refers to technological changes that aim to improve value such as improving yield, efficiency or sustainability. The plan has identified the barriers to the growth of agricultural technology, which include shortage of capital to invest and connectivity within the sector. The plan has a number of actions to respond to the barriers identified, alongside progressing a number of priority agricultural technology projects.

¹⁷ (NZAGRC, 2017)

¹⁸ See <https://www.pggrc.co.nz/> and www.agmatters.nz

¹⁹ (Hamill & Stephenson, 2020)

²⁰ The Biological Emissions Reference Group was an industry and government collaboration to build an evidence base for mitigation options in agriculture (BERG, 2018)

²¹ (NZAGRC, 2017)

²² (Reisinger et al., 2018)

²³ (Ministry of Business, Innovation & Employment, 2020)

The package of actions described here is targeted at emissions from pastoral agriculture. Emissions reduction actions in horticulture and arable farming have not been discussed in detail, as they are a small proportion of agricultural emissions. Actions to reduce emissions in horticulture and arable farming largely relate to reducing nitrogen oxide released from fertiliser, including through more efficient application, timing of application and reducing overall fertiliser use.

Assuming these options do become available to farmers in the future, the BERG estimated that overall biological emissions could potentially be reduced by between 10% and 21% by 2030, and by 22% and 48% in 2050 from baseline projections at the time the report was prepared (taken as a package combining all emissions reduction actions and assuming varied rates of adoption by farmers).²⁴

Emissions reductions beyond those achievable with management change could be achieved with land-use change and/or significant reductions in livestock numbers. Where these are pursued by landowners, they are likely to have a significant impact on sources of revenue generated by that land. Whether such changes happen would depend on a range of factors, including other management actions, targets set, associated policies, and the feasibility or desirability of such changes. The potential emissions reductions and impacts of different combinations or levels of action are considered in *Chapter 12: Long-term scenarios to meet the 2050 target*.

Many actions taken to reduce emissions would also reduce impacts on water quality, and vice versa. This is because both nitrous oxide emissions and leaching of nitrogen into waterways are caused by nitrogen being deposited on soils. The recently implemented freshwater regulations will also contribute to reductions in greenhouse gas emissions.²⁵

Iwi/Māori face particular challenges. Treaty of Waitangi settlements have left many Iwi/Māori with steeper, less versatile land that is often underdeveloped. In addition, many Iwi/Māori have reduced the intensity of their production in line with a te ao Māori view. Any legislation that ‘benchmarks’ in environmental performance based on intensity of the current use lowers the flexibility of less intensively used land. Governance arrangements for Māori trusts (e.g., established under Te Ture Whenua Act 1993) are often complex, with several people required to make decisions for parcels of land.

Box 7.2: Example- Opepe Farm Trust

Exploring alternative land use and land-use diversification is important to Opepe Farm Trust.²⁶ As kaitiaki of the whenua, Opepe regularly make trade-offs between culturally appropriate practice, industry best practice, governance responsibilities, owners’ aspirations and the commercial realities of managing a farm and a forest (imposed through historic government policy).

While transition away from dairy is within the aspirations of the trustees, land conversion could be asking to wind back years of significant investment that poses a risk to the owners. Achieving diversification within the farming system is seen as a financial and environmental risk management strategy. Opepe Farm Trust holds the view that the time for large scale expansive pastoral agriculture has passed and a mixed land-use approach to farming is the future.

²⁴ Ibid

²⁵ (Djanibekov & Wiercinski, 2020)

²⁶ Engagement with Opepe Farm Trust

7.3 On-farm management changes

The actions described below can potentially reduce both biogenic methane and nitrous oxide emissions. Some actions may impact one gas more than the other.

Table 7.1: Opportunities and challenges of on-farm management changes for reducing agricultural emissions

Options	Opportunities and challenges
<p>Adjusting stocking rates and feed</p>	<p>Two closely linked elements play an important role in the overall emissions efficiency and profile of an individual farm: stocking rates and how feed is managed. These elements of farm management interact with each other, so changes to one would have implications for emissions in other parts of the farm system.</p> <p>Stocking rate refers to the number of animals being grazed per hectare. Adjusting stocking rates can help to optimise herd productivity and reduce emissions. A herd with fewer cows that maintains the same production (through higher production per cow) would require less feed overall. This can lead to lower biogenic methane and nitrous oxide emissions. Stocking rates can be adjusted by improving livestock reproductive performance or removing unproductive animals.</p> <p>The BERG found that reducing stocking rates and improving productivity per animal could reduce emissions by up to 10% for dairy farms, and between 2% and 5% for sheep and beef farms. This could also lead to increased profitability, depending on the improvements in productivity. This finding was consistent across different farm systems and was the case even when pasture quality was assumed to decline slightly due to lower fertiliser use. Because such a system required fewer inputs, BERG also found the economic benefits of reduced stocking rates were greater when milk solid pay-outs were lower.²⁷</p> <p>Farmers generally manage feed to optimise the productivity of their herd. Most livestock in Aotearoa graze on pasture, and skilled management is required to manage pasture growth and optimise its nutritional value. Many farms also use nitrogen fertiliser and supplementary feed to deal with gaps in pasture growth, and/or to boost production.</p> <p>There is a direct link between feed consumed by livestock and the emissions they produce, as discussed in Box 7.1 on sources of livestock emissions. Some types of feed can help to reduce nitrous oxide emissions by reducing the amount of nitrogen eaten and excreted onto pasture. Feed that is more easily digested and</p>

²⁷ (Reisinger et al., 2017, p. 36)

Options	Opportunities and challenges
	<p>requires less fermentation in the rumen can also lead to lower biogenic methane emissions and increase animal efficiency.</p> <p>Using supplementary feed can help to boost production, but biogenic methane emissions would increase if an animal consumed more feed overall. The additional cost of using supplementary feed would also eventually be greater than the marginal revenue received from the additional production it supports.</p> <p>The amount of nitrogen added to the farm system in the form of feed and fertiliser, as part of feed management, will affect how much nitrous oxide is emitted from soil. A system that has fewer animals but maintains the same production requires less feed and thus less nitrogen fertiliser or imported feed inputs, which would reduce nitrous oxide emissions. Precision farming approaches, such as the use of sensors or targeted application mechanisms, may enable further reductions in fertiliser use without compromising pasture growth.</p> <p>Care must also be taken to not reduce one set of emissions at the expense of another. Forage rape for example, has been shown to reduce biogenic methane emissions²⁸ but can lead to an increase in nitrous oxide emissions.²⁹</p> <p>Careful balancing of stocking rates, pasture and fertiliser management and supplementary feed can lead to a farm system where production, profit and emissions are optimised.³⁰</p> <p>Farms are complex biological systems and the mix of animals, plants, soils and feed mean that each farm has its own unique emissions profile. Changing one element of the farm system would have impacts on other parts of the system and on emissions. For example, changing what an animal is fed will affect how much meat or milk it produces, how much biogenic methane it emits, as well as how much nitrogen is deposited on soils.³¹</p> <p>What an optimal system looks like would vary considerably between farms, and the total emissions reductions a given farm can achieve will depend on how that farm is managed overall. For example, dropping stocking rates too far can make it difficult to manage pasture quality and weed growth for a given area of grazed land.</p> <p>There is a lot of information available for farmers; however, it can be difficult for farmers to identify or take up relevant information. This information is often focussed on a specific farm management issue and is not tailored around farm-wide actions that could reduce emissions. This could be addressed through avenues such as access to trusted sources, sharing information across farming communities and independent farm advisors.</p>

²⁸ (Sun et al., 2015, 2016)

²⁹ (AgMatters, 2020b; Carlson et al., 2016)

³⁰ (de Klein & Dynes, 2017)

³¹ (Journeaux & Kingi, 2020)

Options	Opportunities and challenges
	<p>Better rural connectivity would help farmers access new ideas and information, and to share what they learn. It is also a critical component of precision agriculture, which requires data to be both collected on-farm and shared with central servers.</p> <p>Much of the existing research in this area, including the research drawn on here, is focused on driving emissions improvements within existing farm systems in Aotearoa. As a result, the research has considered actions farmers could take that would reduce emissions without significant decreases in production or profitability.</p>
Low-nitrogen feed	<p>The type of feed livestock eat can affect how much nitrogen is excreted and thus the nitrous oxide emitted from agricultural soils.</p> <p>As noted above, most livestock in Aotearoa feed on pasture with a relatively high nitrogen content. This means that grazing livestock generally consume more nitrogen than they need, and the excess ends up in the livestock’s urine and dung.</p> <p>Some pasture species, such as plantain, can reduce total nitrogen excretion in urine. Pasture can also be supplemented with lower nitrogen feed, such as fodder beet.³² Research is also underway to develop a genetically modified type of ryegrass with lower nitrogen than the current pasture – this will be discussed further in the following section. Some farmers could reduce emissions by using low nitrogen supplementary feed – for example, replacing use of Palm Kernel Expeller/Extract (PKE) with lower-nitrogen maize silage.³³ The use of PKE has been controversial in the public domain in Aotearoa in recent years. Use of palm products in supply chains have been linked to increases in emissions from deforestation overseas (in regions such as South East Asia).³⁴</p> <p>The overall impact of using low-nitrogen feed on emissions levels would depend on other aspects of farm management.³⁵ Increasing the proportion of these feeds in animals’ diets may reduce emissions, but likely only where these feeds are used as substitutes, rather than increasing overall feed demand.</p> <p>There are limits to the amount of some feeds which can be used. For example, feeding fodder beet above certain levels can be toxic for animals.</p> <p>Implementation time for low-nitrogen feeds is relatively short, as new crops can be grown in a matter of months.</p>

³² (Reisinger et al., 2017)

³³ (Bryant et al., 2020)

³⁴ This controversy persists even though efforts have been made to source sustainable PKE.

³⁵ For example, whether supplementary feed is used in addition to pasture to support higher stocking rates.

Options	Opportunities and challenges
<p>Reductions in application of synthetic nitrogen fertiliser</p>	<p>Reductions in synthetic nitrogen fertiliser can be part of the combination of management practices associated with reducing on-farm emissions.³⁶</p> <p>However, additional emissions reductions could be achieved through more drastic cuts in, or even the elimination of synthetic nitrogen fertiliser use in dairying.^{37,38} These emissions reductions would come through the reduction in direct nitrous oxide emissions from the fertiliser application and indirect reductions of nitrous oxide and biogenic methane as less pasture is grown and thereby consumed.</p> <p>Eliminating synthetic nitrogen fertiliser on dairy farms would mean lower levels of production. The evidence regarding the economic impact of this is mixed. While some farms would certainly become less profitable, there is also evidence that some dairy farms could maintain or increase their profitability while eliminating synthetic nitrogen.</p> <p>Eliminating synthetic nitrogen fertiliser could also have significant co-benefits, particularly for water quality through reduced nitrogen leaching.^{39,40}</p> <p>There is potential for farmers that eliminate synthetic nitrogen fertiliser use to attract a premium for their product. This could come through becoming a certified organic farm or achieving other emerging certifications that may be associated with an elimination of nitrogen fertiliser in the future, such as for regenerative agriculture.⁴¹ Recent premiums for organic milk have been strong, highlighting the potential for such approaches to overcome losses in profitability from lower input and lower production systems.</p>
<p>Once a day milking</p>	<p>Switching from a twice a day milking system to once a day milking can result in lower biogenic methane and nitrous oxide emissions, but could maintain profitability if reduced labour costs balance a reduction in total milk production.⁴² The extent to which this is the case is uncertain, and would vary widely depending on breed, farm management, farm layout and farmer skill.</p>

³⁶ (Journeaux et al., 2020; Reisinger et al., 2017)

³⁷ There is less emissions reduction potential for eliminating synthetic N use in other types of farming. Sheep, beef, and deer farms use small amounts of nitrogen fertiliser, and generally for more targeted strategic purposes. The potential is also limited in horticulture and arable farming because of the high levels of economic dependency on nitrogen fertiliser and the relatively small land areas mean the total emissions reduction potential is insignificant (Journeaux et al., 2020; Reisinger et al., 2017).

³⁸ (Glasse et al., 2013)

³⁹ (Yang et al., 2020)

⁴⁰ (Monaghan et al., 2008)

⁴¹ Noting that an elimination of synthetic nitrogen fertiliser is not a strict requirement of regenerative agriculture, which is an outcomes-based rather than an input-based approach.

⁴² (BERG, 2018)

Options	Opportunities and challenges
	<p>If cows are only milked once a day, they require less feed to support milk production which would lead to a drop in biogenic methane emissions. On some farms supplementary feed would be reduced to match lower production, which could lead to less nitrogen excreted onto soils and lower nitrous oxide emissions.</p> <p>Because fewer inputs (feed and labour) would be required, profitability would likely be maintained despite lower overall production. The BERG estimated that once a day milking could potentially lead to a 6-7% drop in emissions, without affecting profitability. Yet they note that there is limited experience with this approach in Aotearoa, so there is a high degree of uncertainty around the potential emissions reductions from this approach.⁴³ There may also be a ‘rebound’ effect as farmers seek to regain the lost production and use unutilised feed by increasing stock numbers.</p>
<p>Further integration of the dairy and beef industry</p>	<p>Using calves from the dairy industry for beef production reduces the need for beef breeding cows. Fewer beef breeding cows means less food is consumed, and therefore there are reduced greenhouse gas emissions (see Figure 7.2 on sources of emissions).⁴⁴</p> <p>However, it is unlikely that the feed not consumed by beef breeding cows would be left to go to waste. A farm manager could use this feed for other animals and keep total emissions levels about the same, similar to the rebound effect described in once a day milking.</p>
<p>Creating a diversified landscape</p>	<p>Different land uses within a farm, water catchments and ecosystems place different pressures on the land and on receiving environments, such as waterways.⁴⁵ Farmers could reduce emissions by switching some of their land away from livestock farming to lower-emissions uses. Many farmers have already done this by planting areas of pasture into crops, allowing native bush to regenerate on pockets of less productive land within their farms while also focusing on riparian planting along waterways.</p> <p>Planting forests and woody vegetation or supporting reversion to native bush, offers considerable carbon benefits and will be discussed in <i>Chapter 9: Removing carbon from our atmosphere</i>. Beyond forestry, horticulture land use could offer much higher profitability while producing considerably lower biological greenhouse gas emissions per hectare.⁴⁶ Estimates suggest that more than 1.5 million hectares of land currently in livestock farming could be (in principle) suitable for horticulture or arable cropping.⁴⁷</p>

⁴³ (BERG, 2018)

⁴⁴ (van Selm et al., 2021)

⁴⁵ (Stats NZ, 2021)

⁴⁶ The BERG estimates that that biological emissions from dairy are about 12 tCO₂e per hectare, and between 3.5-2.1 tCO₂e for sheep and beef. They estimate that biological emissions from horticulture range from 0.17 -1 tCO₂e per hectare.

⁴⁷ (Reisinger et al., 2017, p. 8). For example, apples, kiwifruit, grapes, vegetables and pulses.

Options	Opportunities and challenges
	<p>However, significant change in land use has not happened despite horticulture already being more profitable per-hectare than dairy or livestock farming in many instances. This indicates there are some barriers to shifting land use in this way. Some of the barriers identified are:</p> <ul style="list-style-type: none"> • Labour constraints, particularly around horticulture, are well documented.⁴⁸ • Capital requirements and high existing debt can make it difficult to invest in building the scale and infrastructure to support a higher production⁴⁹ – confidence is needed by both the landowner and their bank. • Gaining access to new markets is a slow process, linked to the negotiation of international agreements⁵⁰ and addressing non-tariffs barriers (e.g. government-to-government negotiations, biosecurity regulations).⁵¹ • Fragmented pockets of land suitable for horticulture and arable agriculture may not be large enough for standalone enterprises. • Limited supply chains and market saturation, particularly for expansion into new areas and/or crops.⁵² • Cultural barriers – some landowners identify themselves as livestock farmers and prefer the lifestyle. • Access to water is becoming more difficult with tightening restrictions and fewer large-scale projects. <p>Currently horticulture accounts for less than 3% of biological emissions from agriculture in Aotearoa, but this may increase if more land goes into horticulture. Therefore, investment in horticultural infrastructure now could position farmers to be open to future opportunities in horticulture. The careful use of fertiliser and irrigation will be important to minimise emissions from these land uses, as well as efforts to minimise the use of energy and fossil fuels for production and processing of horticultural products. As with pastoral farming, precision agriculture and on-farm decision support tools could assist with this, but rural connectivity may hinder their uptake.</p> <p>There is potential for Aotearoa to develop a plant-protein ingredients sector which would be complex and requires careful consideration and significant capital investment.⁵³</p>

⁴⁸ (NZIER, 2019)

⁴⁹ Productive kiwifruit orchards sell for about NZ\$350,000/ha for Green and NZ\$500,000/ha for Zespri Gold, severely limiting new entrants to the industry (Cradock-Henry, 2017).

⁵⁰ (Horticulture New Zealand, 2019)

⁵¹ (Westpac, 2016)

⁵² (Journeaux et al., 2017)

⁵³ (Food HQ, 2021)

Options	Opportunities and challenges
<p>Soils</p>	<p>Studies suggest there is potential for some soils to increase the quantity of carbon they store, even though Aotearoa generally has naturally high soil carbon stocks.⁵⁴ Some farm practices (for example the use of deeper-rooted pasture plants, inversion tillage or no-till pasture renewal) have been advocated by stakeholders as ways to increase carbon storage in the soil. However, there is currently no robust evidence of their long-term effectiveness in Aotearoa. Soil carbon can also be lost quickly during periods of drought or from soil erosion events, such as slips.⁵⁵</p> <p>It is not completely clear whether Aotearoa is increasing or decreasing in soil carbon stock overall. There is ongoing research to determine changes in soil carbon and how management practices, such as those outlined in the regenerative approach below, affect this. It may take decades of data to establish reliable links between management practices and soil carbon levels.^{56,57}</p> <p>Other areas of current focus for soil carbon research linked to practices include irrigated land use, and full inversion tillage for pasture systems as part of long-term pasture renewal (e.g. once every ~30 years). More information on soil carbon can be found in <i>Chapter 9: Removing carbon from our atmosphere</i>.</p>
<p>Regenerative agriculture</p>	<p>Regenerative agriculture involves techniques that focus on improving the quality and health of the whole ecosystem, including soils.⁵⁸</p> <p>Practices and principles that have been referred to as regenerative agricultural practices include no-till techniques, use of organic fertiliser, increasing diversity of plant species, cover cropping, and minimal use of herbicides, pesticides and synthetic fertilisers. These kinds of practices have been applied in other countries to increase the carbon stored in soil, protect the soil from erosion, minimise soil disturbance and reduce nutrient loss. Many farmers in Aotearoa have started applying some of these practices.⁵⁹</p> <p>Research on the efficacy of regenerative agriculture in Aotearoa is ongoing and there are no robust estimates of the potential emissions reductions. Some farmers have told us that the reduction in input costs, market premium and increased ecosystem services derived from using more regenerative practices has increased their profitability and resilience.⁶⁰</p>

⁵⁴ (McNally et al., 2017)

⁵⁵ (Schipper et al., 2017)

⁵⁶ (NZAGRC, 2019b)

⁵⁷ (Smith et al., 2020)

⁵⁸ There are no formal definitions of regenerative agriculture. For an overview of the latest definitions see: (Newton et al., 2020) and a summary of principles: (White, 2020).

⁵⁹ (Grelet et al., 2021)

⁶⁰ (Maan, 2020)

Options	Opportunities and challenges
	The Ministry for Primary Industries (MPI) has an ongoing fund for research proposals to investigate regenerative farming practices. ⁶¹
Organic agriculture	<p>The term organic refers broadly to agricultural practices that cover resource usage and animal welfare. Organic practices frameworks have been established by several international organisations and many countries to formalise and certify organic producers.⁶²</p> <p>Some of the key international organic certification provisions are:</p> <ul style="list-style-type: none"> • No or restricted use of chemicals in fertilisers and pesticides • Crops and pastures to be planted with untreated organic seed • No or restricted use of hormones and antibiotics • No use of genetic modification • Dairy wastewater to be retained on site and must not pollute natural waterways. <p>Many organic farmers have managed to attract a premium for their products, which can increase profitability even if production drops.⁶³</p>

7.4 Technological changes

Some technologies target both biogenic methane and nitrous oxide, while others reduce one specific gas. The technologies are at various states of readiness, with some on the market (e.g. urease inhibitors), some expected to be on the market in the next few years (e.g. nitrous oxide inhibitors) and others still being developed in laboratories (e.g. biogenic methane vaccines).

The use of any compounds of veterinary medicines to help manage plants and animals is controlled by the Agricultural Compounds and Veterinary Medicines (ACVM) Act 1997. This is one of the pieces of legislation which plays an important role in ensuring products from Aotearoa are safe and trusted in international markets.

The use of inhibitors could pose risks to trade, food safety and animal and plant health. We have heard from stakeholders that it is not clear whether inhibitors are covered by the ACVM, and that it could be a long process for approving them under the ACVM if they are.⁶⁴

Table 7.2: Opportunities and challenges of technological changes for reducing agricultural emissions

⁶¹ (Ministry for Primary Industries, 2021)

⁶² (KPMG, 2018)

⁶³ (Yang et al., 2020)

⁶⁴ (Ministry for Primary Industries, 2020)

Options	Opportunities and challenges
<p>Breeding for low-emissions animals</p>	<p>Just as livestock can be bred for favourable traits like improved meat or milk production, selective breeding of animals to be low emitting is attracting increasing attention as an emissions reduction option.</p> <p>Targeted breeding of livestock to emit less biogenic methane per kilogram of feed consumed has been an active area of research in Aotearoa for many years. However prioritising breeding for this trait could come at the opportunity cost of breeding for other desirable traits.</p> <p>Research has identified a large variation in the amount of biogenic methane different sheep emit when eating the same diet. This low biogenic methane trait has been shown to be heritable. It is starting to be introduced into the national flock,⁶⁵ and could filter through the sheep population in a couple of decades as the national flock turns over.</p> <p>Low biogenic methane sheep have been monitored for growth, reproduction and performance, and they appear to be outperforming high biogenic methane sheep on commercial breeding values.⁶⁶ The sheep are now being trialled by breeders with effort focused on how this low biogenic methane trait can be added into the sheep breeding index.</p> <p>Research into the potential for breeding low-emissions cows is less advanced. Some studies have confirmed that their biogenic methane yield also varies significantly and the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) is working to identify genetic traits for low-emitting cattle, and the potential impacts on animal production.</p> <p>If the low biogenic methane trait is shown to be heritable in cattle, it could be incorporated into the dairy cattle population relatively easily as most dairy cattle in Aotearoa are bred from a small number of bulls. It would likely take at least 10-15 years to introduce this approach to the national herd, as the research is in early stages, and the turnover rate for an average dairy herd is around 8-10 years.</p>
<p>Plant breeding/modification</p>	<p>New research has focused on new types of low-emissions feed. Scientists at AgResearch have developed a type of genetically modified ryegrass with the potential to reduce emissions of both biogenic methane and nitrous oxide. The ryegrass is currently being trialled in the United States. Initial modelling suggested that the ryegrass may lead to a 15% reduction in biogenic methane emissions per kilogram of feed consumed, and a 10% reduction in nitrous oxide emissions.⁶⁷</p> <p>In theory, a low-emissions ryegrass could have the technical potential to replace current dominant ryegrass species used as pasture in Aotearoa. However, the product is still in its early stages and its efficacy is far from certain. The use of genetic modification in Aotearoa would have to be considered alongside wider issues, such as potential trade premiums and public acceptability.</p>

⁶⁵ (Rural News Group, 2020)

⁶⁶ (NZAGRC, 2019a)

⁶⁷ (Reisinger et al., 2018)

Options	Opportunities and challenges
	Views on genetic modification in te ao Māori deserve further exploration. The level of uptake of genetically modified ryegrass is hard to predict.
Biogenic methane inhibitors	<p>Biogenic methane inhibitors are chemical compounds that, when fed to livestock, reduce emissions by targeting the biogenic methane-producing microbes (methanogens) within the rumen. An inhibitor can reduce the emissions methanogens produce either by killing them, or by depriving them of the hydrogen they need to produce biogenic methane.</p> <p>A single dose of a biogenic methane inhibitor would not permanently reduce biogenic methane production. For it to be effective, the inhibitor would need to be inside the rumen while feed is being digested. For this reason, it would need to be administered frequently (for example, mixed in with feed or water).⁶⁸</p> <p>Mixing an inhibitor into animal feed is not well suited to Aotearoa pastoral system. An alternative approach could be to deliver it by inserting a bolus or tablet that would slowly dissolve inside the rumen. This would take time and effort to administer and would require a compound that is effective at low concentrations.</p> <p>There are already biogenic methane inhibitors that are close to market. The product 3-nitrooxypropanol (Bovaer, manufactured by the Dutch-owned company DSM) is well advanced, and likely to be available to European producers in the next few years.⁶⁹ Several long-term tests have shown Bovaer to be effective at reducing biogenic methane emissions by around 30%, but it has been developed to work in feedlot-type systems where the compound is mixed into every mouthful of feed the animals consume. DSM are working with partners in Aotearoa to develop a slow-release product, pasture-based delivery system or feed to young animals that would be better suited to the pastoral system in Aotearoa. This could be available in the next few years, subject to the progress on regulations governing the use of inhibitors in Aotearoa.^{70,71}</p> <p>Some readily available compounds, such as bromoform, have also been proven to act as a biogenic methane inhibitor. However, they have not been widely used as they are suspected carcinogens and ozone-depleting substances. Some seaweeds contain bromoform, and research is currently underway to see if feeding cows or sheep seaweed could effectively and safely reduce biogenic methane emissions.^{72,73}</p>

⁶⁸ (NZAGRC & PGgRc, 2017)

⁶⁹ (DSM, 2019)

⁷⁰ (AgMatters, 2020a)

⁷¹ The availability is likely to be impacted by the work of the Ministry for Primary Industries, which is considering options for managing the regulatory oversight of inhibitors to make sure the primary sector can safely and effectively use inhibitors, see (Ministry for Primary Industries, 2020).

⁷² (CSIRO, 2018)

⁷³ A recent study found supplementing *Araspagopsis taxiformis* (seaweed) had no measurable bromoform residues, no detrimental iodine residual effects in the product, and did not alter meat quality or sensory properties (Roque et al., 2021).

Options	Opportunities and challenges
<p>Biogenic methane vaccine</p>	<p>The goal of a biogenic methane vaccine is to trigger an animal’s immune response to generate antibodies that suppress the activity of methanogens. These antibodies would be produced in the animal’s blood and saliva, and continually delivered into the rumen through the saliva.⁷⁴</p> <p>Because a vaccine would trigger the production of antibodies, one dose of a vaccine would, in theory, suppress biogenic methane production over a prolonged period. A vaccine would be particularly well-suited to Aotearoa pasture-based farming system as it would only need to be administered periodically. Research suggests that once developed, a biogenic methane vaccine could be effective in livestock globally.</p> <p>Research to develop a biogenic methane vaccine is still in relatively early stages. Researchers have had some success in laboratory trials, but to date the process has not been proven to work in animals.⁷⁵ The BERG report assumes that a successful biogenic methane vaccine could achieve a similar level of reduction to a biogenic methane inhibitor – reducing biogenic methane emitted per animal by around 30%.</p> <p>Without a working prototype, the biogenic methane reduction potential of this approach remains speculative. Researchers estimate that any vaccine is still a long way off and it is almost certain that a vaccine, if it can be developed, would not be available before 2030.</p>
<p>Nitrification inhibitor</p>	<p>Nitrification inhibitors are chemical compounds that slow down the rate at which microbes in the soil convert nitrogen into nitrous oxide.⁷⁶ Inhibitors can be spread onto pasture or incorporated into nitrogen fertilisers. Although nitrification inhibitors already exist, they are treated here as a future emissions reduction option because the use of these nitrification inhibitors have been discontinued.</p> <p>The nitrification inhibitor dicyandiamide (DCD) was used in Aotearoa for several years, until it was withdrawn from use in 2012 after traces of the compound were found in milk.⁷⁷ Although it is considered harmless in trace amounts, there is currently no international food safety standard for DCD. MPI are working to develop international standards, which means DCD could become available to farmers again.⁷⁸</p> <p>Urease inhibitors are coated onto fertiliser and suppress the microbial processes that break down the urea in the fertiliser which lead to nitrate and nitrous oxide. Urease inhibitors can also increase the effectiveness of fertilisers and they already make up a substantial proportion of market sales.⁷⁹</p>

⁷⁴ (Reisinger et al., 2018)

⁷⁵ (NZAGRC, 2019a)

⁷⁶ (Ruser & Schulz, 2015)

⁷⁷ (Ministry for Primary Industries, 2016)

⁷⁸ (Reisinger et al., 2018, p. 34)

⁷⁹ Ravensdown – personal communications.

Options	Opportunities and challenges
	<p>Based on experience with DCD, the effectiveness of nitrification inhibitors varies widely, affected by factors like temperature, soil moisture and the timing of fertiliser application. A series of studies around the country showed that the effectiveness of DCD on individual urine patches ranged from 18% to 82%, with an annual effectiveness of about 40%.⁸⁰ As its application would be limited to accessible land, only a proportion of farmers might use an inhibitor.</p> <p>Research is underway into novel inhibitors that are more effective than DCD, lower cost, and present minimal risk of residues.</p> <p>There are also regulatory barriers to using some of these approaches. Most inhibitors are regulated under the Hazardous Substances and New Organisms (HSNO) Act 1996, which protects the environment and the health and safety of people and communities by preventing or managing the adverse effects of hazardous substances and new organisms. However, HSNO does not manage risks such as trade risks from residues, as occurred with DCD.⁸¹</p>

7.5 Assisting farmers to make change

Enabling practice change and encouraging technology uptake is not simple. Some change can occur naturally as individual farmers see opportunities or farmers come together to share ideas. However, enabling change at a national scale and at a faster rate of adoption needs to be well planned. Advisory services can support the adoption of knowledge and technology as well as encouraging behaviour change and are important in achieving on-farm emissions reductions.⁸² There are a range of factors such as farm type, geography and climate which influence the adoption of new practices. Adoption is not always immediate, simple or as expected. Therefore, having a diverse range of advisory services available can provide greater support.

7.5.1 Advisory Programmes

Effective advisory programmes can help farmers gain the knowledge and skills they need to identify possible changes to achieve improved economic, social and environmental outcomes. Advisory programmes can also provide farmers support for adoption of new practices and technologies. Advisory programmes are often delivered by independent and trusted experts. It is beneficial when these experts can assess the entire farming landscape and provide support regarding a range of land uses. Farmers get information in a range of ways, including from formal and informal networks, field days, rural professionals, catchment groups, farm visits, demonstration farms and their sector bodies.⁸³ Future advisory services can build on the services and networks that already exist to avoid duplication and ensure integration with other advice and training farmers are receiving on outcomes like productivity, water quality, biodiversity and soil health.

⁸⁰ (Parliamentary Commissioner for the Environment, 2016)

⁸¹ (Ministry for Primary Industries, 2020)

⁸² (Ministry for Primary Industries, 2015)

⁸³ (Beef + Lamb New Zealand, 2021)

Industry bodies, agricultural processors, fertiliser companies and central and local government are all involved in advisory programmes. He Waka Eke Noa has stated that their goals and milestones will be aligned with existing advisory (information-sharing and education) programmes.⁸⁴ Regional councils across Aotearoa also have policy and advisory programmes to support agricultural emissions reduction and environmental improvement. It is important that there is alignment between national, regional and local advisory programmes for efficiency and effectiveness.

7.5.2 Advisory services for Māori

There is evidence that the current mainstream models of agricultural education, training and advisory services are not fit for purpose for Māori needs.⁸⁵ Due to the complexities including land ownership structures and governance, Māori landowners and those working on Māori land need bespoke solutions to support emissions mitigation. Programmes and advisory services that target the specific needs of Māori landowners with their unique governance and decision-making challenges are often more effective at supporting practice change than the current mainstream approaches.

7.5.3 Farm advisors

Farmers will need advice from experts to understand how to measure agricultural emissions and for the implementation of measurable emissions reduction practices. Building the greenhouse gas measurement and mitigation skillset of farm advisers across Aotearoa will take some years and investment in training organisations.⁸⁶ It is important there are enough farm advisers with this capability to assist farmers to make changes to meet 2050 targets under the Climate Change Response Act (CCRA). These advisers can also provide support to farmers to know their greenhouse gas emissions by the end of 2022 to meet their obligation under the CCRA.

7.5.4 Farm environment plans

By 1 January 2025, all farms will be required to have a written plan in place to measure and manage their greenhouse gas emissions through farm planning.⁸⁷ This could be achieved with a Farm Environment Plan (FEP) with a greenhouse gas management component. A FEP is a tool that can help farmers recognise on-farm environmental risks and set out a programme to manage those risks. FEPs are unique to a property and reflect factors such as the local climate, soil type, the type of farming operation and actions used on-farm.⁸⁸ There are a range of emissions calculation methods that can be used to quantify greenhouse gas emissions. The complexity of the calculation method influences which emissions reduction actions can be recognised. The agricultural sector, Government and Māori Primary Sector Climate Action Partnership published guidance on managing greenhouse gas emissions within farm planning in December 2020.⁸⁹

⁸⁴ (He Waka Eke Noa, 2021)

⁸⁵ (BERL & FOMA, 2019)

⁸⁶ (BECA, 2018)

⁸⁷ (*Climate Change Response (Zero Carbon) Amendment Act 2019 No 61, Public Act Contents – New Zealand Legislation*, 2019 Section 5)

⁸⁸ (DairyNZ, 2021)

⁸⁹ (He Waka Eke Noa, 2020)

7.5.5 Behaviour change

Research shows that there are a complex range of factors driving farmer behaviour across a range of socio-economic factors such as personal and family circumstances, goals, support networks, financial security, the personality of the farmer and their interaction with communication channels. A literature review⁹⁰ shows that most learning is self-directed, and that other farmers are an important source of information to their fellow farmers. While group learning is important, particularly to give positive reinforcement, the greatest level of learning takes place at a 1:1 level. From the literature review it is also clear that achieving farmer behaviour-change is a specialist skill that requires expertise in a range of systems, approaches, and practical implications of information, technology or management practices.

Barriers to behaviour change include a range of factors such as economic, inadequate availability of information, lack of institutional support, resistance to change, compatibility with existing practices and perceived efficiency of the practice or access to finance.

7.6 Research and development

There are many existing research programmes within Aotearoa and internationally which support agricultural greenhouse gas measurement and mitigation including:

- The New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC), which was created to build on existing research, working with existing organisations to create an effective, trusted partnership to bring cost-effective, simple solutions to Aotearoa farms, and contribute world leading results to the international science community.⁹¹
- The Pastoral Greenhouse Gas Research Consortium (PGgRc) exists to provide knowledge and tools for the farmers of Aotearoa, so they can mitigate greenhouse gas emissions from the agricultural sector. The PGgRc is funded by eight agricultural sector partners in Aotearoa and works in collaboration with the New Zealand Government.⁹²
- Crown Research Institutes and Universities in Aotearoa which undertake research relevant to agricultural emissions reductions.⁹³
- Private organisations (e.g. Alltech)
- The Global Research Alliance which has the goal of bringing countries together to find ways to grow more food without growing greenhouse gas emissions.⁹⁴ Aotearoa is a member of the Alliance.

It is important that there is a coordinated approach to developing and implementing the necessary technologies and practice changes. This can be done through a research and development strategy and associated investment which aligns with the needs of farmers and policy timeframes. There is also a need for a clear pathway for research and new technologies to be utilised on farms for

⁹⁰ (Journeaux et al., 2018)

⁹¹ (NZAGRC, 2021)

⁹² (Pastoral Greenhouse Gas Research Consortium, 2021)

⁹³ (Science New Zealand, 2021)

⁹⁴ (Global Research Alliance, 2021)

effective emissions reductions. Effective communication and education alongside new technologies can support their success.⁹⁵

7.7 Early action

Policy decisions have not yet been made on how farm emissions could be priced, and if they would be benchmarked against a specific date. Many farmers are hesitant to take action before this decision is made. The CCRA requires this decision to be made by the end of 2022, after which farmers could have more certainty that the actions they take to reduce on-farm emissions now would be recognised and rewarded.⁹⁶

There are farmers across Aotearoa that are proactive in their decisions and actions to reduce emissions from their farms. It is important that decisions on how emissions are priced take this into account and reward early action where appropriate.

⁹⁵ (New Zealand Productivity Commission, 2018)

⁹⁶ (He Waka Eke Noa, 2019)

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