Ministry for Primary Industries
Manatū Ahu Matua

Impacts of climate change mitigation policy scenarios on the primary sector

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Contents

Page

Glossary

Biological emissions: Refers to the methane and nitrous oxide emissions from New Zealand agriculture.

Carbon sequestration: Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide, such as by growing trees or capturing carbon and storing it.

Emissions factor: A factor that provides the estimated GHG emissions associated with the production of a product. In this report, the emissions factor relates the tonnes of carbon dioxide equivalents (t/CO_2e) emitted for each tonne of milk solids or kilogram of meat produced or tonne of nitrogen fertiliser used by farmers.

Free allocation: An allocation of GHG emissions provided at no cost to an emitter. For example, 90% free allocation in the agricultural context means 10% of the GHG emissions being emitted by a farming operation are paid for in any given year.

GHG emissions price: The price paid by farmers for the GHG emissions associated with their farming operation or by processors for the GHG emissions for the meat and milk they process or fertiliser they sell. The GHG emissions factors assigned to milk, meat and fertiliser are a proxy for the GHG emissions associated with the production of these products.

Incentive payment: The total payment a farmer receives as an incentive to reduce GHG emissions through changing farm management or adopting new technologies.

Incentive price: The per unit price paid to farmers for the reduction in GHG emissions they achieve. The price is the unit price for each tonne of CO_2e reduced from changing management practices or adopting new technologies that lower the GHG emissions from the farm.

Mitigation option: Management practices or technologies that reduce the methane and/or nitrous oxide emissions generated by activities on a farm.

Point of obligation: The point of obligation in the NZ Emissions Trading Scheme is the entity that is required to report a defined set of information and surrender emissions units. An 'upstream' point of obligation is at a point in the supply chain before the emissions are generated (e.g. fertiliser manufacturers). A 'downstream' point of obligation is at a point in the supply chain after the emissions are generated (e.g. at the processor level for livestock emissions).

Executive Summary

He Waka Eke Noa, a partnership between the primary sectors, was formed to develop a system for measuring, managing, and reducing agricultural greenhouse gas emissions (GHG), rather than using farm products as a proxy for GHG emissions in the NZ Emissions Trading Scheme (ETS). In 2022, He Waka Eke Noa provided a set of recommendations to the Minister for Agriculture and the Minister for Climate Change on the pricing of agricultural emissions.

The purpose of this report for the Ministry for Primary Industries (MPI) and Ministry for the Environment (MfE) is to provide modelling and an analysis of a range of pricing options associated with different climate policy scenarios to support ministerial decisions and inform the Regulatory Impact Assessment for these scenarios. The analysis assesses the environmental and economic impacts of the climate policy scenarios.

For this analysis, we use an agri-environmental economic optimisation model – New Zealand Forestry and Agricultural Regional Model (NZFARM). This national-scale analysis provides insights into the adoption of management practices and technologies to reduce GHG emissions, and changes in net agricultural and forestry revenues, GHG emissions, carbon sequestration, agricultural production, and land use.

Scenarios

This modelling and analysis included 8 primary climate policy scenarios (Table S1):

- GHG target scenario
- Processor ETS scenario where all mitigation options are rewarded
- Processor ETS scenario where only technology mitigation options are rewarded
- Processor Hybrid scenario where methane and nitrous oxide emissions have the same price, and technology mitigation options are rewarded
- Processor Hybrid scenario with split gas prices where methane and nitrous oxide emissions have different prices, and technology mitigation options are rewarded
- Farm Split Gas Levy scenario where methane and nitrous oxide emissions have different prices, and technology mitigation options are rewarded
- Farm LUC Rebate scenario where methane and nitrous oxide emissions have the same price, and a rebate is paid based on Land Use Capability class
- Farm LUC Rebate scenario with split gas prices where methane and nitrous oxide emissions have different prices, and a rebate is paid based on Land Use Capability class.

These scenarios were provided by, and their parameterisation agreed with, the MPI and MfE. The modelling assessed the potential GHG emissions reductions for the different scenarios at the same NZU price (\$108.62/tCO_2e) to determine how the economic and environmental (GHG) impacts changed between the scenarios. Biological GHG emissions (methane and nitrous oxide) and carbon sequestration were included in this analysis. Given the uncertainty surrounding the cost and effectiveness of the technology mitigation options available to the pastoral sectors to reduce their biological emissions, two technology settings were modelled. The 'tailwind' technology setting reflects the situation where technologies are more cost-effective in 2030, while the 'headwind' technology setting is where the technologies are less cost-effective in 2030. Most scenarios included incentive payments to encourage mitigation option adoption or a rebate. The modelling of further refinements to the processor-based and Farm Split Gas Levy scenarios are included in the Section 8 Annex.

Table S1 Overview of scenarios modelled

Scenario name	Description	Point of obligation	Basis of payment	Basis of rebates to/incentives for farmers
GHG Target	10% reduction in biogenic CH_4 and 11% reduction in long-lived GHG emissions by 2030.	Not applicable	Not applicable	Not applicable
Processor ETS (all mitigation options rewarded)	Legislated backstop for agricultural biological emissions in the ETS with free allocation. GHG reductions from all mitigation options are rewarded.	Processor	Emission factor for milk, meat & fertiliser	Reductions in GHG emissions from all mitigation options
Processor ETS (technology mitigation options rewarded)	Legislated backstop for agricultural biological emissions in the ETS with free allocation. GHG reductions from technology mitigation options are rewarded.	Processor	Emission factor for milk, meat & fertiliser	Reductions in GHG emissions from technology mitigation options
Processor Hybrid (same gas price)	Split gas pricing at processor level where CH_4 and N_2O are priced the same and with free allocation. GHG reductions from technology mitigation options are rewarded.	Processor	Emission factor for milk, meat & fertiliser	Reductions in GHG emissions from technology mitigation options
Processor Hybrid (split gas price)	Split gas pricing at processor level where CH_4 and N_2O are priced differently and with free allocation. GHG reductions from technology mitigation options are rewarded.	Processor	Emission factor for milk, meat & fertiliser	Reductions in GHG emissions from technology mitigation options
Farm Split Gas Levy	Split gas pricing at farm level for biological GHG emissions where CH_4 and N_2O are priced differently. Prices are initially low as there is no free allocation. GHG reductions from technology mitigation options are rewarded via different CH_4 and N_2O incentive payments. A range of methane incentive payments are modelled.	Farm	CH_4 & N_2O emissions	Reductions in GHG emissions from technology mitigation options
Farm LUC Rebate (same gas price)	Split gas pricing at farm level for biological GHG emissions where CH_4 and N_2O are priced at the NZU price. A rebate to farmers is assigned by LUC class to reflect the free allocation.	Farm	CH_4 & N_2O emissions	LUC classes on the farm
Farm LUC Rebate (split gas price)	Split gas pricing at farm level for biological GHG emissions where CH_4 and N_2O are priced differently. The rebate to farmers is assigned by LUC class to reflect the free allocation.	Farm	CH_4 & N_2O emissions	LUC classes on the farm

Note: All scenarios retire riparian areas as a proxy for the implementation of the National Policy Statement for Freshwater Management and National Environmental Standard for Plantation Forestry.

High-level results: Primary scenarios

The key modelling results for changes in GHG emissions, land use, net revenue, and production for each of the primary scenarios is provided in Table S2. These results are for the tailwind technology setting and where there is no payment for the new carbon sequestered in the scrub mitigation option for the sheep and beef sector. Results for the other settings are in the main body of the report.

GHG emissions

- All scenarios, except Farm LUC scenarios, are predicted to achieve the GHG targets for reducing methane emissions.
- Most scenarios are predicted to achieve the GHG targets for reducing biological GHG emissions. The exceptions are the Farm LUC scenarios and the Farm Split Gas Levy with a higher methane incentive price.
- While mitigation options to reduce GHG emissions are important, at some incentive prices they are unlikely to be sufficient to reduce GHG emissions to future target levels, unless the effectiveness of those mitigation options improves even more to counteract the effect of more livestock remaining in the agriculture sector.

Most scenarios achieve the GHG targets for GHG emissions reductions. The processor-based scenarios with the same emissions price for methane and nitrous oxides are estimated to have reductions in GHG emissions of around 18%. The split gas pricing for the processor hybrid scenario where the emissions price of methane is lower than the long-lived gas price for nitrous oxide emissions results in a smaller decrease in GHG emissions reductions, at just under 12%. The lower methane emissions price benefits all pastoral farming, and we see smaller area reductions of dairy and sheep and beef land. Correspondingly, we see smaller increases in forestry, arable and horticulture land from dairy or sheep and beef land being converted to these land uses.

Most of the Farm Split Gas Levy scenarios show GHG emissions reductions between 14.4 and 15%, except for the highest methane incentive price with the tailwind technology setting. This latter scenario is projected to achieve the methane reduction target but not the GHG reduction target. Here, the incentive price means the adoption of more expensive (and more effective) mitigation options like bromoform bolus is profitable, and thus less land moves out of sheep and beef and dairy. This leads to a corresponding smaller reduction in methane and nitrous oxide emissions.

The Farm LUC Rebate scenarios do not meet the GHG targets because of the rebate system implemented.

Overall, the processor-based scenarios with the same emissions price for methane and nitrous oxide emissions result in the biggest reduction in GHG emissions, followed by most of the Farm Split Gas Levy scenarios, and then the Processor Hybrid scenario with different GHG emissions prices. The GHG Target scenario is modelled to meet the GHG targets.

Land use

- Land use change for the dairy sector ranges from 2 to 3% for the scenarios which use split gas emissions pricing but is around 5% in the processor-based scenarios where methane and nitrous oxide emissions are priced the same.
- The sheep and beef sector are estimated to experience the greatest land use change, with the extent of change being smaller for those scenarios with split gas emissions pricing.
- Arable, horticultural and forestry area are predicted to increase across all scenarios.

There is a similar land use trend for the processor-based scenarios with the same price for methane and nitrous oxide emissions. Land in sheep and beef is estimated to fall by around 20% and dairy by 5–6%, while forestry area increases by about 5%, arable between 10 and 11%, and fruit and vegetables between 4 and 7%.

The Processor Hybrid scenario where methane emissions are priced lower than nitrous oxide emissions see less land moving out of the pastoral land uses (~11% for sheep and beef and ~3% for dairy), and correspondingly less land moving into forestry (~3%), arable (~6%) and horticultural (2–4%) uses. The lower methane emissions price means the impact on profitability from pricing biological GHG emissions is lower causing less land to change uses.

In the Farm Split Gas Levy scenarios, the land use change induced by the GHG emissions prices paid by farmers remains relatively stable across incentive prices until the higher methane incentive price. At 5 times the base methane incentive price ($5.02/ t$CO_2$e for this analysis), there is an estimated reduction in sheep and beef area of ~18%, while at 10 and 20 times the base methane incentive price there is an ~17% and 4% decrease in area, respectively. For dairy, there is an estimated 2.3% decrease in area at 20 times the base methane incentive price, and a 2.7–3.1% area decrease at lower incentive prices.

Comparing the two similar split gas price scenarios – Processor Hybrid (split gas price) and Farm Split Gas Levy (20 times the base methane incentive price) – shows a difference in the extent and type of land use change induced in the sheep and beef sector. The emissions payment in the processor-based scenarios are based on emissions factors for meat and milk production and fertiliser use, and GHG emissions are the basis of the farm-level scenarios emissions payment. Therefore, different sheep and beef farm systems are exposed to different emissions pricing signals between the two scenarios. While the meat emissions factor is meant to account for emissions associated with wool production, the pricing signal for wool appears to be muted as those farm systems with greater wool than meat production in the South Island are less impacted in the Processor Hybrid scenario. In total there is an estimated 11% decrease in sheep and beef area in the Processor Hybrid scenario, compared with a 3.5% decrease in area in the Farm Split Gas Levy. The greater reduction in South Island sheep and beef area in the Farm Split Gas Levy is being offset by a greater change to the beef-only system in the North Island. The impact on the area of dairy land use is similar for both scenarios (between 2 and 3%) as milk is the only commodity produced, and it is explicitly priced in the Processor Hybrid (split gas price) scenario.

In all scenarios there is an increase in horticultural (from 0.2 to 6.9% depending on the scenario) and arable (from 2 to 10.9% depending on the scenario) areas as some of the pastoral land moves to those land uses in response to the pricing of GHG emissions. The Forestry area is also estimated to increase in all scenarios (from 0.1 to 5.2%, depending on the scenario). As with horticultural and arable land, the increase in area between scenarios reflects the variation in GHG emissions pricing.

The GHG Target had quite a different pattern of land use change compared to the other scenarios. This scenario is designed to meet the GHG targets without any emissions payments or incentives. The 'least economic cost' approach to meeting the GHG targets is to reduce dairy area by 24%, while other land uses increase in area. While the area in sheep and beef production increased, this sector also had the largest uptake of the reduced stocking rate management practice. This scenario shows how emissions pricing and incentives changes the distribution of costs and benefits.

Net revenue

- There is an estimated 4 to 5% reduction in net revenue for the agricultural sector from the pricing of GHG emissions for most scenarios.
- Across the scenarios, the sheep and beef sector are estimated to see the biggest reduction in net revenue (12 to 36% reduction) followed by the dairy sector (~7 to 11% reduction). Arable and horticultural net revenue is expected to increase (~2 to 10% increase).
- There is estimated to be a slightly greater impact on net revenue when only the technology mitigation options are rewarded in the Processor ETS scenario compared to where all mitigation options are rewarded.

The processor-based scenarios with the same GHG emissions price are estimated to have the largest decrease in overall net revenue (5.8–5.9%) for the agricultural and forestry sectors, followed by Farm Split Gas Levy (with lower methane incentive prices) at ~5–5.1%, the Processor Hybrid (split gas price) scenario at 4.5–4.6%, and the Farm Split Gas Levy (with highest methane incentive price). The Farm LUC Rebate scenarios have the lowest decrease in net revenue at 3.9% and 2.8% respectively but don't meet the GHG targets.

Again, there is a difference between the split gas emissions price scenarios for the processor and similar Farm Split Gas Levy scenario (which have similar methane but different nitrous oxide incentive prices) and this seems to relate to the pricing signal. With the Farm Split Gas

Levy scenario, the estimated decrease in net revenue for South Island sheep and beef systems, which have greater wool production, is higher than the Processor Hybrid scenario where wool production is not explicitly priced. In the North Island, this higher methane incentive price induces a greater switch to the beef-only system with the adoption of bromoform bolus in the Farm Split Gas Levy scenario. This change mutes the impact on net revenue for the North Island and the sector overall for this scenario. The impact on net revenue for the dairy sector, however, is similar for both scenarios at just under a 7% decrease.

There is a greater impact on net revenue when only the technology mitigation options are rewarded in the Processor ETS scenarios as more land is estimated to be retired than where all mitigation options are rewarded.

The total net revenue for the horticultural and arable sectors increases in all scenarios as more land moves into these uses and away from the pastoral uses.

Agricultural production

- For most scenarios, beef production falls the most with emissions pricing followed by lamb production and then wool production. Milk solid production also falls but by less than meat and wool production.
- There are emissions and incentive prices which induce a change to a beef-only system in the sheep and beef sector when the uptake of bromoform bolus becomes profitable. Bromoform bolus, while expensive, is effective at reducing methane emissions. This estimated increase in the area of this beef-only system leads to a corresponding increase in beef production.
- Horticultural and arable production increases in all scenarios.

Similar reductions in the production of milk solids, lamb, beef, and wool occur for the processor-bases scenarios with the same GHG emissions prices. For the tailwind technology setting, there is a ~9.5% decrease in milk solids, ~23.5% decrease in lamb, ~61% decrease in beef, and ~22% decrease in wool. The smaller impact on beef production with split gas pricing in the processor hybrid scenario flows from the lower methane emissions price resulting in less land use change. The greater reduction in beef production compared with lamb and wool for all processor-based scenarios appears to reflect there is no explicit GHG emissions pricing of wool production. Therefore, those sheep and beef systems with greater beef production are more affected by a GHG emissions price than those with lower or no beef production.

At higher methane incentive prices for the Farm Split Gas Levy scenario though, the modelling shows it becomes profitable for some mixed sheep and beef farm systems area to move into a beef-only farm system with the adoption of bromoform bolus. Bromoform bolus is an expensive, but effective, mitigation option that becomes a viable mitigation option at higher methane incentive prices. Bromoform bolus is adopted on both new and existing areas of this beef-only system. This reduces the impact on beef production. It should also be noted the beef production figures do not include the beef from dairy cull cows, so the actual beef production impacts are likely less than modelled. While the quantity of beef from dairy cull cows is not included in the modelling, the revenue from the sale of these cows is included in net revenue for each dairy system.

The production of horticultural and arable commodities increases in all scenarios. While timber production was not tracked in the modelling (only net revenues), based on the increase in forestry area across all scenarios, an increase in timber production would be expected. However, this increase is mitigated by the riparian areas being taken out of production with the implementation of the National Environmental Standard for Plantation Forestry.

Emissions payments, incentive payments and rebates

The payments for GHG emissions by the farmer or the processor vary depending on the emissions prices they face. The incentive payments in each scenario were constrained to be equal or less than the total payments made by processors or farmers for their GHG emissions. In most instances, the incentives payment is a fraction of the GHG emissions payments. There are less mitigation options adopted in the headwind technology setting than the tailwind technology setting resulting in lower incentive payments in those scenarios.

Table S2 Relative Change (%) in the primary scenarios GHG, methane and nitrous oxide emissions, land use, net revenue and production compared with the 2030 Baseline (tailwind technology setting with no payment for carbon sequestered in the scrub mitigation option for the sheep and beef sector)[a]

Scenarios	2030 Baseline	GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)[d]	Farm Split Gas Levy (x5)[d]	Farm Split Gas Levy (x10)[d]	Farm Split Gas Levy (x20)[d]	Farm LUC – Same Price	Farm LUC – Diff Price
	tCo₂e	*GHG emissions*										
GHG emissions[c]	50,569,127	-10.4%	-18.2%	-18.3%	-18.3%	-11.7%	-14.4%	-14.5%	-15.0%	-8.4%[b]	1.4%[b]	1.5%[b]
CH_4 emissions	38,216,894	-8.5%	-19.0%	-19.1%	-19.1%	-12.3%	-15.0%	-15.1%	-16.3%	-10.7%	1.6%[b]	1.8%[b]
N_2O emissions	12,352,233	-16.2%	-15.9%	-15.8%	-15.8%	-9.9%	-12.6%	-12.6%	-10.9%	-1.3%	0.6%	0.6%
	'000 ha	*Land use area*										
Arable	213	-1.2%	10.3%	10.6%	10.6%	5.7%	6.2%	6.1%	6.0%	3.6%	2.4%	2.0%
Fruit	138	11.2%	4.6%	4.7%	4.7%	2.7%	3.4%	3.4%	3.2%	2.1%	0.3%	0.2%
Vegetables	18	20.7%	6.7%	7.0%	6.9%	3.8%	4.6%	4.5%	4.4%	3.0%	0.4%	0.4%
Dairy	2,632	-24.0%	-5.3%	-5.7%	-5.7%	-3.0%	-2.7%	-2.7%	-3.1%	-2.3%	-2.0%	-2.0%
Sheep & Beef	7,564	4.6%	-19.7%	-20.0%	-20.0%	-11.0%	-17.8%	-17.8%	-16.7%	-3.5%	7.8%	8.0%
Forestry	2,986	7.2%	4.9%	5.1%	5.1%	2.8%	3.9%	3.9%	3.7%	2.2%	0.1%	0.1%
Scrub/Ind. forest	8,136	0.7%	17.9%	18.2%	18.2%	10.0%	15.8%	15.8%	14.9%	3.1%	-6.7%	-6.9%
	$ Million	*Total net revenue*										
Net revenue		-4.20%	-5.80%	-5.90%	-5.90%	-4.50%	-5.10%	-5.10%	-5.00%	-3.90%	-2.80%	-2.80%
	'000 t	*Production levels*										
Milk solids	2,336	-29.1%	-9.3%	-9.5%	-9.5%	-6.2%	-5.3%	-5.3%	-5.6%	-4.6%	-4.5%	-4.4%
Lamb	777	4.7%	-23.3%	-23.6%	-23.6%	-14.7%	-21.4%	-21.4%	-24.4%	-18.9%	-3.2%	-2.6%
Beef[e]	636	1.8%	-62.0%	-60.8%	-60.8%	-36.9%	-36.7%	-36.7%	-0.7%	80.2%	47.8%	45.2%
Wool	305	7.0%	-21.9%	-22.0%	-22.0%	-13.9%	-21.1%	-21.1%	-24.3%	-19.3%	-1.8%	-1.1%

a: see relevant sections for other scenario settings/variations.

b: grey indicates where GHG targets are not met. Table data represent the change from the 2030 baseline emissions, not from 2017, on which CCRA target is based on. Comparing the change in emissions with the 2020 emissions (as a proxy for the CCRA target) reductions of 8.5% for CH_4 and 10.4% for GHG emissions equate to meeting the GHG targets.

c: GHG emissions are the sum of methane and nitrous oxide emissions.

d: refers to incentive prices that are 1x, 5x, 10x and 20x the base methane incentive price of $5.02/t$CO_2$e.

e: beef production does not include the beef from dairy cull cows. Thus, the impact on beef production is likely over-estimated.

High-level results: Refined scenarios

- Lower methane emissions prices may mean the GHG reduction target is not always achieved; however, the methane reduction targets are likely to be achieved.
- As expected, higher emissions prices have a greater impact on net revenue.
- There is, at least, a 10% reduction in sheep and beef area estimated in those scenarios that achieved both GHG targets.
- There is a larger area of South Island sheep and beef farm systems in the Processor Hybrid scenario than the Farm Split Gas Levy. South Island sheep and beef farm systems produce more wool which suggests the emissions pricing signal for wool production is muted when meat production alone is priced in the processor-based scenarios.
- The differences in the emissions pricing signal between the Processor Hybrid scenario and Farm Split Gas Levy has implications for the adoption of some technology options. For example, if a technology reduces GHG emissions without affecting production (e.g. bromoform bolus) then this will result in lower emissions payments in the Farm Split Gas Levy scenario. However, the emissions payments remain the same for the Processor Hybrid scenario as emissions are priced via production levels, and there is less adoption of those technologies.

There are five further scenarios modelled for the processor-based and Farm Split Gas Levy scenarios (see Section 8 Annex and Table S3). These scenarios are designed to be comparable having similar emissions and incentive prices but with different pricing signals. The tailwind technology setting is used for the modelling and carbon sequestration from the scrub mitigation option for the sheep and beef sector is rewarded. The modelling setup for these scenarios differs to the primary scenarios and therefore are not directly comparable.

Similar patterns emerge between the processor-based and Farm Split Gas Levy scenarios as with the primary scenarios. The largest reduction in GHG emissions is the Processor ETS scenario which has the highest methane emissions price. At lower methane emissions prices there are smaller reductions in GHG emissions, and the GHG emissions reduction target is not always achieved; the methane reduction target is achieved with all scenarios. Net revenue impacts follow the same trend as GHG emissions with greater impacts on revenue estimated at higher methane emissions prices.

More land stays in South Island sheep and beef farming systems with the Processor Hybrid scenario than in the Farm Split Gas Levy scenario. South Island sheep and beef systems produce more wool which suggests that the Processor Hybrid pricing signal is muted when only meat production is explicitly priced. There is also a correspondingly smaller reduction in wool production in the Processor Hybrid scenario.

There is a different story emerging for North Island sheep and beef systems, again related to the emissions pricing signal. There is a large, estimated increase in the beef-only farm system with bromoform bolus adoption with the Farm Split Gas Levy. As the Farm Split Gas Levy prices GHG emissions, this system benefits as bromoform bolus reduces methane emissions without compromising beef production. Thus, the emissions payment decreases. The Processor Hybrid scenario, however, prices emissions via meat production and as meat production is not affected by this technology there is no reduction in emissions payments for that system.

For the scenarios that achieved both GHG targets there is, at least, an estimated 10% reduction in the area of sheep and beef land. The modelling estimates that dairy is less affected by emissions pricing with less land use change out of dairy and smaller decreases in net revenue. There is also less difference between the processor-based scenarios and the Farm Split Gas Levy for the dairy sector.

Table S3 Relative Change (%) in the refined scenarios GHG, methane and nitrous oxide emissions, land use, net revenue and production compared with the 2030 Baseline (tailwind technology setting with a payment for the carbon sequestered in the scrub mitigation option for the sheep and beef sector)

Scenario	2030 Baseline area ('000 ha)[a]	Processor ETS – Tech Mit	Processor Hybrid – split gas price (Medium CH_4 Price)	Farm Split Gas Levy (Low CH_4 Price)	Farm Split Gas Levy (Medium CH_4 Price)	Farm Split Gas Levy (High CH_4 Price)
	tCO_2e	*GHG emissions*				
GHG emissions[b]	50,889,072	-15.7%	-9.1%[a]	-10.1%[a]	-11.2%	-12.3%
CH_4 emissions	38,437,940	-16.7%	-9.4%	-11.2%	-12.4%	-13.6%
N_2O emissions	12,451,132	-12.6%	-8.1%	-6.5%	-7.5%	-8.2%
	'000 ha	*Land use area*				
Arable	212	7.8%	3.7%	3.1%	3.8%	4.4%
Fruit	138	3.5%	1.8%	1.7%	2.0%	2.3%
Vegetables	18	5.1%	2.5%	2.4%	2.8%	3.2%
Dairy	2,666	-4.0%	-1.9%	-1.9%	-2.1%	-2.4%
Sheep & Beef	7,557	-15.6%	-7.1%	-8.2%	-10.2%	-12.0%
Forestry	2,980	3.8%	1.9%	2.0%	2.3%	2.7%
Scrub/Indigenous Forest	8,115	14.2%	6.5%	7.5%	9.2%	10.8%
	$ Million	*Total net revenue*				
Net revenue	13,264,175	-5.9%	-4.3%	-4.4%	-4.7%	-4.9%
	'000 t	*Production levels*				
Milk solids	2,369	-7.6%	-4.8%	-4.3%	-4.5%	-4.7%
Lamb	776	-18.5%	-8.7%	-15.8%	-17.8%	-20.1%
Beef[a]	635	-51.4%	-44.4%	11.2%	7.7%	9.7%
Wool	305	-18.3%	-8.2%	-15.8%	-17.7%	-20.1%

a: grey indicates where GHG targets are not met. Comparing the change in emissions with the 2020 emissions (as a proxy for the CCRA target) reductions of 8.5% for CH_4 and 10.4% for GHG emissions equate to meeting the GHG targets.
b: GHG emissions are the sum of methane and nitrous oxide emissions.
c: beef production does not include the beef from dairy cull cows. Thus, the impact on beef production is likely over-estimated

Insights and conclusions

The following insights and conclusions can be drawn from the modelling and analysis of the primary scenarios. These insights are also consistent with those insights that emerge from the refined scenarios for the processor-based and Farm Split Gas Levy scenarios.

Meeting the GHG target

Most climate policy scenarios achieved the GHG targets at the modelled NZU price of $108.62. The processor-based scenarios with the same emissions price for methane and nitrous oxides projected GHG emissions reductions of around 18%, regardless of whether there is a payment for carbon sequestered by the scrub mitigation option for sheep and beef land or the technology setting. The reduction in GHG emissions is estimated to fall by just under 12% where methane and nitrous oxide emissions are priced differently in the Hybrid Processor scenario.

Most of the Farm Split Gas Levy scenarios show GHG emissions reductions between 14.4 and 15%. The exception is the Farm Split Gas Levy (with 20 times the base methane incentive price) scenario with the tailwind technology setting. In this scenario the incentive price has reached a level where it is profitable for farms to take up more expensive (and more effective) mitigation options like bromoform bolus. Therefore, less land moves out of sheep and beef and dairy. The larger area that remains in sheep and beef and dairy means a smaller reduction in total methane and nitrous oxide emissions and the GHG targets may not be achieved. Incentive prices may also reach a level at which some scrub and indigenous forest might be brought into agricultural production, reducing the amount of carbon being sequestered.

The Farm LUC Rebate scenarios (headwind and tailwind technology settings and both GHG emissions pricing alternatives) are not projected to achieve the GHG target. In these scenarios, the per-hectare rebate farmers receive for some farm systems is markedly higher than the payment they make for their GHG emissions, which increases their profitability. This results in increases in sheep and beef area in some regions and LUC classes with a resulting increase in overall sector GHG emissions, and corresponding increases in net revenue, area and production for the sheep and beef sector.

Importance of mitigation options and incentive payments

The design of incentives and incentive prices change the profitability of different farm systems and how these farm systems respond to the pricing of GHG emissions. The different scenarios modelled incentivise change in different parts of the agricultural system. While the overall GHG emissions reductions are similar across most scenarios, how those GHG emissions reductions are achieved differs. This is seen by the mitigation options that are taken up by different farm systems and what land use change is projected to occur in each scenario.

Looking at both tailwind and headwind technology settings gives a range of potential responses to the climate policy scenarios and helps assess the sensitivity of the results. The mitigation options adopted and possible land use change resulting from the modelled scenarios provides an insight into where the impacts of the different scenarios are more likely to fall.

The headwind technology setting assumes the technology mitigation options are more costly and/or less effective than the tailwind technology setting in 2030. Therefore, there is less adoption of technology mitigation options even at higher incentive prices with the headwind technology setting and slightly more land use change in the scenarios modelled.

With the tailwind technology setting, higher incentive prices induce greater uptake of technology mitigation options and sometimes less land use change. As a result, the modelling predicts that GHG targets are not always met, such as with the Farm Split Gas Levy scenario with higher methane incentive prices as less land moves to lower emitting uses. This suggests that while mitigation options to reduce GHG emissions are important, they are unlikely, alone, to be sufficient to reduce GHG emissions to future GHG target levels, unless the effectiveness of those mitigation options improve even more to counteract the effect of more livestock remaining in the agriculture sector.

Incentive payments for all mitigation options versus only technology mitigation options changes the mix of mitigation options taken up. The modelling estimates there is a greater negative impact on net revenue when only the technology mitigation options are rewarded as more land is retired. Providing a payment for the management mitigation options, not just the technology mitigation options, gives pastoral farmers a greater suite of profitable mitigation options (after the incentive payment), reducing land use change and the subsequent impact on net revenue. It may, at least initially, be beneficial to incentivise all mitigation options with a transition to incentivising only technology mitigation options as these become more cost-effective. As the incentive payments estimated through the modelling are a fraction of the GHG emissions payments, incentivising all mitigation options is likely possible, as is increasing the incentive payments of some or all mitigation options and helping to facilitate the transition to new land uses on some land.

Processor-based vs farm-level policy signals

Processor-based scenarios tie their emissions payments to meat and milk production and fertiliser use while GHG emissions are the basis of the farm-level scenario emissions payment. Therefore, different sheep and beef farm systems are exposed to different emissions pricing signals between the processor-based and farm-level scenarios.

Those sheep and beef farm systems with greater wool production don't explicitly see a price signal for wool in the processor-based scenario and appear less exposed to emissions pricing compared with the farm-level scenarios where the emissions payments are based on GHG emissions rather than output/input levels. Therefore, the modelling suggests that the processor-based scenarios preferentially benefit South Island sheep and beef farm systems as they often produce more wool and less meat. North Island sheep and beef farm systems experience greater impacts, especially those with higher beef to sheep ratios.

The pricing signal also affects how and if the GHG emission reduction benefits of emissions reducing technologies are rewarded. The Farm Split Gas Levy, for instance, does reward the adoption of technologies that reduce GHG emissions without compromising production through lower emissions payments. However, the processor-based scenarios have the same emissions payments as emissions pricing is via production which is unchanged for these technologies.

In summary

The pricing and incentive signals of the different climate policy scenarios, including the further refinements in the Annex, have different impacts, and these impacts change depending on farm system and livestock ratio, particularly for the sheep and beef sector. The modelling shows that the GHG targets can be met, but some land use change will occur, reducing production levels and hence net revenue for the agricultural sector. The modelling provides insights into where the negative impacts of the different policy scenarios are most likely to fall and how different incentive designs may, or may not, alleviate some of these impacts. These results, along with other considerations such as equity implications, administrative costs, and transaction costs, can be helpful in identifying policy levers that meet GHG targets while minimising the impacts on the agricultural sector, and what may be needed to ease that transition.

1 Introduction

In October 2019, the New Zealand government agreed to a proposal from the primary sector to work together and with iwi/Māori to develop a system for measuring, managing, and reducing agricultural greenhouse gas emissions (GHG), rather than simply using farm products as a proxy for GHG emissions in the NZ Emissions Trading Scheme (ETS).

He Waka Eke Noa (the Partnership) was formed to develop this system and to equip farmers and growers with the knowledge and tools they need to reduce GHG emissions, while continuing to sustainably produce quality food and fibre products for domestic and international markets. By 2025, the Partnership was tasked with designing a practical and cost-effective system for reducing emissions at the farm level that includes designing an appropriate farm-level pricing system.

In early 2022, the Partnership engaged with farmers on three options for pricing agricultural emissions – a farm-level option, a processor-level hybrid levy option, and the NZ ETS backstop option. The Partnership provided a set of recommendations to the Minister for Agriculture and the Minister for Climate Change in April 2022 and by the end of 2022 these Ministers are required to make final decisions on agricultural emissions pricing.

The purpose of this report is to provide modelling and an analysis of a range of pricing options associated with different climate policy scenarios to support ministerial decisions and inform the Regulatory Impact Assessment for these scenarios.

The modelling and analysis in this report included 8 climate policy scenarios – a GHG target, 4 processor-based policies, and 3 farm-level policies. An additional set of scenarios are included in the Annex (Section 8) which further refined the settings of these initial 8 scenarios. The modelling assessed the potential GHG emissions reductions for the different scenarios at the same NZU price (\$108.62/tCO_2e) to determine how the impacts changed between the scenarios. Biological GHG emissions (methane and nitrous oxide) and carbon sequestration were included in this analysis. Given the uncertainty surrounding the cost and effectiveness of the technology mitigation options available to the pastoral sectors to reduce their biological emissions, two technology settings were modelled. The 'tailwind' technology setting reflects the situation where technologies are more cost-effective in 2030 while the 'headwind' technology setting is where the technologies are less cost-effective in 2030.

For this analysis, we used an agri-environmental economic optimisation model – New Zealand Forestry and Agricultural Regional Model (NZFARM). This national-scale analysis provides insights into adoption of management practices and technologies to reduce GHG emissions, and changes in net agricultural and forestry revenues, GHG emissions, carbon sequestration, land use, and agricultural production.

2 Methods

2.1 NZFARM model

We use NZFARM to assess the economic impacts of the proposed agricultural climate policy scenarios. NZFARM was developed through the Sustainable Land Management and Climate Change Research Programme (SLMACC) and has been used to assess climate and water quality policy scenarios across New Zealand (e.g. Daigneault et al. 2012, 2017; Djanibekov et al. 2018).

NZFARM is a comparative static model that accounts for all major farming and land uses in New Zealand. It maximizes the net revenue from agricultural and forestry production subject to feasible land use area and GHG emission reduction constraints.

NZFARM facilitates a 'what if' scenario analysis by showing how changes in climate change mitigation policies could affect the uptake of agricultural mitigation options, changes in land use, and any subsequent spill-over effects on a group of performance indicators important to decision-makers. The 'what if' scenario analyses are performed by solving for a baseline, or status quo, economic optimal condition, then imposing specific policies or other changes on the system and solving the model again to compute a new economic optimal condition consistent with the scenario.

Performance indicators tracked within NZFARM for this analysis include economic (e.g. net revenue, production) and environmental (e.g. carbon sequestration and GHG emissions) parameters.

The model includes the following land uses: dairy, sheep and beef, arable, forestry, fruit, vegetables, and scrub. Dairy includes 4 different systems distributed across New Zealand – dairy system 2, dairy system 3, dairy system 4, and dairy system 5. The sheep and beef land use includes farming systems from 7 of the 8 Beef + Lamb New Zealand's (B+LNZ) farm classes (data from class 8 farms was not available). A schematic of the NZFARM model is outlined in Figure 1 with a more detailed description of the model provided in Appendix 1.

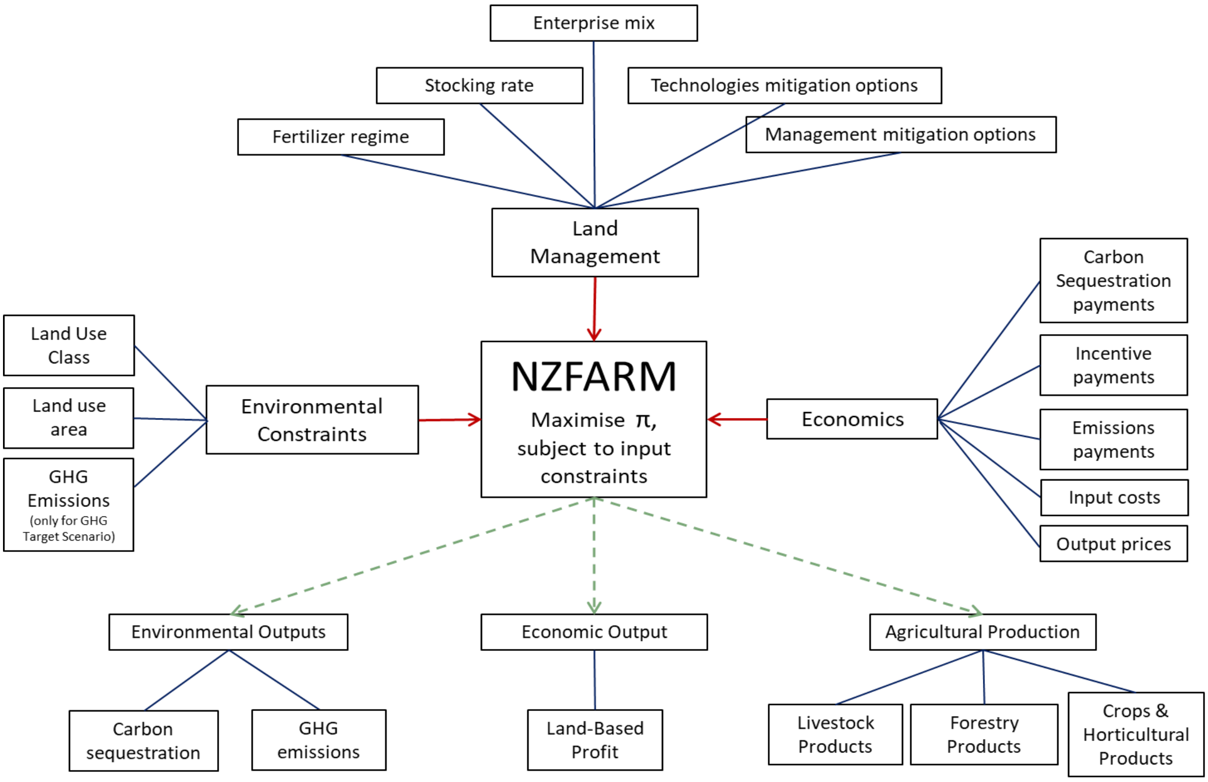

Figure 1 NZFARM model structure.

2.2 On-farm mitigation options

The NZFARM model includes different on-farm GHG mitigation options for dairy, sheep and beef, arable and horticultural land uses (Table 1–Table 3). The GHG mitigation options cover a range of land and stock management practices as well as GHG reducing technologies for pastoral land uses. Mitigation options for dairy include the 'output' approach,[1] reduction in fertiliser use, changes in supplemental feed, reduction in cow numbers with no change in per cow milk production, and once-a-day milking (DairyNZ Economic Group 2017, 2018). Bromoform bolus, 3NOP fed twice a day, ecoponds, low methane genetics, and a nitrification inhibitor are the technology mitigation options for dairy (Table 1). The economic and environmental parameters associated with the mitigation options differ by dairy system, intensity of the mitigation option and region. Summary statistics for the dairy sector GHG emissions and net revenue, by mitigation option are given in the Appendix 2.

There were two sets of assumptions modelled for the technology mitigation options. The tailwind technology setting reflects the situation where technologies are more cost-effective in 2030, while the headwind technology setting is where the technologies are less cost-effective in 2030. The assumptions and subsequent settings for the tailwind and headwind technology mitigation options were provided by MPI (2022; Appendix 3).

[1] The output approach includes farm-specific changes targeting nitrogen fertiliser, supplementary feed, and stocking rates to reduce GHG emissions all implemented at the same time.

Table 1 Description of management and technology mitigation options considered for the dairy sector in 2030

Mitigation options	Description				
Business-as-usual	No change in current management and no uptake of new technologies				
	Farm management mitigation options				
		Intensities of management practices			
		a	b	c	d
(1) Output approach reducing GHG emissions	Farm-specific, cost-effective farm system changes targeting nitrogen fertiliser, supplementary feed, stocking rate and irrigation efficiency (Canterbury only) to reduce GHG emissions	5% decrease in GHG emissions	10% decrease in GHG emissions	15% decrease in GHG emissions	20% decrease in GHG emissions
(2) Reduction in fertilizer use	N fertilizer reductions, then reduce stocking rate to match feed supply and demand	25% decrease in N fertilizer	50% decrease in N fertilizer	75% decrease in N fertilizer	100% decrease in N fertilizer
(3) Change in supplement feed	High protein imported supplement reductions, then either replaced with a low protein alternative or reduce stocking rate to match feed supply and demand	Reduce high protein feed by 50% and replace with low protein feed	Remove all high protein feed and replace with low protein feed	Reduce high protein feed by 50% and reduce stocking rate	Reduce all high protein feed and reduce stocking rate
(4) Reduction in cow numbers with no change in milk production per cow	Stocking rate reductions, then reduce feed and N fertilizer inputs to match feed supply and demand. Milk production per cow remains constant but total farm milk production reduces	5% decrease in stocking rate	10% decrease in stocking rate	15% decrease in stocking rate	20% decrease in stocking rate
(5) Once-a-day milking	Introduce once-a-day milking	Half season	Entire season		
	Technology mitigation options				
		Tailwind settings	**Headwind settings**		
(7) Bromoform bolus (CH_4 inhibitor)	Methane inhibitor that reduces methane emissions	55% decrease in CH_4 emissions	36% decrease in CH_4 emissions		
(8) 3NOP fed twice a day (CH_4 inhibitor)	Methane inhibitor fed twice a day. Assumed only to be applied in dairy systems 3 to 5	16% decrease in CH_4 emissions	8% decrease in CH_4 emissions		
(9) Ecopond	Chemical compound added to effluent to inhibit methane-generating microbe activity	8% decrease in CH_4 emissions	8% decrease in CH_4 emissions		
(10) Low methane genetics	Reduction in methane per cow	0.9% decrease in CH_4 emissions	0.9% decrease in CH_4 emissions		
(11) Nitrification inhibitor	Reduction only applies to nitrous oxide from urine and dung applied to pasture	25% decrease in N_2O emissions	17% decrease in N_2O emissions		

Source: DairyNZ Economic Group (2017, 2018), MPI (2022).

Sheep and beef sector mitigation options are based on MPI (2022) and include two management mitigation options – reduce stocking rate and scrub, and three technology mitigation options – low methane breeding, bromoform bolus, and a nitrification inhibitor (Table 2).

Farm forestry on pastoral land for carbon sequestration was also considered. However, in discussions with MPI, it was agreed any farm forestry should have entered the ETS and therefore be captured in the 2030 baseline. Thus, the farm forestry option in MPI (2022) was used to develop a regenerating scrub mitigation option where the impacts on production and stocking rates were assumed to be the same as the farm forestry mitigation option, but with a lower carbon sequestration rate.

The economic and environmental parameters associated with the mitigation options differ with each sheep and beef farm system (represented by individual farms with different stocking rates, see MPI 2022) and intensity of the mitigation option. Summary statistics for the sheep and beef sector GHG emissions and net revenue with the different mitigation options are given in Appendix 2.

Table 2 Description of farm management and technology mitigation options considered for sheep and beef in 2030

Mitigation options	Description		
Business-as-usual	No change in current management and no uptake of new technologies		
	Farm management mitigation options		
		Intensities of management practices	
		a	b
(1) Reduce stocking rate	Stocking rates reduced	Small reduction in stocking rate (differs depending on farm)	Medium reduction in stocking rate (differs depending on farm)
(2) Scrub	Land is allowed to regenerate to scrub		
	Technology mitigation options		
		Tailwind settings	**Headwind settings**
(3) Low methane breeding stock	Allows sheep farmers to emphasise low CH_4 breeding traits during ram selection (leads to overall lower CH_4 flocks over time)	60% reduction in CH_4 emissions	40% reduction in CH_4 emissions
(4) Bromoform bolus (CH_4 inhibitor)	Bolus is a pill which sits in the rumen and releases bromoform slowly (assumed to reduce CH_4 from enteric fermentation)	60% reduction in CH_4 emissions	40% reduction in CH_4 emissions
(5) Nitrification inhibitor	Chemical compound that is applied to flat land to reduce N_2O emissions from agricultural soils.	25% reduction in N_2O emissions	22.5% reduction in N_2O emissions

Source: MPI (2022).

The mitigation options for the horticultural and arable land uses are based on Daigneault and Elliot (2017) and relate to a reduction in fertiliser application rates (Table 3). The economic and environmental parameters tracked are changes in net revenue and GHG emissions. To determine the impact of these mitigation options on net revenue we assumed the change in arable and horticulture production associated with these mitigation options led to the same proportional change in net revenue.

Table 3 Description of farm management mitigations considered for arable and horticulture

Land use	Mitigation option	Description
Arable	Reduce fertiliser rate	15% lower fertiliser application rates and 1.3% reduction in net revenues.
Horticulture	Reduce in N application	10% lower N application levels and 30% reduction in net revenues.

Source: Daigneault and Elliot (2017).

2.3 Data Sources

2.3.1 Land use area

The initial land use area was derived using data from 2018 to 2020. The year range area acknowledges the updates to the Agribase database, one of the input datasets, is rolling with approximately one-third of the property details updated each year. Therefore, the 2020 Agribase dataset will contain information from 2018, 2019, and 2020. For the purposes of the modelling, however, we refer to the base year for the initial land use area as 2020.

The land use areas were derived using the New Zealand Land Cover Database (LCDB) version 5 (Newsome et al. 2017; MWLR 2018), the AgriBase database (September 2020 dataset; AssureQuality 2020), Land Information New Zealand (LINZ) parcels[2] (current and primary parcels in 2021), and LINZ Topographic layers (1:50,000 golf courses, and sports fields).

The distribution of different pastoral farming systems at a regional level was based on information provided by DairyNZ and assigning Beef+Lamb NZ farm classes to Land Use Capability (LUC) classes.[3] Table 4 outlines how Beef + Lamb NZ farm classes were assigned to LUC classes using MPI (MPI 2022). We acknowledge that sheep and beef operations often contain multiple LUC classes. However, assignment of each farm system to a LUC class is necessary for the modelling purposes. The assigned LUC classes are consistent with the geographic distribution of these farm systems.

[2] https://data.linz.govt.nz/layer/50772-nz-primary-parcels/.
[3] Land use capability classes are found on the NZLRIS portal (https://lris.scinfo.org.nz/layer/48076-nzlri-land-use-capability-2021/)

Table 4 Assignment of Beef + Lamb NZ farm classes to LUC classes

South Island		North Island	
Beef+Lamb NZ farm classes	*Assigned corresponding LUC class*	*Beef+Lamb NZ farm classes*	*Assigned corresponding LUC class*
Class 1	7 & 8	Class 3	7 & 8
Class 2	5 & 6	Class 4	3, 4, 5 & 6
Class 6	3 & 4	Class 5	1 & 2
Class 7	1 & 2		

2.3.2 Projected land use area

The 2030 distribution of land uses was projected using the Land Use in Rural New Zealand model (LURNZ; see Dorner et al. 2018) and 2020 land use area. LURNZ assumed there was no change in agricultural climate policy and that the ETS price for the carbon sequestered by forestry increased from $85 in 2022 with the interest rate.[4] Other indicators for the different land uses remain constant. Land classified as urban, Department of Conservation and other public land, non-productive land (e.g. quarries), and land for other animal production were assumed to remain constant over time. Therefore, changes in pastoral land, forest, scrub and indigenous forest, and arable/horticultural land were projected for 2030.

2.3.3 Riparian and fenced area

We assumed there was a 3 m riparian buffer required to meet the requirements of the National Policy Statement for Freshwater Management (NPSFM). To account for this riparian area no longer being available for agricultural production we excluded the production from this area from our analysis. Similarly, there is a riparian set back requirement in the National Environmental Standards for Plantation Forestry (NESPF). To account for this, we used a 10 m riparian buffer for land under exotic forestry production and excluded this area from forestry net revenue estimates. To estimate these riparian buffer areas, we combined the LINZ river polygon dataset[5] with the LINZ river centrelines dataset[6] and the 2020 land use map.

Only areas not fenced incurred a fencing cost. To estimate the unfenced pastoral riparian area, we used information from the Survey of Rural Decision Makers (Stahlmann-Brown 2022). Once we had excluded already fenced riparian areas of dairy and sheep and beef land, there were an additional 2,748 ha of dairy land and 52,991 ha of sheep and beef area that

[4] Interest rates used are 3.2% in 2022 with a constant rate (3.1%) till 2030. The interest rate is the 90-day bank bill rate from the Treasury's Half Year Economic and Fiscal Update (The Treasury 2021).
[5] https://data.linz.govt.nz/layer/50328-nz-river-polygons-topo-150k/
[6] https://data.linz.govt.nz/layer/50327-nz-river-centrelines-topo-150k/

were taken out of production in the modelling. The area taken out of production is the same for all scenarios.

All riparian buffer areas were assumed to be regenerating scrub and received a payment for the carbon sequestered by the scrub. We did not include a fencing cost for riparian buffer areas within plantation forestry. The data on the costs of afforestation on the riparian pastoral area taken out production are from Forbes (2021). Data on fence costs for afforestation in riparian area and for scrub are also from Forbes (2021).

2.3.4 Scrub

The carbon sequestered by regenerating scrub for the sheep and beef scrub mitigation option is assumed to be 4 tCO_2/ha (Jamie Ash and Darran Austin, pers. comms).

2.3.5 Forestry

The data for forestry used in the modelling comes from the Forest Investment Framework (FIF; Yao 2019). The FIF provides data on carbon revenue as well as a combined revenue value from carbon and timber. From the carbon revenue, we derived the amount of carbon sequestered by forestry using the \$25/tCO_2e carbon price used in the FIF modelling. However, as the combined carbon and timber revenue value also included the cost of land purchase, we were unable to derive the amount of timber produced. Timber production, therefore, is not tracked in this analysis.

2.3.6 Dairy

The data on dairy farm systems for each region are from 2017 DairyNZ dairy farm budgets (DairyNZ Economic Group 2017, 2018; Djanibekov et al. 2018). This dataset includes a range of farm management practices and the corresponding net revenues, GHG emissions, production, and nutrient (nitrogen and phosphorous) losses. All dairy environmental parameters are estimated using Overseer (version 6.2.3). Only the methane and nitrous oxide emissions were used as the CO_2 emissions include embodied carbon for some inputs. Farmax (version 7.1.2.06) was used to derive the farm budgets.

Beef production from culled cows is not included in dairy system data. However, the revenue associated with the sale of culled cows are included in the net revenue for each dairy system. This has implications for the beef production quantities estimated in the modelling, as the beef production output modelling results do not capture beef from culled cows.

2.3.7 Sheep and beef

The sheep and beef information are derived from case study farms selected for modelling based on actual data sources through MPI's Farm Monitoring programme (MPI, 2022). The anonymised data were sourced from B+LNZ Economic Farm Survey (2019/20). The system characteristics (such as feed eaten, timing of the fertiliser application, etc.) for each farm were sourced from associated OverseerFM® reports. Average 5-year product prices (meat and wool schedules) and 5-year average prices of crop and supplements (NZX Grain and Feed Insight) were applied to standardise the commodity prices across the regions and classes.

The dataset included 21 sheep and beef farms with a range of farm management practices and the corresponding net revenues, production and GHG emissions. The North Island farm systems included 3 B+LNZ class 3 farms, 6 B+LNZ class 4 farms, and 3 B+LNZ class 5 farms. The South Island farm systems included 1 B+LNZ class 1 farm, 2 B+LNZ class 2 farms, 4 B+LNZ class 6 farms, and 2 B+LNZ class 7 farms. The selection of farms across each farm class aimed to provide a representative diversity of farm types by geography. The number of farms chosen in each farm class was determined from the proportion of farms in each class. Farms within each of the farm classes were selected to ensure diversity and that when combined the farm class sample would reflect the farm class averages for farm size (farm hectares and stock units) and stocking rates. Physical parameters from the B+LNZ Economic Farm Survey were used to guide selection and included: region, grazable area (farm area), stock units (including species ratio) and stocking rate. A secondary criterion for farm selection also included nitrogen fertiliser use and profitability to ensure a range of farm performance was captured in the modelled mitigation scenarios.

The sheep and beef farms were modelled using Farmax (version 8.1.0.49) to provide data on net revenue, production, and methane and nitrous oxide emissions for each farm system. There are no corresponding nutrient budgets for sheep and beef farming systems.

The sheep and beef farms were incorporated into NZFARM as separate farm systems to reflect the heterogeneity of the sector in the modelling. The heterogeneity of these farms showed how the different policy scenarios affected different aspects of sheep and beef farms, e.g. those with different stock ratios.

The data used in this analysis differ from previous NZFARM analyses (e.g. Djanibekov 2018; Djanibekov, Bell, et al. 2019; Djanibekov et al. 2019). The data in earlier reports are drawn from the B+LNZ sheep and beef farm survey (Beef+Lamb New Zealand 2017) with resulting data being an average for each B+LNZ farm class.

2.3.8 Other land uses

The horticultural farm budgets are from Horticulture New Zealand (Djanibekov et al. 2018), while the arable cropping farm budgets are based on Daigneault et al. (2017). The GHG emissions from these sectors are estimated using the New Zealand GHG inventory methodology (MfE 2017). Information on mitigation practices for arable land and horticulture is from Daigneault and Elliot (2017).

2.3.9 GHG emissions factors

GHG emission factors for milk solids, meat and fertiliser were provided by MPI (Jamie Ash, pers. comm.). The GHG, methane and nitrous oxide emissions factors are listed in Table 5.

Table 5 Emissions factors for processor payments. Emissions factors provided by MPI

Commodities	**2020 Emissions Factors[a]**		
	GHG (CO_2e)	N_2O	CH_4
Slaughtering certain cattle, deer, goats, pigs, poultry or sheep)			
Cattle (per kg of meat processed)			
Bull (other than a calf or vealer)	14.60	0.0066	0.4586
Cow (other than a calf or vealer)	14.60	0.0066	0.4586
Heifer (other than a calf or vealer)	14.60	0.0066	0.4586
Steer (other than a calf or vealer)	14.60	0.0066	0.4586
Sheep (per kg of meat processed)			
Hogget	14.60	0.0066	0.4586
Lamb	14.60	0.0066	0.4586
Ram	14.60	0.0066	0.4586
Other adult sheep (ewe or wether)	14.60	0.0066	0.4586
Others (per kg of meat processed)			
Deer	35.96	0.0134	1.1578
Goat[b]	14.60	0.0066	0.4586
Dairy processing of milk or colostrum			
Per tonne of milk solids from cows	9.48	0.0049	0.2921
Importing or manufacturing synthetic fertilisers containing nitrogen			
Per tonne of nitrogen imported/exported	4.66		
Non-urea	4.80		
Urea	4.69		
Urea with UI	4.50		

a: The emissions factors for N_2O and CH_4 can be converted to CO_2e using GWP values of 28 (methane) and 265 (nitrous oxide).
b: goats are not included in the modelling. They are included in the table for completeness to show what livestock production has an emissions factor.

2.3.10 Rebate for farm-level LUC scenarios

The rebate payments for the farm-level LUC scenarios were based on a per hectare rebate. The per ha rebate was calculated using a per ha rebate share derived using dry matter intake by stock unit. The approach is outlined below:

Per ha rebate$_{LUCi}$ = per ha rebate share$_{LUCi}$ * total funding available for the rebate

Where

LUCi represents each LUC class with i being LUC class 1 through 8.

Per ha rebate share$_{LUCi}$ = dry matter intake per ha$_{LUCi}$ / total dry matter intake

Total dry matter intake = dry matter intake per ha$_{LUCi}$ * area$_{LUCi}$

Dry matter intake per ha$_{LUCi}$ = stock units (SU) per ha$_{LUCi}$ * 550 kg DM/SU intake

The stock units per ha and dry matter are based on Hanly et al. (2018). It is assumed that there are no stock units and no dry matter produced for land in LUC 8.

The initial total available funding for the rebate where methane and nitrous oxide emissions are priced the same was $5,083,604,867. This is 90% of the total payment for methane and nitrous oxide emissions (with NZU price of $108.62/t$CO_2$e) in the 2030 baseline.

The initial total available funding for the rebate where methane and nitrous oxide emissions are priced differently was $3,020,946,182. This is 90% of the total payment for methane (based on an emissions price of $50.20/t$CO_2$e) and nitrous oxide emissions (with NZU price of $108.62/t$CO_2$e) in the 2030 baseline.

The resulting per hectare rebate when methane and nitrous oxide emissions are priced the same are listed in Table 6 and the rebate when methane and nitrous oxide emissions are priced differently are listed in Table 7.

Table 6 Stock units, dry matter intake and rebate levels, per hectare and where CH_4 and N_2O emissions are priced the same

LUC	Stock units, SU/ha[a]	Dry matter intake, kg/ha	Rebate value, $/ha
1	29.9	16,445	811
2	27.1	14,905	735
3	23.8	13,090	646
4	16.6	9,130	450
5	14	7,700	380
6	13.1	7,205	355
7	4.4	2,420	119
8	-	-	0

a: base carrying capacity stocking rates from Hanly et al. (2018).

Table 7 Stock units, dry matter intake and rebate levels, per hectare and where CH_4 and N_2O emissions are priced differently

LUC	Stock units, SU/ha[a]	Dry matter intake, kg/ha	Rebate value, $/ha
1	29.9	16,445	482
2	27.1	14,905	437
3	23.8	13,090	384
4	16.6	9,130	268
5	14	7,700	226
6	13.1	7,205	211
7	4.4	2,420	71
8	-	-	0

a: base carrying capacity stocking rates from Hanly et al. (2018).

3 Scenarios

3.1 Baseline

The baseline for this analysis is 2030. We used the land use area in 2020 and projected it to 2030 using LURNZ (Dorner et al. 2018). The LURNZ 2030 baseline projection included the ETS and carbon sequestration payments for exotic forest that had entered the ETS, but no other environmental policies or the pricing of agricultural emissions were included. The NZ Unit (NZU) price was assumed to increase over time with the interest rate (see section 2.3.2). A carbon price of \$85/tCO_2e in 2022 (approximate price for carbon sequestered by forests in 2020) equated to \$108.62/tCO_2e in 2030.

Table 8 shows the 2030 baseline or 'business as usual' land use area, net revenue, and GHG emissions (negative GHG emissions represent net sequestration). Table 9 shows methane and nitrous oxide emissions from the different land uses. Table 10 provides information on agricultural production in the 2030 baseline. As noted above, as it was not possible to derive timber production from the FIF model output, timber output is not reported in this table.

The LURNZ 2030 projected land use shows an increase in forestry and dairy areas and a decrease in sheep and beef and scrub areas compared with the initial 2020 land use. The dairy area increased by approximately another 410,600 ha and the forestry area increased by about 980,000 ha, while sheep and beef area decreased by approximately 1.16 million ha and scrub decreases by about 290,000 ha. Arable and horticultural area increased by ~2,300 ha.

Table 8 Total land-use area, net revenue and GHG emissions, 2030 baseline

Land-use category	Land-use area (1,000 ha)	Net revenue (\$ million)	GHG emissions (1000 tCO_2e^{-1})
2030 baseline			
Dairy	2,632	4,297	23.976
Sheep and beef	7,564	1,360	26,339
Arable	213	351	212
Fruits	138	1,021	35
Vegetables	18	199	6
Forestry[a]	2,986	5,992	-39,596
Scrub	8,136	n.a.	n.a.
Other	4,081	n.a.	n.a.

a: includes timber and carbon sequestration revenue.

n.a. means the information is not available or not applicable; negative values in forestry GHG emissions represents carbon sequestration.

Table 9 Total CH_4 and N_2O emissions, 2030 baseline

Land uses	CH_4 emissions (1,000 tCH_4)	N_2O emissions (1,000 tN_2O)
Dairy	17,034	6,942
Sheep and beef	21,183	5,157
Fruits	n.a.	35
Vegetables	n.a.	6
Arable	n.a.	213
Forestry	n.a.	n.a.

n.a. means the information is not applicable.

Table 10 Total agricultural production, 2030 baseline

Commodities	Output (1,000 t)
Milk solid	2,336
Beef	636
Lamb	777
Deer	15
Wool	305
Wheat	638
Barley	531
Maize	886
Berries	368
Kiwifruit	292
Vegetables	757

Note: as it was not possible to derive timber production from the FIF output, timber output is not reported.

3.2 Policy scenarios

We have modelled 8 primary climate policy scenarios (Table 11) – GHG target, 4 processor-based policies, and 3 farm-level policies. For each scenario (except GHG Target) tailwind and headwind settings for the technology mitigation options were included. These settings are based on different assumptions around the timing, cost and effectiveness of the technology mitigation options in 2030. Except for the GHG Target scenario, there was variation in the treatment of the sheep and beef scrub mitigation option for each modelled scenario. One variation of each scenario included a payment for the carbon sequestered by the sheep and beef scrub mitigation option. For the other variation there was no payment for the carbon sequestered by the scrub mitigation option for the sheep and beef sector.

The policy scenarios, and their parameterisation, was agreed with MPI and MfE.

Table 11 Overview of primary scenarios modelled

Scenario name	Description	Point of obligation	Basis of payment	Basis of rebates to/incentives for farmers
GHG Target	10% reduction in CH_4 and 11% reduction in GHG emissions by 2030.	Not applicable	Not applicable	Not applicable
Processor ETS (all mitigation options rewarded)	Legislated backstop for agricultural biological emissions in the ETS with free allocation. GHG reductions from all mitigation options are rewarded.	Processor	Emission factor for milk, meat & fertiliser	Reductions in GHG emissions from all mitigation options
Processor ETS (technology mitigation options rewarded)	Legislated backstop for agricultural biological emissions in the ETS with free allocation. GHG reductions from technology mitigation options are rewarded.	Processor	Emission factor for milk, meat & fertiliser	Reductions in GHG emissions from technology mitigation options
Processor Hybrid (same gas price)	Split gas pricing at processor level where CH_4 and N_2O are priced the same and with free allocation. GHG reductions from technology mitigation options are rewarded.	Processor	Emission factor for milk, meat & fertiliser	Reductions in GHG emissions from technology mitigation options
Processor Hybrid (split gas price)	Split gas pricing at processor level where CH_4 and N_2O are priced differently and with free allocation. GHG reductions from technology mitigation options are rewarded.	Processor	Emission factor for milk, meat & fertiliser	Reductions in GHG emissions from technology mitigation options
Farm Split Gas Levy	Split gas pricing at farm level for biological GHG emissions where CH_4 and N_2O are priced differently. Prices are initially low as there is no free allocation. GHG reductions from technology mitigation options are rewarded via different CH4 and N2O incentive payments. A range of methane incentive payments are modelled.	Farm	CH_4 & N_2O emissions	Reductions in GHG emissions from technology mitigation options
Farm LUC Rebate (same gas price)	Split gas pricing at farm level for biological GHG emissions where CH_4 and N_2O are priced at the NZU price. A rebate to farmers is assigned through a structured assistance approach (in this case, by LUC class) to reflect the free allocation.	Farm	CH_4 & N_2O emissions	LUC classes on the farm
Farm LUC Rebate (split gas price)	Split gas pricing at farm level for biological GHG emissions where CH_4 and N_2O are priced differently. The rebate to farmers is assigned through a structured assistance approach (in this case, by LUC class) to reflect the free allocation.	Farm	CH_4 & N_2O emissions	LUC classes on the farm

3.2.1 Common attributes of all scenarios

Attributes common across all scenarios are outlined below.

NZU price and C sequestration payments

The NZU price used in 2030 across the scenarios was \$108.62/tCO_2e (equivalent to \$85/tCO_2e in 2022).[7] Exotic forest received the full NZU payment, while any new scrub associated with the scrub mitigation option for sheep and beef farm systems was priced at 75% of the NZU price.

Emissions discounting and free allocation

The GHG emissions prices faced by agriculture assumes in 2025 agriculture would pay for 5% of the price of the GHG emissions they were generating, with a 1% increase each year. This is a discount of 95% of the NZU price with the phasing out consistent with proposed NZ ETS settings (HWEN 2022).

Therefore, in 2030 the agricultural sectors are responsible for 10% of their biological GHG emissions for the scenarios where discount/free allocation is applicable. Free allocation is modelled in different ways across the scenarios. For the processor-based scenarios, processors only pay 10% of the GHG emissions price (either the NZU price or prices assigned to methane and long-lived gases like nitrous oxide). The Farm LUC Rebate scenarios assign free allocation using a rebate payment to farmers instead of a discount on the emissions price. There is no free allocation in the Farm Split Gas Levy but a discount like free allocation is used.

Treatment of riparian areas from complementary environmental policy

We considered the National Policy Statement for Freshwater Management (NPSFM) by removing 3 m riparian areas from dairy and sheep and beef production. We assumed that pastoral area taken out of production no longer has any agricultural production.

In addition, we included the National Environmental Standards for Plantation Forestry (NESPF) by removing a 10 m riparian area from land under exotic forestry production. Forestry area taken out of production is not used for other primary sector activities and does not have any production.

In all scenarios, regardless of whether payments were being made for the carbon sequestered in the scrub mitigation option on sheep and beef land, there was a payment made for the carbon being sequestered in the riparian areas. This payment was 75% of the NZU price. The area taken out of production for riparian areas and subsequent payment for the carbon sequestered in the riparian areas is the same across all scenarios.

[7] A GHG price of \$85/tCO_2e in 2022 is equivalent to a GHG price of \$108.62/tCO_2e in 2030, where the 2022 price increased with the interest rate (see section 2.3.2).

Treatment of carbon sequestered by exotic forestry and native scrub on farms

In consultation with MPI and MfE, it was agreed new native scrub/indigenous forest should be included as a mitigation option only for the sheep and beef sector. It was also agreed for the modelling that any farm forestry on sheep and beef, or dairy farms would have already been captured in the 2030 baseline, which included carbon sequestration payments from exotic forestry through existing ETS settings. Thus, only scrub associated with the scrub mitigation option for the sheep and beef sector is eligible to receive a carbon sequestration payment. This area is accounted for within the sheep and beef area and not the scrub/indigenous forest land use area. Any increase in the scrub/indigenous forest land use reflects land that is being retired (with no incentive payment), while a decrease is where this area is being converted to productive uses.

For scenario variations where the scrub mitigation option for sheep and beef farm systems is included, the price for the carbon sequestered is 75% of the NZU price (or \$81.47/tCO_2e).

3.2.2 The GHG Target

The GHG target scenario estimates the response by the agricultural sector, in terms of land use and management change (via uptake of mitigation options), to meet a specified reduction in GHG emissions in the absence of other climate-related policy signals such as emissions pricing or incentive payments. The modelled 2030 target for reducing methane emissions was 10% below 2020 baseline levels[8] and gross GHG emissions was 11% below 2020 baseline levels.[9] The target for the reduction in methane emissions aligns with the domestic targets under the Climate Change Response Act (CCRA) (New Zealand Government 2019) with the gross emissions target provided by MPI and MfE.

The CCRA requirement for methane emissions reductions is 10% below the 2017 baseline. However, the initial derived 2020 land use map for agricultural production is based on LCBD version 5 (2018), Agribase dataset (September 2020 version), and other data sources. Therefore, for this analysis it was assumed that the GHG emissions for 2020 were the same as those for 2017.

This scenario is only modelled for the tailwind technology setting with no payment for the carbon sequestered in scrub mitigation option for the sheep & beef sector. The modelling results reflect the changes that occur to meet the targets at least economic cost in the absence of any emissions payments, incentives, or rebates. The scenario was not intended to reflect a plausible policy option for government. Rather, it is included to see how the responses differed when the GHG targets had to be achieved but there is no assistance or more nuanced policy signals. It shows that other policy scenarios change the impacts compared to the 'least cost' solution.

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[8] equivalent to reducing methane emissions to the level of 34,969,577 tCO_2e.
[9] equivalent to reducing GHG emissions to the level of 45,318,162 tCO_2e.

3.2.3 Processor-based policy scenarios

The processor is the point of obligation for all processor-based scenarios. This means the processor is paying the cost of emissions on behalf of the farmers, based on the quantity of meat or milk solids they process or fertiliser they produce. The amount a processor pays is based on an emissions factor assigned to the kilograms of meat processed, tonnes of milk solids processed, or tonnes of nitrogen fertiliser sold. Processors are then assumed to pass these costs onto the farmers who are generating the GHG emissions.

The NZU price modelled in these scenarios is \$108.62/tCO_2e. The \$108.62/tCO_2e roughly corresponds to The Treasury's low-price projection for the NZU in 2030. The emissions and incentive prices for the processor-based scenarios are outlined in Table 12.

Four options were modelled:

1) Processor ETS (all mitigation options rewarded) (Processor ETS – All Mit)

This Processor ETS scenario is based on the current settings for including a processor-based levy for agriculture into the ETS.

The GHG emissions price for this scenario is the NZU price of \$108.62/tCO_2e. The processor pays 10% of the NZU price on the quantity of meat and milk processed and the quantity of nitrogen fertiliser sold. This is akin to the 90% free allocation on GHG emissions. Meat and milk sent to the processor from each farm system and the amount of nitrogen fertiliser used by each farm system is the proxy for what processor payments are based on. The payment was calculated using the GHG emissions factors for commodities in Table 5.

An incentive price of \$108.62/tCO_2e was paid for reducing emissions in this Processor ETS scenario from the uptake of both farm management and technology mitigation options. The incentive prices are 10 times the price paid for the emissions.

The total amount paid to farmers for the reduction in GHG emissions from the uptake of mitigation options is constrained to be less than the revenue raised from the processor levy. The common attributes for the scenarios outlined in Section 3.2.1 apply.

2) Processor ETS (technology mitigation options rewarded) (Processor ETS – Tech Mit)

This Processor ETS scenario is the same as the Processor ETS (all mitigation options rewarded) scenario outlined above, except for what mitigation options are rewarded. Only reductions in GHG emissions from the adoption of technology mitigation options are rewarded. The incentive price is \$108.62/tCO_2e.

The amount paid to farmers for the reduction in GHG emissions from the uptake of mitigation options is constrained to be less than the revenue raised from the processor levy. The common attributes for the scenarios outlined in Section 3.2.1 apply.

3) Processor Hybrid (same gas price) (Processor Hybrid – Same Price)

This scenario is the same as the Processor ETS (technology mitigation options rewarded) scenario except that it has split gas emissions pricing. The emissions prices for this scenario are the same for methane and nitrous oxides at \$108.62/tCO_2e, with processors paying 10% of this price. The methane and nitrous oxide emissions factors to calculate the processor emissions payment are in Table 5.

An incentive payment of \$108.62/tCO_2e was paid for reducing emissions from the uptake of technology mitigation options.

The amount paid to farmers for the reduction in GHG emissions from the uptake of mitigation options is constrained to be less than the revenue raised from the processor levy. The common attributes for the scenarios outlined in Section 3.2.1 apply.

4) Processor Hybrid (split gas price) (Processor Hybrid – Diff Price)

This scenario is the same as the Processor Hybrid (same gas price) scenario except there is a different methane emissions price. The emissions price for methane emissions is \$50.20/tCO_2e, while the emissions price for nitrous oxide emissions is \$108.62/tCO_2e. Again, the processor pays 10% of these prices and an incentive price of \$108.62/tCO_2e is paid for reducing emissions from the uptake of technology mitigation options.

The amount paid to farmers for reductions in GHG emissions from the uptake of mitigation options is constrained to be less than the revenue raised from the processor levy. The common attributes for the scenarios outlined in Section 3.2.1 apply.

Table 12 GHG prices for processor-based scenarios

	Processor ETS – All Mit	**Processor ETS – Tech Mit**	**Processor Hybrid – Same Price**	**Processor Hybrid – Diff Price**
	All mitigation options rewarded	*Technology mitigation options rewarded*	*Technology mitigation options rewarded*	*Technology mitigation options rewarded*
GHG emissions price	Commodity emissions factors 10% of GHG price (\$108.62/tCO_2e)	Commodity emissions factors 10% of GHG price (\$108.62/tCO_2e)	Commodity emissions factors 10% of CH_4 & N_2O prices (\$108.62/tCO_2e)	Commodity emissions factors 10% of CH_4 price (\$50.20/tCO_2e) & 10% of N_2O price (\$108.62/tCO_2e)
Methane incentive price	\$108.62/tCO_2e	\$108.62/tCO_2e	\$108.62/tCO_2e	\$108.62/tCO_2e
Nitrous oxide incentive price	\$108.62/tCO_2e	\$108.62/tCO_2e	\$108.62/tCO_2e	\$108.62/tCO_2e
C sequestered by exotic forestry price[a]	\$108.62/tCO_2e	\$108.62/tCO_2e	\$108.62/tCO_2e	\$108.62/tCO_2e
C sequestered by scrub price[b]	\$81.47/tCO_2e	\$81.47/tCO_2e	\$81.47/tCO_2e	\$81.47/tCO_2e

a. Aligns with ETS payment for exotic forestry; price is 1 NZU/tCO_2e sequestered by forestry; NZU price was \$108.62/tCO_2e.
b. Aligns with the Partnerships proposal that scrub C sequestration receives 75% of NZU/tCO_2e; NZU price was \$108.62/tCO_2e.

3.2.4 Farm-level policy scenarios

The farmer is the point of obligation for all farm-level scenarios. Where the NZU price was used for the emissions or incentive prices it is modelled at \$108.62/tCO_2e. The \$108.62/tCO_2e roughly corresponds to The Treasury's low-price projection for the NZU in 2030. A summary of the emissions pricing, incentive prices, and rebate is listed in Table 13.

Three options were modelled:

1) Farm Split Gas Levy

For the Farm Split Gas Levy scenario, the split gas emissions payment is based on the GHG emissions from each farm system. The methane emissions were priced at \$5.02/tCO_2e (this price was provided by MPI and MfE to align with the Partnership's suggested methane price of 11 cents/kg CH_4 which was inflated to a 2030 price). The nitrous oxide emissions price is \$10.86/tCO_2e, which is 10% of the NZU price (\$108.62/tCO_2e) and reflects an emissions price discount similar to the 90% free allocation of emissions.

The incentive payment for reducing methane and nitrous oxide emissions in the Farm Split Gas Levy scenarios rewards the uptake of technology mitigation options. Only the pastoral sector receives payments for reducing methane emissions. A range of methane incentive prices are modelled to identify the incentive price(s) which induced different responses by the various pastoral farm systems. The base methane incentive price was equal to the methane emissions price (\$5.02/ tCO_2e). The incentive prices modelled were the base methane incentive price, two times (\$10.04/tCO_2e), five times (\$25.10/ tCO_2e), ten times (\$50.20/ tCO_2e) and twenty times the base methane incentive price (\$100.40/tCO_2e).

The incentive price to reduce nitrous oxide emissions was 2.5 times the \$10.86/tCO_2e nitrous oxide emissions price. This equates to \$27.16/tCO_2e for the reduction in nitrous oxide emissions from the adoption of technology mitigation options. The '2.5' multiplier was provided by MPI and MfE to align with the Partnership's modelling of the climate policy scenarios.

The amount paid to farmers for reductions in methane and nitrous oxide emissions from the uptake of technology mitigation options is constrained to be less than the revenue raised from the pricing of emissions. The common attributes for the scenarios outlined in Section 3.2.1 apply.

2) Farm LUC Rebate (same gas price) (Farm LUC – Same Price)

For this scenario, the GHG emissions from farms are priced and the rebate to farmers is based on Land Use Capability (LUC). Farmers faced the full NZU price (i.e. \$108.62/tCO_2e emitted) for their methane and nitrous oxide emissions.

The calculation for the rebate paid to farmers is outlined in the Data Sources section (Section 2.3.10). The rebate amounts are listed in Table 6. The rebate is assumed to be the same across different land uses, only differing by the LUC class of the land, i.e. the same rebate is given to dairy, sheep and beef, arable and horticulture if they are located on land with the same LUC class. Land in scrub or indigenous forest does not receive a rebate as this land has not contributed to an emissions payment.

The total rebate to the agricultural sector is constrained to be less than the revenue raised from the pricing of emissions in the 2030 baseline. The common attributes for the scenarios outlined in Section 3.2.1 apply.

3) Farm LUC Rebate (split gas price) (Farm LUC – Diff Price)

This scenario is the same as the previous scenario except there is a different price for methane and nitrous oxide emissions. Methane emissions are levied at the full price of $50.20/tCO_2e$, and nitrous oxide emissions are levied at the full price of $108.62/tCO_2e$.

The rebate structure is also the same as the previous scenario with the rebate amounts listed in Table 7. The aggregate emissions payment in 2030 differs in this scenario as different emissions prices are applied to methane and nitrous oxide emissions. As the emissions payment determines the total funds available for the rebate payments, the per hectare rebate is smaller than the Farm LUC Rebate (same gas price) scenario.

The total rebate to the agricultural sector is constrained to be less than the revenue raised from the pricing of emissions. The common attributes for the scenarios outlined in Section 3.2.1 apply.

Table 13 GHG prices for farm-level scenarios

	Farm Split Gas Levy	Farm LUC – same price	Farm LUC – diff price
	Technology mitigation options rewarded[a,b,c]	*Rebate derived from LUC productive potential*[d]	*Rebate derived from LUC productive potential*[d]
Methane emissions price	\$5.02/tCO_2e	\$108.62/tCO_2e	\$50.20/tCO_2e
Nitrous oxide emissions price	\$10.86/tCO_2e	\$108.62/tCO_2e	\$108.62/tCO_2e
Methane incentive price	\$5.02/tCO_2e \$10.04/tCO_2e \$25.10/tCO_2e \$50.20/tCO_2e \$100.40/tCO_2e	Not applicable	Not applicable
Nitrous oxide incentive price	\$27.16/tCO_2e	Not applicable	Not applicable
LUC-based incentive price	Not applicable	Different rebates for different LUC classes (see Table 6)	Different rebates for different LUC classes (see Table 7)
C sequestered by exotic forestry price[d]	\$108.62/tCO_2e	\$108.62/tCO_2e	\$108.62/tCO_2e
C sequestered by scrub price[e]	\$81.47/tCO_2e	\$81.47/tCO_2e	\$81.47/tCO_2e

a. Accounts for 90% payment discount on NZU price in 2030 (NZU price is \$108.62/tCO_2e).
b. A range of multipliers (x1, x2, x5, x10, x20) on the base methane incentive price (\$5.02/tCO_2e) for the methane incentive payment is modelled to show how the methane incentive price influenced land use change and/or update in technology mitigation options.
c. A 2.5 multiplier on the discounted NZU price (or \$10.86/tCO_2e) for the nitrous oxide incentive price is used as per discussions with MPI and MfE and to align with some of the Partnership's assumptions.
d. Farmers faced the full price of GHG emissions.
e. Aligns with ETS payment for exotic forestry; price is 1 NZU/tCO_2e sequestered by forestry; NZU price was \$108.62/tCO_2e.
f. Aligns with the Partnerships proposal that scrub C sequestration receives 75% of NZU/tCO_2e; NZU price was \$108.62/tCO_2e.

3.3 Summary of assumptions and caveats

Some of the key assumptions in the analysis include:

- The methane emissions for 2020 were the same as those for 2017. The CCRA requirements relate to a 2017 baseline but some of the key data used to derive the agricultural land use map was only available for 2020 (see section 2.3.1).
- There is no uptake of GHG mitigation options in the baseline. We assumed all mitigation options for the primary sector are adopted in the scenarios.
- To distinguish the impacts of climate policies, other agri-environmental policies such as the 1 Billion Trees Programme and Erosion Control Funding Programme were not modelled.

- There is an efficient approach operating to distribute incentive payments to farmers in all scenarios and that the distribution costs for the payments are the same across scenarios.

Forestry, scrub, and carbon sequestration assumptions:

- All exotic forestry (*Pinus radiata*) receives a carbon sequestration payment at the NZU price of \$108.62/tCO_2e.
- We did not differentiate between stock change accounting and averaging accounting approaches in calculating the carbon sequestration from exotic forestry, as both approaches result in similar carbon sequestration for forestry in 2030.
- Payment for new scrub, via a scrub mitigation option, is assumed to be only applicable for a subset of sheep and beef farms. The farms with this option have some areas with lower pasture production potential. It is these areas that revert to scrub. The price paid for carbon sequestered by the scrub mitigation option for sheep and beef farm systems was 75% of the NZU price. As only a portion of the land on a farm goes to scrub, this means the farm remains as a 'working farm', which aligns with the Partnership's proposal only to reward new scrub on working farms. It is assumed dairy land would not have marginal land that may be better suited to scrub. The new scrub area on sheep and beef land is captured within the sheep and beef land use area, not the scrub and indigenous forest land use area.
- All exotic forest on farms enters the ETS and is captured in the projected 2030 baseline.
- All riparian buffer areas are assumed to contain regenerating scrub. The carbon sequestered by the scrub received a payment equivalent to 75% of the NZU price. The area of and payments received for scrub in the riparian buffers is the same across all scenarios.

Pricing assumptions:

- A GHG price of \$85/tCO_2e in 2022 is equivalent to a GHG price of \$108.62/tCO_2e in 2030, where the 2022 price increased with the interest rate (see section 2.3.2).

Processor assumptions:

- The quantity of meat sold to the works, or the milk produced or fertiliser used in each farm system is equivalent to what the processor emissions payment applies to.
- The processor will pass a price signal for emissions back to farmers and farmers will respond by adopting mitigation options or changing land use.

Mitigation option assumptions:

- There is no signup needed to receive an incentive payment for adopting eligible mitigation options. The CET functions in the model do ensure the uptake of mitigation option is not driven purely by profit and that there is a more gradual uptake of options over time.

Data assumptions:

- The Beef+Lamb NZ farm classes were distributed across New Zealand based on the assumption that the location of farm classes would correspond to certain LUC classes. The assignment of Beef + Lamb NZ farm classes to LUC classes is provided in Table 4.

Policy assumptions

- A 3 m riparian buffer was needed to meet the requirements for the National the National Policy Statement for Freshwater Management, and this area would no longer be available for agricultural production
- Similarly, a 10 m riparian buffer for land under exotic forestry production would reflect the riparian set back requirements in the National Environmental Standards for Plantation Forestry. This is the requirement for perennial rivers with a bankfull channel width of 3 m or more (New Zealand Government 2017; 4Sight Consulting 2018). This definition of rivers is used as this is the more likely river size captured in the river datasets used in this modelling.

Some points to note for the analysis include:

- Deer were farmed on 3 of the 21 dry stock farms from MPI (2022) used for the modelling. Therefore, the results for the impact on deer should be used with caution due to the small representation in the modelling.
- Aggregate areas of different land uses and land use change are tracked. Land conversion costs are not accounted for as the model does not spatially track which land use converts to another land use.
- Timber production was not tracked as it was not possible to derive timber production or timber sales from the outputs of the FIF.
- Only biological emissions and carbon sequestration are included in the analysis. Carbon dioxide emissions associated with agricultural production are excluded as most of these emissions are fossil fuel emissions and already accounted for in the ETS. Lime and organic soil emissions could be an exception, but the farm systems included in the modelling did not apply lime and we did not account for organic soils. Also, dairy GHG emissions were estimated using Overseer and carbon dioxide emissions in the version of Overseer used included embodied carbon of some inputs.
- Commodity prices were held constant in the modelling. If commodity prices were to increase, less land use change is likely to occur or there may be a higher uptake of mitigation options. If commodity prices decrease, there may be more land use change or a lower uptake of more costly mitigation options. Fixed and variable costs are also held constant, with any increase(decrease) in costs likely to lead to more(less) land use change or adoption of mitigation options.

4 Results and discussion

The results section is organised by the key impacts of the agricultural climate policy scenarios modelled – GHG emissions, land use, net revenue, agriculture production, and emissions payments, incentive payments and rebates.

There are two variations for the scenarios modelled. One where a scrub mitigation option is available to the sheep and beef sector and there is a payment for the carbon sequestered. The other variation is where there is no scrub mitigation option or subsequent sequestration payment available in the sheep and beef sector. In terms of overall results there is little difference between these two variations, i.e. total GHG emissions reduction or change in agricultural net revenue are similar. Looking more closely at the disaggregated results, some differences emerge. Where there is a payment for the carbon sequestered in the scrub mitigation option, more scrub mitigation is adopted; however, fewer other mitigation options are adopted. In comparison, where there is no scrub mitigation option, the mix of mitigation options adopted differs but the overall reduction in GHG emissions and net revenue from that mix of mitigation options is similar to where there is a payment for the carbon sequestered in the scrub mitigation option. Given the similarities in the results, the variation with a payment for the carbon sequestered by new scrub through the scrub mitigation option for the sheep and beef sector is only specifically discussed in the following sections.

There is not a separate section on the uptake of mitigation options. Instead, mitigation option adoption is discussed in the different sections where differences in adoption help explain the modelling results. The results of all scenarios and scenario variations, including the uptake of mitigation options, can be found in Appendices 4–8.

4.1 Interpreting the results

The results need to be carefully interpreted based on the signals being sent by the different policy scenarios. Some of the key differences to note for interpretation are:

- What is being priced – the processor emissions payments are based on a sub-set of agricultural commodities being produced, namely milk and meat and the amount of nitrogen-based fertiliser being used. Emissions factors attached to production are used as a proxy for the GHG emissions from a farm. The farm-level emissions payments are based on the estimated methane and nitrous oxide emissions being generated by agricultural production. Biological GHG emissions from all components of the farm system – not just milk, meat, and fertiliser – face an emissions price.
- What is being incentivised – most of the scenarios incentivise the uptake of technology mitigation options. However, one of the Processor ETS scenarios incentivises all mitigation options, and the rebate in the Farm LUC Rebate scenarios are based on land productivity, not the reduction in GHG emissions.

- GHG emissions prices – the emissions price for most processor-based scenarios is 10% of the NZU price (i.e. \$10.86/tCO_2e), except for the Processor Hybrid scenario where methane emissions are priced at \$5.20/tCO_2e (reflecting the price requested by MPI and MfE to align with the Partnership's lower price for methane). The emissions prices in the Farm Split Gas Levy scenario are similar to the Processor Hybrid prices.
- Incentive prices – The incentive prices for the processor-based scenarios is the NZU price of \$108.62/tCO_2e. For the Farm Split Gas Levy scenarios, the nitrous oxide incentive price is \$27.16/tCO_2e (i.e. 2.5 times 10% of the NZU price) while the methane incentive price ranges from \$5.02 to \$100.40/tCO_2e depending on the multiplier attached to the base methane incentive price (\$5.02/tCO_2e).

Results are driven by the key differences between the scenarios and the uptake of mitigation options and land use changes that occur in response.

While the meat emissions factor is meant to account for emissions associated with wool production, the pricing signal for wool appears to be muted as those farm systems with greater wool than meat production in the South Island are less impacted in the Processor Hybrid scenario

As an example, compare the Farm Split Gas Levy scenario and the Processor Hybrid (split gas price) scenario. In this comparison, there is a greater reduction in sheep and beef land area, revenue, lamb production, and GHG emissions in the Farm Split Gas Levy scenario. In particular, there is a greater reduction in South Island sheep and beef land in the Farm Split Gas Levy scenario. This is likely driven by the Farm Split Gas Levy scenario pricing the emissions from all sheep and beef land the same across the country. The Processor Hybrid scenario, in comparison, only prices meat and milk production and fertiliser usage, and not wool explicitly. While the meat emissions factor is meant to account for emissions associated with wool production, the pricing signal for wool appears to be muted as those farm systems with greater wool than meat production in the South Island are less impacted in the Processor Hybrid scenario. If the meat emissions factor does not also fully account for the emissions from wool production, then this would explain why there is a smaller reduction in South Island sheep and beef area in the Processor Hybrid scenario.

The differences between the scenarios that pay for carbon sequestration from the sheep and beef scrub mitigation option and the same scenarios where there is no payment for scrub carbon sequestration often produce similar aggregated results. However, there are differences in the scrub mitigation area taken up by the sheep and beef sector. These area differences are small compared with the total area of sheep and beef land and thus have little impact on the aggregated results.

4.2 GHG Emissions

The impact on GHG emissions from each scenario are outlined in Table 14. Of note, the results in Table 14 represent the change in emissions compared with the 2030 baseline emissions, not the 2017 emissions on which the CCRA target is based. Using the 2020 baseline emissions as a proxy for the base year for the CCRA target, a reduction in methane emissions of 8.5% and GHG emissions of 10.4% equates to meeting the GHG targets.[10] Most scenarios achieve the 10% reduction in methane emissions and 11% reduction in GHG emissions. There is no reduction target for nitrous oxide emissions.

The GHG Target scenario is modelled to meet the specified GHG targets.

The processor-based scenarios with the same emissions price for methane and nitrous oxides estimate reductions in GHG emissions of around 18% across all variations, technology settings and mitigation options incentived. The uptake of mitigation options, however, does differ between incentivising all mitigation options or just technology mitigation options (see Appendix 6). As expected, more management mitigation options are taken up when all mitigation options are incentivised, and there are fewer technology mitigation options adopted. While this results in different mitigation options being taken up and differences in land use change in some sectors, the overall reduction in GHG emissions is similar across scenarios. The payment for new scrub area on sheep and beef land through the scrub mitigation option has little influence on the results.

As expected, using split gas pricing where the emissions price of methane is lower than the long-lived gas price for nitrous oxide results in less GHG emission reductions in the Processor Hybrid (split gas price) scenario. For the NZU price modelled the GHG targets are still achieved, with GHG emissions estimated to fall by just under 12%. The lower methane emissions price benefits all pastoral farming, and we see smaller area reductions of dairy and sheep and beef land. Correspondingly, we see smaller increases in forestry, arable and horticulture land from dairy or sheep and beef land being converted to these land uses.

Most of the Farm Split Gas Levy scenarios show GHG emissions reductions between 14.4-15%, except with the tailwind technology setting where the methane incentive price is 20 times the base methane incentive price (\$5.02/tCO_2e). This scenario is projected to achieve the methane reduction target but not the GHG reduction target. In this scenario, the incentive price has reached a level where it is profitable for farms to take up more expensive (and more effective) mitigation options like bromoform bolus which reduces methane emissions. Therefore, less land moves out of sheep and beef and dairy. The larger area that remains in sheep and beef and dairy means the methane and nitrous oxide emissions do not reduce as much.

For the headwind technology settings, the cost of technology mitigation options is often higher, and they are not as effective in 2030 (see Appendix 3). However, the GHG targets were achieved for all incentive prices. Even with the higher methane incentive prices for the technology mitigation options (i.e. 20 times the base methane incentive price) there are fewer (and different) technology mitigation options adopted and more land use change

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[10] The methane reduction target is a requirement in the CCRA, while the overall GHG emissions reduction target was specified by MPI and MfE.

compared with the tailwind technology setting. This outcome suggests that while mitigation options to reduce GHG emissions are important, they are unlikely to be sufficient to reduce GHG emissions to future target levels, unless the effectiveness of those mitigation options improves even more to counteract the effect of more livestock remaining in the agriculture sector.

The Farm LUC Rebate scenarios also do not meet the GHG targets because of the rebate system implemented. In this scenario, farmers face the full NZU price and receive a rebate based on LUC class(s) on the farm.[11] For some farm systems the per-hectare rebate farmers receive is markedly higher than their current profits and the payment they make for their GHG emissions, which increases their overall profitability, particularly for sheep and beef. This results in an increase in the area of sheep and beef land in some regions and LUC classes, with a resulting increase in GHG emissions. There is still an overall decrease in dairy GHG emissions as their emissions payments are often still higher than the rebate they receive. Forestry also decreases in some areas as the profitability of sheep and beef farms increases and some forestry land is converted to pastoral uses. Similarly, areas of existing scrub and indigenous forest which earn no revenue also move into sheep and beef.

Overall, of the scenarios modelled, the processor-based scenarios with the same emissions prices for methane and nitrous oxide emissions result in the biggest reduction in GHG emissions, followed by the Farm Split Gas Levy scenarios, and then the processor-based Hybrid scenario with different GHG prices. The processor-based scenarios have a different pricing signal as they explicitly price milk and meat production, and fertiliser use, but not wool production. This, arguably, means those sheep and beef farm systems with greater wool production are less exposed to emissions pricing compared with the farm-level scenarios where the emissions payments are based on GHG emissions rather than on output/input levels. The processor-based scenarios preferentially benefit South Island sheep and beef farm systems as they produce more wool and less meat. North Island sheep and beef farm systems experience greater impacts, especially those with higher beef to sheep ratios.

Appendix 4 provides more detailed results by sector for GHG, methane and nitrous oxide emissions.

[11] For the modelling, we have assigned each sheep and beef farm system and dairy farm system to LUC classes. We recognise, though, most farms will contain a mix of LUC classes.

Table 14 Relative Change (%) in GHG, methane and nitrous oxide emissions compared with the 2030 Baseline (grey highlight indicates those scenarios that do not meet the reduction targets set out in the CCRA[a])

Scenarios	2030 Baseline (tCo_2e)	GHG Target[c]	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)	Farm LUC – Same Price	Farm LUC – Diff Price
Tailwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector												
GHG emissions[b]	50,569,127	-10.4%	-18.2%	-18.3%	-18.3%	-11.7%	-14.4%	-14.5%	-15.0%	-8.4%	1.4%	1.5%
CH_4 emissions	38,216,894	-8.5%	-19.0%	-19.1%	-19.1%	-12.3%	-15.0%	-15.1%	-16.3%	-10.7%	1.6%	1.8%
N_2O emissions	12,352,233	-16.2%	-15.9%	-15.8%	-15.8%	-9.9%	-12.6%	-12.6%	-10.9%	-1.3%	0.6%	0.6%
Tailwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector												
GHG emissions[b]	50,569,127	NA	-18.2%	-18.3%	-18.3%	-11.7%	-14.4%	-14.5%	-14.9%	-8.4%	1.4%	1.5%
CH_4 emissions	38,216,894	NA	-18.9%	-19.1%	-19.1%	-12.2%	-15.0%	-15.1%	-16.3%	-10.7%	1.6%	1.8%
N_2O emissions	12,352,233	NA	-15.8%	-15.8%	-15.7%	-9.9%	-12.6%	-12.6%	-10.9%	-1.3%	0.6%	0.6%
Headwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector												
GHG emissions[b]	50,569,127	NA	-18.0%	-18.1%	-18.1%	-11.9%	-14.5%	-14.5%	-14.5%	-14.6%	1.4%	1.5%
CH_4 emissions	38,216,894	NA	-18.6%	-18.8%	-18.8%	-12.3%	-15.1%	-15.1%	-15.1%	-15.2%	1.6%	1.8%
N_2O emissions	12,352,233	NA	-16.2%	-16.1%	-16.0%	-10.7%	-12.6%	-12.6%	-12.6%	-12.5%	0.6%	0.6%
Headwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector												
GHG emissions[b]	50,569,127	NA	-18.0%	-18.1%	-18.1%	-11.9%	-14.5%	-14.5%	-14.5%	-14.6%	1.4%	1.5%
CH_4 emissions	38,216,894	NA	-18.6%	-18.8%	-18.7%	-12.3%	-15.1%	-15.1%	-15.1%	-15.2%	1.6%	1.8%
N_2O emissions	12,352,233	NA	-16.2%	-16.0%	-16.0%	-10.7%	-12.6%	-12.6%	-12.6%	-12.5%	0.6%	0.6%

a: the data in the table represents the change from the 2030 baseline emissions, not from 2017, on which CCRA target is based on. Comparing the change in emissions with the 2020 emissions (as a proxy for the CCRA target) reductions of 8.5% for methane and 10.4% for GHG emissions equates to achieving the GHG targets.

b: GHG emissions are the sum of methane and nitrous oxide emissions.

c: not all variations were modelled for the GHG Target scenario; NA means this variation was not modelled.

4.3 Land use

Land use changes demonstrate a similar trend as the changes in GHG emissions across the scenarios (Figure 2 and Figure 3). Appendix 5 provides more detailed results on land use change by sector for all variations of the scenarios.

The processor-based scenarios where the processor faces the same emissions price for methane and nitrous oxide emissions (for milk and meat production and fertiliser use) produces similar degrees of land use change across all scenarios. Land in sheep and beef is estimated to fall by around 20% and dairy by 5–6%, while forestry area increases by about 5%, arable between 10 and 11%, and fruit and vegetables between 4 and 7%.

The Processor Hybrid (split gas price) scenario where methane emissions have a lower emissions price than nitrous oxide emissions results in less land moving out of the pastoral land uses (~11% for sheep and beef and ~3% for dairy), and correspondingly less land moving into forestry (~3%), arable (~6%), and horticultural (2–4%) uses. The lower methane emissions payments mean the impact on profitability from pricing biological GHG emissions is lower causing less land to change uses.

The Farm LUC Rebate scenarios, as noted in the previous section, increase the area in sheep and beef (by ~8%). The per-hectare rebate, especially in higher LUC classes, means the profitability of some sheep and beef farm systems increase substantially even though they now face a GHG emissions price. Therefore, less sheep and beef land converts to other uses or is retired. These scenarios, however, do not meet the GHG targets (Table 14).

In the Farm Split Gas Levy scenarios, the land use change induced by the GHG emissions prices remains relatively stable across methane incentive prices until the incentive price for methane is between 5 and 10 times the base methane incentive price ($5.02/tCO$_2$e) for the tailwind technology setting. Between these methane incentive prices, different mitigation options for different sheep and beef farm systems become profitable and are taken up. The greater uptake of mitigation options means a smaller area of sheep and beef land changes land use. At 5 times the base methane incentive price, there is an estimated reduction in sheep and beef area of ~18%, while at 10 and 20 times the base methane incentive price, there is ~17% and 4% decrease in area, respectively.

Still with the tailwind technology setting, it is not until the methane incentive price is between 10 and 20 times the base methane incentive price there is greater uptake of technology mitigation options for dairy, particularly bromoform bolus, and there is a decrease in land use change. At 1, 5 and 10 times the base methane incentive price, the decrease in dairy area is estimated to be 2.7–3.1%, while at 20 times, it is estimated at 2.3%.

The lower 2030 cost-effectiveness of technology mitigation options for the headwind technology setting in the Farm Split Gas Levy scenario, however, result in little variation in technology mitigation option uptake and subsequent land use change across all methane incentive prices modelled. The estimated reduction in the area in sheep and beef is ~18% and around 2.7% for dairy.

There is a difference in the extent of land use change induced in the sheep and beef sector between the Processor Hybrid (split gas price) and the Farm Split Gas Levy scenarios. These scenarios are similar in terms of GHG emissions prices, with the 20 times base methane incentive price for Farm Split Gas Levy being similar to the methane incentive for the Processor Hybrid (split gas price) scenario. There is still a difference in the nitrous oxide incentive payment. As noted in the GHG emissions section (Section 4.2), the processor-based scenarios tie their emissions payments explicitly to meat and milk production and fertiliser use, while GHG emissions are the basis of the farm-level scenarios emissions payment. Therefore, different sheep and beef farm systems are exposed to different emissions pricing signals between the scenarios. Those farm systems with greater wool than meat production are less impacted in the modelling by GHG emissions pricing in the Processor Hybrid (split gas price) scenario. This scenario has a lower impact on South Island sheep and beef farm systems where there are more sheep and beef farm systems with higher wool than meat production in the South Island.

The impact on the area of dairy land use is similar for both split gas scenarios (at around 2 to 3%). The mix of technology mitigation options adopted does change (see Appendix 6) between the split gas scenarios. There is a greater uptake of the dairy bromoform bolus in the Processor Hybrid (split gas price) scenario. For all pastoral farming the higher nitrous oxide incentive price in the Processor Hybrid (split gas price) scenario results in nitrous oxide-focused technologies being adopted over a larger area.

In all scenarios there is an increase in horticultural (from 0.2 to 6.9% depending on the scenario) and arable (from 2 to 10.9% depending on the scenario) areas as some of the pastoral land moves to those land uses in response to the pricing of GHG emissions. A slightly larger area of land moves to those land uses under the headwind technology setting as the technology mitigation options are less cost-effective than in the tailwind technology setting in 2030, and thus offer fewer cost-effective mitigation options for the pastoral land uses. Higher GHG emissions prices (i.e. processor ETS scenarios) also result in bigger increases in the area in horticulture and arable uses than the scenarios with lower methane emissions prices.

The forestry area is estimated to increase in all scenarios (from 0.1 to 5.2%, depending on the scenario). As with horticultural and arable land, the increase in area between scenarios reflects the variation in GHG emissions pricing.

The GHG Target had quite a different pattern of land use change compared with the other scenarios. Dairy, which has the highest emissions, was estimated to decrease by about 24%, while the area in most other land uses increased (see Appendix 5). This is driven by the requirement for the agricultural sector to the meet the GHG targets with no reward given for the uptake of mitigation options or payment for GHG emissions. Thus, reducing dairy area is the 'least cost' approach to meet the GHG targets under these conditions. While the area in sheep and beef production increased, this sector also had the largest uptake of the reduced stocking rate management practice (see Appendix 6).

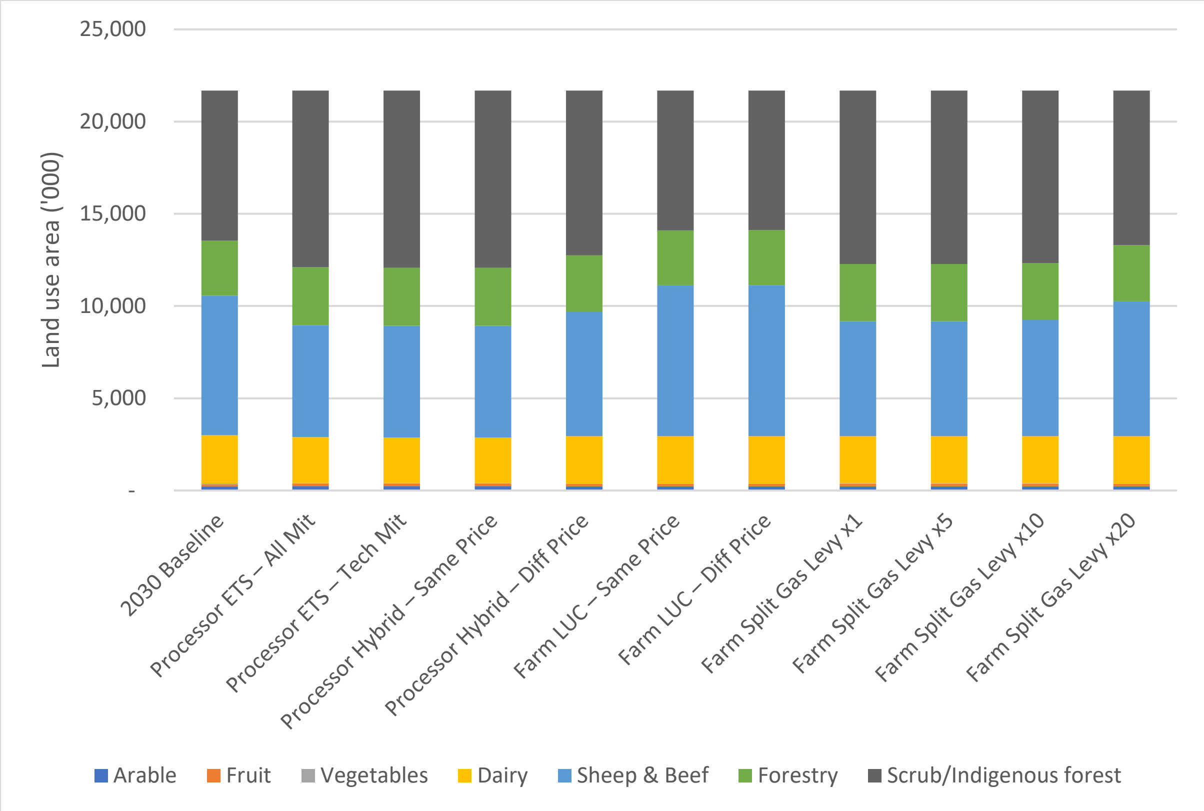

Figure 2 Land use area (ha) by sector for each scenario using tailwind technology setting and where there is no payment for the new carbon sequestered by the sheep and beef scrub mitigation option (Appendix 5 provides the results where there is a payment for the carbon sequestered). Note: GHG target is not included in this table.

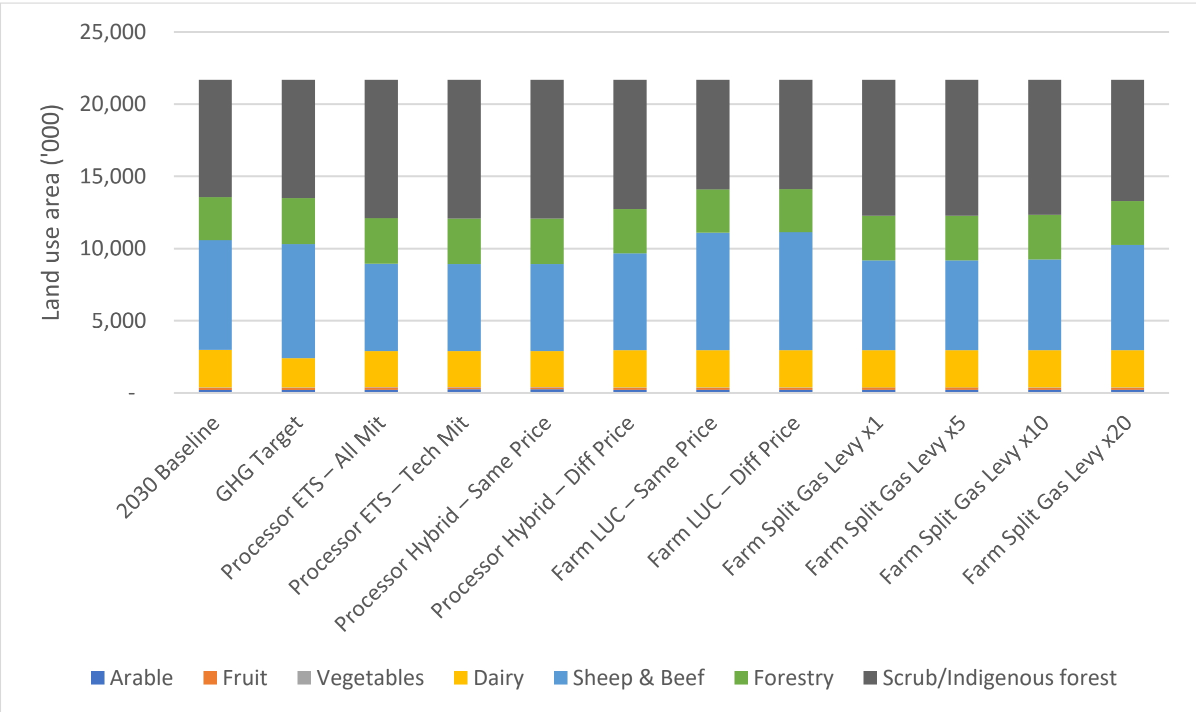

Figure 3 Land use area (ha) by sector for each scenario using headwind technology setting and where there is no payment for the new carbon sequestered by the sheep and beef scrub mitigation option (Appendix 5 provides the results where there is a payment for the carbon sequestered). Note: GHG target is not included in this table.

4.4 Net revenue

The changes in net revenue have a similar trend as the changes in GHG emissions across the scenarios (Table 15). Appendix 7 provides more detailed results by sector for the changes in net revenue.

The processor-based scenarios with the same GHG price are estimated to have the largest decrease in overall net revenue (5.8–5.9%) for the agricultural and forestry sectors, followed by Farm Split Gas Levy (lower methane incentive price) at ~5–5.1% and Processor Hybrid (split gas price) scenario (4.5–4.6%). The Farm Split Gas Levy (20 times the base methane incentive price) and the Farm LUC Rebate scenarios have the smallest decrease in net revenue at 3.9% and 2.8% respectively but do not meet the GHG targets (Table 14).

There is a difference in the change in net revenue between the Processor Hybrid (split gas price) and the Farm Split Gas Levy (20 times base methane incentive price) scenarios, despite these scenarios having similar GHG emissions pricing and methane incentive prices. The emissions pricing signals seems to be driving this difference. Pricing milk and meat production and fertiliser use in the Processor Hybrid (split gas price) scenario results in more dairy area moving into Dairy System 3 in some regions, which has lower milk solid production but is still quite profitable. So, despite there being more total dairy land use change in the Processor Hybrid (split gas price) scenario, the emissions pricing structure and corresponding change from higher output dairy systems to lower output dairy systems offsets the reduction in net revenue.

There is also greater uptake of the bromoform bolus and 3NOP technology mitigation options in the Processor Hybrid (split gas price) scenario particularly in Dairy 3 and Dairy 4 systems. Of all the mitigation options, bromoform bolus, while relatively expensive, reduces methane emissions most.

The impact on net revenue for the processor-based scenarios with the same GHG emissions prices is greater than the Processor Hybrid (split gas price) scenario. The lower impact on net revenue in this scenario is primarily due to the lower methane emissions price.

The greater impact on net revenue when only the technology mitigation options are rewarded in the Processor ETS (technology mitigation options rewarded) scenario comes from more land being retired than in the Processor ETS (all mitigation options rewarded) scenario. Providing a payment for the management mitigation options as well as for the technology mitigation options gives pastoral farmers more profitable mitigation options (after the incentive payment), thus reducing land use change and the subsequent impact on net revenue.

The increase in net revenue for the sheep and beef sector in the Farm LUC Rebate scenarios comes from the per-hectare rebate making some sheep and beef farm systems very profitable, especially those on lower LUC class land. Thus, more land is moving to sheep and beef, as even with a GHG price on emissions these farm systems become quite profitable. The adoption of mitigation options is consequently lower. These scenarios, as noted above, however, do not meet the GHG targets (Table 14).

The overall trends and results for net revenue are very similar between the headwind and tailwind technology settings. There are some differences in the uptake of technology mitigation options between the two settings (see Appendix 6). This is best illustrated in the Processor ETS (all mitigation options rewarded) scenario, where more management mitigation options and fewer technology mitigation options are adopted under the headwind technology setting than under the tailwind setting for dairy and sheep and beef farm systems. This is similar for all scenarios.

The total net revenue for the horticultural and arable sectors increases in all scenarios as more land moves into these uses and away from the pastoral uses. The profitability of pastoral land uses is more negatively impacted by GHG emissions pricing than the horticultural and arable land uses. Profitability increases more under the headwind technology setting than under the tailwind setting, reflecting there are fewer cost-effective technology options available to the pastoral sectors and that the arable and horticultural land uses offer comparable or greater net revenue. Consequently, there is some movement from pastoral land uses to horticultural and arable land uses.

Table 15 Relative Change (%) in total net revenue compared to the 2030 Baseline for each scenario

Scenarios	Tailwind Technology Setting		Headwind Technology Setting	
	No SNB Scrub Payment[a]	SNB Scrub Payment[b]	No SNB Scrub Payment	SNB Scrub Payment
GHG Target	-4.2%	NA	NA	NA
Processor ETS – All Mit	-5.8%	-5.8%	-5.8%	-5.8%
Processor ETS – Tech Mit	-5.9%	-5.9%	-5.9%	-5.9%
Processor Hybrid – Same Price	-5.9%	-5.9%	-5.9%	-5.9%
Processor Hybrid – Diff Price	-4.5%	-4.5%	-4.6%	-4.6%
Farm Split Gas Levy (x1)	-5.1%	-5.1%	-5.1%	-5.1%
Farm Split Gas Levy (x5)	-5.1%	-5.1%	-5.1%	-5.1%
Farm Split Gas Levy (x10)	-5.0%	-5.0%	-5.1%	-5.1%
Farm Split Gas Levy (x20)	-3.9%	-3.9%	-5.0%	-5.1%
Farm LUC – Same Price	-2.8%	-2.8%	-2.8%	-5.0%
Farm LUC – Diff Price	-2.8%	-2.8%	-2.8%	-2.8%

a: there is no payment for the carbon sequestered by new scrub in the sheep and beef scrub mitigation option.
b: there is a payment for the carbon sequestered by new scrub in the sheep and beef scrub mitigation option.

4.5 Production levels

The changes in production levels mostly follow a similar trend to the other parameters (Table 16) with decreases in the production of livestock commodities for most scenarios and increases in horticultural and arable commodities in all scenarios. Our input data for forestry did not include timber production (only net revenues) so we are unable to estimate what changes in timber production may result from these scenarios. However, based on the increase in forestry areas across all scenarios, an increase in timber production would be expected. This increase is mitigated, however, by the riparian areas being taken out of production with the implementation of the National Environmental Standard for Plantation Forestry.

Similar reductions in the production of milk solids, lamb, beef, and wool occur across the processor-bases scenarios with the same GHG emissions prices for each commodity. For the tailwind technology setting, this is ~9.5% decrease in milk solids, ~23.5% decrease in lamb, ~61% decrease in beef,[12] and ~22% decrease in wool. The smaller impact on production of the split gas pricing in the Processor Hybrid (split gas price) scenario flows from the lower methane price resulting in less land use change. For example, in the tailwind technology setting there is an ~37% decrease in beef production in the Processor Hybrid (split gas price) scenario compared to ~61% for the Processor Hybrid (same gas price) scenario. The greater reduction in beef production compared with lamb and wool for all processor-based scenarios likely reflects there is no explicit GHG emissions pricing of wool production. In the modelling, those sheep and beef systems with greater beef production are more affected by a GHG emissions price in the processor-based scenarios than those systems with lower or no beef production.

Between 5 and 10 times the base methane incentive price in the Farm Split Gas Levy scenario with the tailwind technology setting, it becomes profitable for some mixed sheep and beef farm systems area to move into a beef-only farm system, with more bromoform bolus being adopted on both new and existing areas. Bromoform bolus on this farm system reduces the impact on beef production (estimated reduction in production of less than 1%) and decreases methane emissions. So, even though this beef system runs at a loss when bolus is adopted, the methane incentive price makes bromoform bolus adoption profitable.

At higher methane incentive price in the Farm Split Gas Levy scenario, even more land goes into this beef-only system, including from existing scrub and indigenous forest. This result is being driven by the one-farm system. This farm system is a lower-profit, beef-only system, but as the methane incentive price increases, the adoption of the bromoform bolus mitigation option makes this system more profitable than other mixed sheep and beef systems. We note that if a different beef-only farm system was used in the modelling it

[12] As noted in Section 2.3.6 beef production from culled cows is not included in beef production estimates. Therefore, the reduction in beef production is likely smaller than what is estimated in the modelling.

might have produced different results. The result, however, does show there will be incentive price where farm systems will move from being less profitable to more profitable, depending on their stock mix, management practices, and the effectiveness of different mitigation options for that system.

As with the other parameters, the negative impacts on production of the Farm LUC Rebate scenarios are lower. For some farm systems the per-hectare rebate farmers receive is markedly higher than the payment they make for their GHG emissions which increases their profitability, particularly for sheep and beef. As a result, production is less impacted. However, these scenarios do not meet the GHG targets (Table 14).

The production of horticultural and arable commodities increases in all scenarios (see Appendix 8). The scale of production increases reflects the variation in the methane prices across the scenarios, where the lower methane price scenarios have smaller increases in horticultural and arable commodity production.

Greater reductions in the production of livestock commodities result under the headwind technology setting than under the tailwind setting. Again, the smaller number of cost-effective technology mitigation options means more pastoral land use change and subsequent decreases in production. Greater subsequent increases in horticultural and arable commodity production arise under the headwind technology settings.

The large decrease in milk solids in the dairy sector in the GHG Target scenario is due to the estimated reduction in dairy area, with the smaller increase in lamb, beef and wool coming from the increase in sheep and beef area in this scenario.

Appendix 8 provides more detailed results by commodity.

Table 16 Relative Change (%) in the production in key pastoral commodities compared to the 2030 Baseline for each scenario

Production (t)	Scenarios										
	GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)	Farm LUC – Same Price	Farm LUC – Diff Price
Tailwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector											
Milk solids	-29.1%	-9.3%	-9.5%	-9.5%	-6.2%	-5.3%	-5.3%	-5.6%	-4.6%	-4.5%	-4.4%
Lamb	4.7%	-23.3%	-23.6%	-23.6%	-14.7%	-21.4%	-21.4%	-24.4%	-18.9%	-3.2%	-2.6%
Beef	1.8%	-62.0%	-60.8%	-60.8%	-36.9%	-36.7%	-36.7%	-0.7%	80.2%	47.8%	45.2%
Wool	7.0%	-21.9%	-22.0%	-22.0%	-13.9%	-21.1%	-21.1%	-24.3%	-19.3%	-1.8%	-1.1%
Tailwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector											
Milk solids	NA	-9.3%	-9.5%	-9.5%	-6.2%	-5.3%	-5.3%	-5.6%	-4.6%	-4.5%	-4.4%
Lamb	NA	-23.2%	-23.6%	-23.6%	-14.7%	-21.4%	-21.4%	-24.4%	-18.8%	-3.2%	-2.5%
Beef	NA	-62.0%	-60.8%	-60.8%	-36.9%	-36.7%	-36.7%	-0.7%	80.2%	47.7%	45.1%
Wool	NA	-21.8%	-22.0%	-22.0%	-13.9%	-21.1%	-21.1%	-24.2%	-19.3%	-1.8%	-1.0%
Headwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector											
Milk solids	NA	-9.6%	-9.8%	-9.8%	-6.4%	-5.3%	-5.3%	-5.3%	-5.2%	-4.5%	-4.5%
Lamb	NA	-22.8%	-23.1%	-23.0%	-13.1%	-21.4%	-21.4%	-21.4%	-21.4%	-3.2%	-2.5%
Beef	NA	-65.4%	-64.7%	-64.7%	-52.2%	-36.7%	-36.7%	-36.7%	-36.3%	48.5%	45.9%
Wool	NA	-21.4%	-21.5%	-21.4%	-12.2%	-21.0%	-21.0%	-21.0%	-21.1%	-1.8%	-1.0%
Headwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector											
Milk solids	NA	-9.6%	-9.8%	-9.8%	-6.4%	-5.3%	-5.3%	-5.3%	-5.2%	-4.5%	-4.5%
Lamb	NA	-22.8%	-23.0%	-23.0%	-13.0%	-21.4%	-21.4%	-21.4%	-21.5%	-3.2%	-2.5%
Beef	NA	-65.4%	-64.7%	-64.5%	-52.2%	-36.7%	-36.7%	-36.7%	-36.3%	48.4%	45.8%
Wool	NA	-21.3%	-21.4%	-21.4%	-12.2%	-21.1%	-21.1%	-21.1%	-21.1%	-1.7%	-1.0%

NA: not available

4.6 Emissions payments, incentive payments and rebates

The payments for GHG emissions by the farmer or the processor vary depending on the emissions prices they face (Table 17). The processor-based scenarios and Farm Split Gas Levy face lower GHG emissions prices reflecting the discounting or free allocation of GHG emissions. The Farm LUC Rebate scenarios faces the full GHG emissions price. The lower methane emissions price results in lower emissions payments for the Processor Hybrid (split gas price) and the Farm Split Gas Levy scenarios.

The incentive payments in each scenario were constrained to be equal or less than the total payments made by processors or farmers for their GHG emissions. In most instances, the incentive payment is a fraction of the GHG emissions payments. The incentive payments in the processor-based scenarios are similar and range between about $35 million and $39 million. The incentive payment increases in the Farm Split Gas Levy scenarios as the methane incentive prices increase. The only scenario, except for the Farm LUC Rebate scenario, where the incentive payments reached the GHG emissions payments was in the tailwind technology setting for the Farm Split Gas Levy (20 times the base methane incentive price). The higher incentive price in this scenario made the higher-priced technology mitigation options more profitable resulting in a large increase in the adoption of these technologies, particularly bromoform bolus.

There is a marked difference in the incentive payments between the tailwind and headwind technology settings, for example, ~$38 million for the Processor Hybrid (split gas price) in the tailwind technology setting but only ~$7 million in the headwind technology setting. The technology mitigation options are less cost-effective in 2030 for the headwind technology setting and result in the lower adoption of technology mitigation options, despite these options being incentivised.

The incentive payments for the carbon sequestered through the adoption of the scrub mitigation option for the sheep and beef sector, however, is similar between both technology settings.

The rebate payment in the Farm LUC Rebate scenarios is much higher than the other scenarios as the Farm LUC Rebate scenarios are designed to spend all the emissions payment via a per-hectare rebate.

Table 17 GHG emissions payments ($), incentive payments and rebates, and the payment for the carbon sequestered in the scrub mitigation option for the sheep and beef sector

	Scenarios									
	Processor ETS – All Mit	**Processor ETS – Tech Mit**	**Processor Hybrid – Same Price**	**Processor Hybrid – Diff Price**	**Farm Split Gas Levy (x1)**	**Farm Split Gas Levy (x5)**	**Farm Split Gas Levy (x10)**	**Farm Split Gas Levy (x20)**	**Farm LUC – Same Price**	**Farm LUC – Diff Price**
Tailwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector										
GHG emissions payments ($)	387,975,223	388,381,754	388,269,498	239,797,966	289,924,221	289,884,111	289,869,275	313,479,591	5,731,776,921	3,399,051,730
Incentive payments/rebates ($)	36,540,275	35,352,205	35,363,868	38,740,223	282,856	1,559,538	61,114,043	313,479,591	5,731,776,921	3,399,051,730
SNB scrub carbon sequestration payment[a] ($)	914,337	377,062	377,127	421,662	350,029	349,936	348,087	389,009	515,277	513,522
Tailwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector										
GHG emissions payments ($)	387,958,637	388,349,386	388,237,161	239,783,527	289,885,686	289,845,585	289,830,539	313,439,793	5,731,330,979	3,398,844,850
Incentive payments/rebates ($)	36,542,838	35,361,278	35,372,947	38,740,223	282,874	1,559,630	61,128,027	313,439,793	5,731,330,979	3,398,844,850
SNB scrub carbon sequestration payment[a]($)	-	-	-	-	-	-	-	-	-	-
Headwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector										
GHG emissions payments ($)	384,713,126	384,704,187	384,748,119	232,402,828	290,317,836	290,320,094	290,319,447	290,112,861	5,741,952,072	3,404,774,375
Incentive payments/rebates ($)	18,393,247	5,670,200	5,669,780	7,035,289	128,470	650,463	1,578,163	10,438,496	5,741,952,072	3,404,774,375
SNB scrub carbon sequestration payment[a] ($)	923,618	378,056	378,107	422,916	350,099	350,034	349,942	349,690	516,163	514,351
Headwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector										
GHG emissions payments ($)	384,635,765	384,666,886	384,510,643	232,383,498	290,373,345	290,375,597	290,374,941	290,168,378	5,741,509,042	3,404,569,272
Incentive payments/rebates ($)	18,394,871	5,670,200	5,670,288	7,035,751	128,464	650,432	1,578,091	10,437,600	5,741,509,042	3,404,569,272
SNB scrub carbon sequestration payment[a] ($)	-	-	-	-	-	-	-	-	-	-

a: The scrub payment is associated with the uptake of the scrub mitigation options on sheep and beef land.

5 Insights and conclusions

The following insights and conclusions can be drawn from this modelling and analysis of the primary scenarios.

Meeting the GHG targets

Most climate policy scenarios achieved the GHG targets at the modelled NZU price of $108.62. The processor-based scenarios with the same emissions price for methane and nitrous oxides projected GHG emissions reductions of around 18% compared with the 2030 baseline,[13] regardless of whether there is a payment for carbon sequestered by the scrub mitigation option for sheep and beef land or the technology setting. GHG emissions are estimated to fall by just under 12% where methane and nitrous oxide emissions are priced differently in the Hybrid Processor scenario.

Most of the Farm Split Gas Levy scenarios show GHG emissions reductions between 14.4 and 15%. The exception is the Farm Split Gas Levy (with 20 times the base methane incentive price) scenario with the tailwind technology setting. In this scenario the incentive price has reached a level where it is profitable for farms to take up more expensive (and more effective) mitigation options like bromoform bolus; therefore, less land moves out of sheep and beef and dairy. The larger area that remains in sheep and beef and dairy means a smaller reduction in total methane and nitrous oxide emissions and the GHG targets may not be achieved. Incentive prices may also reach a level at which some scrub and indigenous forest might be brought into agricultural production, reducing the amount of carbon being sequestered.

The Farm LUC Rebate scenarios (headwind and tailwind technology settings and both GHG emissions pricing alternatives) are not projected to achieve the GHG targets. In these scenarios, the per-hectare rebate farmers receive for some farm systems is markedly higher than the payment they make for their GHG emissions, which increases their profitability. This results in increases in sheep and beef area in some regions and LUC classes with a resulting increase in overall sector GHG emissions, and corresponding increases in net revenue, area and production for the sheep and beef sector.

Importance of mitigation options and incentive payments

The design of incentives and incentive prices change the profitability of different farm systems and how these farm systems respond to the pricing of GHG emissions. The different scenarios modelled incentivise change in different parts of the agricultural system. While the overall GHG emissions reductions are similar across most scenarios, how those GHG emissions reductions are achieved differs. This is seen by the mitigation options that are

[13] The GHG emissions reduction below the 2030 baseline that equates to the GHG targets is a reduction in methane emissions of 8.5% and in GHG emissions of 10.4%.

taken up by different farm systems and what land use change is projected to occur in each scenario.

Looking at both tailwind and headwind technology settings gives a range of potential responses to the climate policy scenarios and helps assess the sensitivity of the results. The mitigation options adopted and possible land use change resulting from the modelled scenarios provides an insight into where the impacts of the different scenarios are more likely to fall.

The headwind technology setting assumes the technology mitigation options are more costly and/or less effective than the tailwind technology setting in 2030. Therefore, there is less adoption of technology mitigation options even at higher incentive payments with the headwind technology setting and slightly more land use change in the scenarios modelled.

With the tailwind technology setting, higher incentive payments induce greater uptake of technology mitigation options and less land use change. As a result, the modelling predicts the GHG targets are not always met, such as with the Farm Split Gas Levy scenario with higher methane incentive prices as less land moves to lower emitting uses. This suggests that while mitigation options to reduce GHG emissions are important, they are unlikely, alone, to be sufficient to reduce GHG emissions to future GHG target levels, unless the effectiveness of those mitigation options improves even more to counteract the effect of more livestock remaining in the agriculture sector.

Incentive payments for all mitigation options versus only technology mitigation options changes the mix of mitigation options taken up. The modelling estimates there is a greater negative impact on net revenue when only the technology mitigation options are rewarded as more land is retired. Providing a payment for the management mitigation options, not just the technology mitigation options, gives pastoral farmers a greater suite of profitable mitigation options (after the incentive payment), reducing land use change and the subsequent impact on net revenue. It may, at least initially, be beneficial to incentivise all mitigation options with a transition to incentivising only technology mitigation options as these become more cost-effective. As the incentive payments estimated through the modelling are a fraction of the GHG emissions payments, incentivising all mitigation options is likely possible, as is increasing the incentive payments of some or all mitigation options and helping facilitate the transition to new land uses on some land.

Processor-based vs farm-level policy signals

Processor-based scenarios tie their emissions payments to meat and milk production and fertiliser use while GHG emissions are the basis of the farm-level scenarios emissions payment. Therefore, different sheep and beef farm systems are exposed to different emissions pricing signals between the processor-based and farm-level scenarios. Those sheep and beef farm systems with greater wool production don't explicitly see a price signal for wool in the processor-based scenario and appear less exposed to emissions pricing compared with the farm-level scenarios where the emissions payments are based on GHG emissions rather than output/input levels. Therefore, the modelling suggests that the processor-based scenarios preferentially benefit South Island sheep and beef farm systems as they often produce more wool and less meat. North Island sheep and beef farm systems experience greater impacts, especially those with higher beef to sheep ratios.

The pricing signal also affects how and if the GHG emission reduction benefits of emissions reducing technologies are rewarded. The Farm Split Gas Levy, for instance, does reward the adoption of technologies that reduce GHG emissions without compromising production through lower emissions payments. However, the processor-based scenarios have the same emissions payments as emissions pricing is via production which is unchanged for these technologies.

In summary

The pricing and incentive signals of the different climate policy scenarios have different impacts, and these impacts change depending on farm system and livestock ratio, particularly for the sheep and beef sector. The modelling shows that the GHG targets can be met, but some land use change will occur, reducing production levels and hence net revenue for the agricultural sector. The modelling provides insights into where the negative impacts of the different policy scenarios are most likely to fall and how different incentive designs may, or may not, alleviate some of these impacts. These results, along with other considerations such as equity implications, administrative costs, and transaction costs, can be helpful in identifying policy levers that meet GHG targets while minimising the impacts on the agricultural sector, and what may be needed to ease that transition.

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Appendix 1 Mathematical representation of NZFARM

A1.1 Mathematical equations

NZFARM's objective function is to determine the maximum summed net revenues from agricultural and forestry activities in New Zealand, subject to area and climate policy constraints. NZFARM identifies the optimal land-use area and set of mitigation options that leads to the maximum net revenues in each simulated scenario. The mathematical representation of the objective function for the processor scenario is:

$$
\begin{aligned}
Max\ NR = \sum_{e,l,m,s,r,p,o} \{ & b_{e,l,m,s,r} X_{e,l,m,s,r} + \alpha\ env_{e,l,m,s,r,"CO2seq"} X_{e,l,m,s,r} \\
& - \tau\ env_{e,l,m,s,r,"N2O"} X_{e,l,m,s,r} - \varphi\ env_{e,l,m,s,r,"CH4"} X_{e,l,m,s,r} \\
& - \tau\ prodGHG_{e,N2O,p}\ prod_{e,l,m,s,r,p} X_{e,l,m,s,r} \\
& - \varphi\ prodGHG_{e,CH4,p}\ prod_{e,l,m,s,r,p} X_{e,l,m,s,r} \\
& - b_{e,\text{forestry},m,s,r} ripforest_{e,\text{forestry,s,r}} \\
& - b_{e,\text{pasture},m,s,r} rippasture_{e,"pasture",\text{s,r}} \\
& + \left(\alpha\ env_{e,l,m,s,r,"CO2seq"} - treeripcst\right) Ripmgmtpast_{e,l,s,r} \\
& + \delta\ env_{e,l,m,s,r,o} X_{e,l,m,s,r} \}
\end{aligned}
\tag{1}
$$

Where

NR is the maximum level of net revenue from all land uses,

b is the earnings before interest and tax (EBIT) of land uses,

X is the land use area,

α is the price on CO_2 sequestration from the scrub mitigation for sheep and beef and the afforestation of riparian pasture area,

env includes GHG emissions and CO_2 sequestration,

τ is the price on nitrous oxide emissions,

φ is the price on methane emissions,

$prodGHG$ is the GHG emissions from agricultural commodities,

$prod$ is the commodity production levels,

$ripforest$ is the riparian forestry area taken out of production,

$rippasture$ is the riparian pasture area taken out of production,

$treeripcst$ is the cost of afforestation on the riparian pasture area taken out of production,

$Ripmgmtpast$ is the area of pasture in the riparian area taken out of production and converts to scrub/indigenous forest, and

δ is the incentive payment for GHG emission reductions from adopting mitigation options.

The objective function sums net revenues (NR) across all land uses (e) such as dairy, sheep and beef, arable, fruit, vegetables, forestry and scrub, land use covers (l) such as pasture, forestry, horticulture, arable and scrub, and management practices (m). This yields the total net revenue from the primary sector across the 16 regions (r) of New Zealand considering land use capability (LUC; s), GHG emissions (o) and CO_2 sequestration ($CO2seq$) price and land use, and commodity production (p).

The objective function for the farm-level scenarios is similar, except the emissions prices (τ and φ) are applied to the GHG emissions from each farm system. The Farm Split Gas Levy has the same structure for incentive payments as the Processor objective function, but the Farm LUC rebate scenario uses a rebate payment based on area of a land use in a LUC class.

Depending on scenarios, methane and nitrous oxide emissions are either fully priced or priced to reflect free allocation or a discount. GHG emissions are levied at farm or at processor level, and incentive payments are for all mitigation options or only technology mitigation options. There are two setting for the technology mitigation options – tailwind or headwind (for scenario descriptions see Section 3.2).

The commodity prices and environmental outputs of land uses were assumed to remain constant over time.

In the GHG target scenario, we assumed that agricultural sector had to reduce gross GHG emissions by 11% and methane emissions by 10% from 2020 levels:

$$\sum_{e,l,m,s,r} env_{e,l,m,s,r,"CH4"} x_{e,l,m,s,r} = \sum_{e,l,m,s,r} 0.9\ env_{e,l,m,s,r,"CH4"} x2020_{e,l,m,s,r} \tag{2}$$

$$\sum_{e,l,m,s,r} env_{e,l,m,s,r,GHGgross"} x_{e,l,m,s,r} = \sum_{e,l,m,s,r} 0.89\ env_{e,l,m,s,r,"GHGgross"} x2020_{e,l,m,s,r} \tag{3}$$

where $x2020$ is the land use area in 2020. In this scenario, GHG emissions are not priced and there are no incentive payments for adoption of mitigation options.

The incentive payments for the adoption of mitigation options for the processor scenario are constrained by the amount levied for GHG emissions:

$$\sum_{e,l,m,s,r,o} \delta\ env_{e,l,m,s,r,o} x_{e,l,m,s,r} \leq \sum_{e,l,m,s,r,p} \{\tau\ prodGHG_{e,N2O,p}\ prod_{e,l,m,s,r,p} x_{e,l,m,s,r} + \varphi\ prodGHG_{e,CH4,p}\ prod_{e,l,m,s,r,p} x_{e,l,m,s,r}\} \tag{4}$$

The incentive payments for the adoption of mitigation options for the Farm Split Gas Levy scenario are constrained by the amount levied for GHG emissions:

$$\sum_{e,l,m,s,r,o} \delta\ env_{e,l,m,s,r,o} x_{e,l,m,s,r} \leq \sum_{e,l,m,s,r,p} \{\tau\ env_{e,l,m,s,r,"N2O"} x_{e,l,m,s,r} + \varphi\ env_{e,l,m,s,r,"CH4"} x_{e,l,m,s,r}\} \tag{4}$$

Depending on scenarios, GHG emissions are differently priced, and farm or processor level obligations for GHG emissions and different technologies are considered.

The maximisation of net revenue is affected by the primary sector production amount, and primary sector area. The choice variable in the model is the allocation area of different land uses, where the optimal land-use area is selected to maximise total net revenue. Land use area is constrained by the available land area in each region:

$$\sum_{e,l,m} X_{e,l,m,s,r} \leq \sum_{e,l,m} d_{e,l,m,s,r} \tag{5}$$

where d is the available land-use area in each region. NZFARM selects the optimal land use pattern for each region considering the climate policies.

Primary sector production is constrained by the product balance equation that specifies production type by land use type. The production constraint is specified as follows:

$$Q_{e,l,m,s,r} \leq prod_{e,l,m,s,r,p}\, X_{e,l,m,s,r} \tag{6}$$

The variables in the model are constrained to be greater or equal to zero, such that land use area or agricultural production cannot be negative:

$$X, Q \ \geq 0 \tag{7}$$

The model is solved using the General Algebraic Modelling System (GAMS).[14]

A1.2 Parametrisation and calibration

To calibrate the baseline area, we use constant elasticity of transformation (CET) functions and their nested forms.

In the model, the main variable is the area for each land use ($X_{e,l,m,s,r}$). NZFARM considers that land uses have a degree of flexibility to adjust the share of the land use and their activities to meet an objective function such as maximum net revenues. Commodity prices and constraints are exogenous variables, and these variables are assumed to be constant across scenarios.

The model is parametrised where responses to climate policies are not drastic and assumed to be instantaneous. The optimal distribution of land uses, management practices, and agricultural and forestry outputs are determined using a nested framework that is calibrated based on land-use areas.

NZFARM simulates allocation of land uses through CET functions. The CET function specifies the rate at which enterprises, land cover, and management practices can be transformed across the array of available options. This approach is well suited to models that impose resource and policy constraints as it allows the representation of a 'smooth' transition across production activities while avoiding unrealistic discontinuities and corner solutions in the simulation solutions (de Frahan et al. 2007). At the highest levels of the CET nest, land use is

[14] https://www.gams.com/

distributed over the region/country based on the fixed area of land uses. Land cover is then allocated between several enterprises, such as livestock (e.g. dairy or sheep and beef), forestry plantation, horticulture (e.g. fruits, vegetables), arable and scrub that will generate the highest net returns for New Zealand.

The CET functions are calibrated using the share of total initial (observed) area for each element of the nest and a CET elasticity parameter for the respective land use area, land cover, and management practices. We do not consider costs from switching from one land use or enterprise activity to another, such as change in infrastructure, upskilling for new management practices or land uses, and other costs. These CET elasticity parameters can theoretically range from 0 to infinity, where 0 indicates that the input is fixed, while infinity indicates that the inputs are perfect substitutes (i.e. no implicit cost from switching from one land use or enterprise activity to another).

The CET elasticity parameters in NZFARM ascend with each level of the nest between land cover, enterprise, and management practices. This is because landowners have more flexibility to change their mix of management and enterprise activities than to alter their share of land cover. The elasticities used in the modelling are as follows: land cover ($\sigma L = -2$), enterprise ($\sigma E = -4$), and land management ($\sigma M = -8$).

Appendix 2 Data on mitigation options

Dairy sector mitigation options

Tables A2.1, A2.2, and A2.3 provide information obtained from DairyNZ (DairNZ Economic Group 2017, 2018) and MPI (2022) on net revenues, methane and nitrous oxide emissions for different dairy systems. Dairy data differ for no mitigation and mitigations by dairy systems and across regions. The tables show the absolute values for no mitigation options and relative (%) change of mitigation options from no mitigation. For more information on dairy mitigation options, see DairyNZ Economic Group (2017, 2018).

Table A2.1 Mean relative change (%) in net revenues for dairy under different mitigation options, per hectare

Mitigation options	Dairy system 2	Dairy system 3	Dairy system 4	Dairy system 5
Baseline (no mitigation), $/ha	1,654	1,932	1,276	1,394
Output approach reducing GHG emissions, % change from no mitigation				
5% reduction	-3.6	-1.9	-2.1	-5.0
10% reduction	-8.3	-5.2	-6.5	-11.0
15% reduction	-13.9	-8.8	-12.0	-16.5
20% reduction	-19.5	-12.0	-17.2	-22.4
Reduction in fertilizer use, % change from no mitigation				
25%	-4.8	-3.1	-5.8	-6.6
50%	-9.0	-5.9	-12.0	-13.1
75%	-12.9	-8.6	-18.2	-19.3
No fertilizer use	-17.7	-11.5	-25.3	-28.4
Change in supplementary feed, % change from no mitigation				
Switch 50% of supplementary feed to low protein feed	-1.4	-3.0	-1.1	-0.8
Switch 100% to low protein feed	-3.3	-5.5	-2.6	-3.8
Reduce imported high protein volumes by 50% and reduce stocking rate	-0.6	-2.1	-1.7	-6.9
Remove all imported high protein volumes and reduce stocking rate	-3.6	-5.0	-3.8	-12.9
Reduction in cow numbers and same milk production per cow, % change from no mitigation				
5%	-7.3	-4.7	-6.4	-8.7
10%	-13.6	-9.2	-14.0	-16.0
15%	-19.0	-15.1	-21.5	-22.2
20%	-26.0	-20.8	-29.3	-29.6
Once-a-day milking, % change from no mitigation				
Half a season	-7.7	-1.9	-2.6	n.a.
Entire season	-4.2	-1.0	-2.2	n.a.
Planting forestry on milking platform, % change from no mitigation				
5% forestry	-7.3	-9.1	-6.6	-5.0

Mitigation options	Dairy system 2	Dairy system 3	Dairy system 4	Dairy system 5
10% forestry	-18.7	-17.3	-13.0	-9.9
15% forestry	-29.7	-24.4	-18.7	-18.8
20% forestry	-40.5	-31.3	-24.5	-19.3
Bromoform bolus, % change from no mitigation				
Tailwind	-8.5	-6.7	-10.1	-12.3
Headwind	14.6	-11.6	-17.5	-21.3
3NOP fed twice a day, % change from no mitigation				
Tailwind	n.a.	-1.9	-2.8	-3.4
Headwind	n.a.	-3.5	-5.3	-6.5
EcoPond, % change from no mitigation	-6.2	-4.3	-5.8	-7.5
Low methane breeding, % change from no mitigation				
Tailwind	-0.3	-0.2	-0.3	-0.4
Headwind	-0.9	-0.8	-1.2	-1.4
Nitrification inhibitor, % change from no mitigation				
Tailwind	-14.5	-12.4	-18.8	-17.2
Headwind	-21.8	-18.6	-28.2	-25.8

Note: The net revenue in the table does not account for any pricing of GHG emissions

Table A2.2 Mean relative change (%) in methane emissions for dairy under different mitigation options, per hectare

Mitigation options	Dairy system 2	Dairy system 3	Dairy system 4	Dairy system 5
Baseline (no mitigation), tCO_2/ha	6.1	6.4	6.5	8.1
Output approach reducing GHG emissions, % change from no mitigation				
5% reduction	-1.8	-2.0	-1.6	-3.0
10% reduction	-4.1	-4.8	-3.7	-5.8
15% reduction	-7.2	-7.7	-6.2	-8.5
20% reduction	-10.3	-10.2	-8.7	-11.2
Reduction in fertilizer use, % change from no mitigation				
25%	-2.6	-2.1	-2.6	-3.6
50%	-5.3	-4.1	-5.1	-7.0
75%	-8.0	-6.4	-8.0	-10.4
No fertilizer use	-10.6	-8.9	-10.9	-14.2
Change in supplementary feed, % change from no mitigation				
Switch 50% of supplementary feed to low protein feed	0.2	0.4	-0.3	-0.2
Switch 100% to low protein feed	0.5	0.8	-0.6	-0.5
Reduce imported high protein volumes by 50% and reduce stocking rate	-1.0	-3.3	-2.1	-3.3
Remove all imported high protein volumes and reduce stocking rate	-3.6	-7.1	-4.4	-6.3
Reduction in cow numbers and same milk production per cow, % change from no mitigation				
5%	-3.9	-4.5	-3.9	-4.7
10%	-7.8	-8.9	-7.5	-9.1
15%	-11.5	-12.9	-11.8	-13.5
20%	-15.0	-16.9	-14.7	-17.0
Once-a-day milking, % change from no mitigation				
Half a season	-1.7	-0.6	-0.2	n.a.
Entire season	-3.2	-1.0	-0.3	n.a.
Planting forestry on milking platform, % change from no mitigation				
5% forestry	-4.2	-4.2	-2.2	-1.3
10% forestry	-8.3	-8.7	-4.3	-2.5
15% forestry	-12.2	-12.5	-6.4	-3.7
20% forestry	-16.1	-16.1	-8.2	-4.9
Bromoform bolus, % change from no mitigation				
Tailwind	-54.6	-54.6	-54.6	-54.6
Headwind	-36.4	-36.4	-36.4	-36.4
3NOP fed twice a day, % change from no mitigation				
Tailwind	n.a.	-16.4	-16.4	-16.4
Headwind	n.a.	-8.2	-8.2	-8.2
EcoPond, % change from no mitigation	-8.0	-8.0	-8.0	-8.0

Mitigation options	Dairy system 2	Dairy system 3	Dairy system 4	Dairy system 5
Low methane breeding, % change from no mitigation				
Tailwind	-0.9	-0.9	-0.9	-0.9
Headwind	-1.6	-1.6	-1.6	-1.6
Nitrification inhibitor, % change from no mitigation				
Tailwind	0	0	0	0
Headwind	0	0	0	0

Table A2.3 Mean relative change (%) in N_2O emissions for dairy under different mitigation options, per hectare

Mitigation options	Dairy system 2	Dairy system 3	Dairy system 4	Dairy system 5
Baseline (no mitigation), tCO_2/ha	2.6	2.5	2.7	3.3
Output approach reducing GHG emissions, % change from no mitigation				
5% reduction	-9.4	-8.6	-9.7	-8.6
10% reduction	-16.0	-16.4	-15.9	-14.6
15% reduction	-23.8	-23.6	-23.3	-21.2
20% reduction	-30.9	-29.2	-29.7	-28.2
Reduction in fertilizer use, % change from no mitigation				
25%	-9.2	-9.0	-9.3	-9.8
50%	-19.5	-16.7	-18.5	-19.3
75%	-28.0	-24.0	-27.1	-28.2
No fertilizer use	-36.6	-31.7	-36.0	-40.6
Change in supplementary feed, % change from no mitigation				
Switch 50% of supplementary feed to low protein feed	-0.4	-0.9	-0.9	-0.7
Switch 100% to low protein feed	-1.8	-2.8	-1.8	-1.6
Reduce imported high protein volumes by 50% and reduce stocking rate	-0.3	-1.6	-1.1	-1.8
Remove all imported high protein volumes and reduce stocking rate	-2.4	-4.4	-2.6	-3.4
Reduction in cow numbers and same milk production per cow, % change from no mitigation				
5%	-7.7	-9.1	-8.5	-8.0
10%	-17.4	-19.2	-16.8	-15.9
15%	-28.4	-24.4	-26.8	-24.0
20%	-38.4	-31.7	-34.1	-28.9
Once-a-day milking, % change from no mitigation				
Half a season	-0.8	-0.4	-0.1	n.a.
Entire season	-1.4	-0.6	-0.2	n.a.
Planting forestry on milking platform, % change from no mitigation				
5% forestry	-4.9	-4.5	-3.9	-1.1
10% forestry	-11.0	-9.1	-6.3	-2.1
15% forestry	-16.2	-13.1	-8.7	-3.1
20% forestry	-21.2	-17.1	-10.9	-4.0
Bromoform bolus, % change from no mitigation				
Tailwind	0	0	0	0
Headwind	0	0	0	0
3NOP fed twice a day, % change from no mitigation				
Tailwind	n.a.	0	0	0
Headwind	n.a.	0	0	0
EcoPond, % change from no mitigation	0	0	0	0

Mitigation options	Dairy system 2	Dairy system 3	Dairy system 4	Dairy system 5
Low methane breeding, % change from no mitigation				
Tailwind	0	0	0	0
Headwind	0	0	0	0
Nitrification inhibitor, % change from no mitigation				
Tailwind	-19.1	-20.0	-19.1	-19.1
Headwind	-12.7	-13.4	-12.7	-12.7

Sheep and beef sector mitigation options

Tables A2.4, A2.5, and A2.6 provide information obtained from MPI (2022) on net revenues, methane and nitrous oxide emissions for different sheep and beef classes, and their farm survey number. The tables show the absolute values for no mitigation options and relative (%) change of each mitigation options compared to no mitigation. For more information on sheep and beef mitigation options, see MPI (2022).

The relative (%) change in net revenue for some mitigation options and sheep and beef farm systems is negative, and oftentimes the reduction in net revenue is greater than 100% (Table A2.4). Where the relative change is greater than 100%, this means the net revenue for that farm system is negative, i.e. the farm systems runs at a loss. This loss, however, is when there is no emissions payment associated with the GHG emissions from the farm system and where there is no incentive for the adoption of a particular mitigation option. When an emissions payment and incentive are factored into the net revenue calculations, the net revenue for those systems may be positive and higher than the base system without the mitigation option.

Table A2.4 Relative change (%) in net revenues for sheep and beef classes under different mitigation options, in % per hectare

Farm class and number	Mitigations											
	Baseline $/ha	Forestry	Scrub	Reduction in stock number		Low methane breeding		Bromoform bolus		Nitrification inhibitor	
				Small	Medium	TW	HW	TW	HW	TW	HW
Class 3, farm 12	324	-11.4	-20.7	n.a.	n.a	-0.2	-0.3	-86.2	-136.2	-2.3	-3.4
Class 4, farm 29	106	-4.8	-17.3	-6.3	-6.3	-0.5	-0.7	-216.5	-348.8	-54.2	-81.3
Class 4, farm 30	328	-6.4	-17.0	n.a.	n.a.	-0.1	-0.2	-61.2	-97.1	-0.3	-0.4
Class 4, farm 33	229	-6.0	-16.2	2.3	n.a.	-0.1	-0.2	-55.1	-88.2	-7.9	-11.8
Class 5, farm 45	135	n.a.	n.a.	-0.8	n.a.	-0.2	-0.3	-215.5	-346.6	-153.4	-230.1
Class 5, farm 59	16	n.a.	n.a.	-201.4	-206.0	0.0	0.0	-635.0	-1096.9	-798.7	-1198.0
Class 4, farm 73	205	-13.3	-19.6	-0.02	n.a.	-0.3	-0.5	-132.9	-211.1	-25.1	-37.6
Class 4, farm 88	237	9.2	5.6	-10.8	n.a.	-0.3	-0.4	-111.3	-176.6	-143.8	-143.8
Class 4, farm 92	250	-15.9	-30.9	-8.1	n.a.	-0.2	-0.3	-95.3	-152.9	-6.0	-9.0
Class 3, farm 134	355	-6.1	-11.1	-5.1	n.a.	-0.2	-0.3	-74.6	-119.0	-5.7	-8.6
Class 5, farm 141	444	-2.4	-3.1	-2.4	n.a.	-0.1	-0.2	-69.9	-111.3	-19.9	-29.8
Class 3, farm 190	65	-59.2	-126.0	-0.5	-3.7	-0.9	-1.4	-367.8	-584.8	-6.5	-9.8
Class 1, farm 1	67	n.a.	n.a.	-2.9	n.a.	-0.2	-0.3	-80.1	-127.6	-17.8	-26.7
Class 2, farm 49	59	8.8	-38.2	-18.1	n.a.	-0.8	-1.2	-316.0	-499.3	-226.3	-339.4
Class 6, farm 50	214	-9.3	-14.6	11.9	n.a.	-0.5	-0.8	-189.0	-298.1	-41.1	-61.7
Class 7, farm 52	184	-13.2	-22.9	-0.3	-7.9	-0.6	-0.9	-223.0	-350.8	-7.3	-11.0
Class 6, farm 84	64	-6.4	-34.0	3.3	n.a.	-1.5	-2.3	-579.4	-913.1	-61.4	-92.2
Class 6, farm 128	199	n.a.	n.a.	-6.8	-16.0	-0.3	-0.4	-85.8	-136.0	-34.4	-51.6
Class 2, farm 179	84	16.8	-18.7	-8.4	n.a.	-0.3	-0.5	-129.8	-206.4	0.0	0.0
Class 6, farm 189	134	1.9	-2.4	-9.2	n.a.	-0.6	-0.8	-216.9	-343.9	-69.9	-104.9
Class 7, farm 504	380	n.a.	n.a.	-3.0	n.a.	-0.2	-0.3	-79.9	-125.6	-52.5	-78.7

Note: n.a. is the mitigation option not applicable; TW is the tailwind technology setting; HW is the headwind technology setting.
Note: The net revenue in the table does not account for any pricing of GHG emissions

Table A2.5 Relative change (%) in methane emissions for sheep and beef classes under different mitigation options, in % per hectare

Farm class and number	Mitigations											
	Baseline, tCO_2/ha	Forestry	Scrub	Reduction in stock number		Low methane breeding		Bromoform bolus		Nitrification inhibitor	
				Small	Medium	TW	HW	TW	HW	TW	HW
Class 3, farm 12	2.6	-9.0	-9.0	n.a.	n.a	-1.6	-1.6	-60.0	-40.0	0.0	0.0
Class 4, farm 29	3.9	-2.0	-2.0	-5.0	-10.2	-1.0	-1.0	-60.0	-40.0	0.0	0.0
Class 4, farm 30	2.1	-8.6	-8.6	n.a.	n.a.	-1.4	-1.4	-60.0	-40.0	0.0	0.0
Class 4, farm 33	3.3	-4.3	-4.3	-4.6	n.a	-0.6	-0.6	-42.3	-28.2	0.0	0.0
Class 5, farm 45	3.1	n.a.	n.a.	-0.8	n.a.	-0.7	-0.7	-61.0	-40.6	0.0	0.0
Class 5, farm 59	4.4	n.a.	n.a.	-5.1	-9.9	0.0	0.0	-59.2	-39.5	0.0	0.0
Class 4, farm 73	3.1	-0.1	-0.1	-5.7	n.a.	-1.5	-1.5	-60.0	-40.0	0.0	0.0
Class 4, farm 88	3.2	-2.2	-2.2	-5.2	n.a.	-1.4	-1.4	-60.0	-40.0	0.0	0.0
Class 4, farm 92	3.2	-8.7	-8.7	-4.5	n.a.	-1.0	-1.0	-60.0	-40.0	0.0	0.0
Class 3, farm 134	3.3	-5.4	-5.4	-5.0	n.a.	-1.3	-1.3	-60.0	-40.0	0.0	0.0
Class 5, farm 141	3.4	-1.2	-1.2	-5.0	n.a.	-1.3	-1.3	-60.0	-40.0	0.0	0.0
Class 3, farm 190	2.8	-12.2	-12.2	-5.0	-9.7	-1.4	-1.4	-59.3	-39.5	0.0	0.0
Class 1, farm 1	0.6	n.a.	n.a.	-4.0	n.a.	-1.2	-1.2	-57.0	-38.0	0.0	0.0
Class 2, farm 49	1.9	-3.6	-3.6	-4.6	n.a.	-1.7	-1.7	-60.0	-40.0	0.0	0.0
Class 6, farm 50	4.2	-2.7	-2.7	-4.6	n.a.	-1.8	-1.8	-60.0	-40.0	0.0	0.0
Class 7, farm 52	3.9	-3.5	-3.5	-4.4	-7.9	-2.0	-2.0	-60.0	-40.0	0.0	0.0
Class 6, farm 84	3.5	-2.1	-2.1	-4.4	n.a.	-1.8	-1.8	-60.0	-40.0	0.0	0.0
Class 6, farm 128	2.1	n.a.	n.a.	-4.8	-9.7	-1.7	-1.7	-60.0	-40.0	0.0	0.0
Class 2, farm 179	1.2	-4.2	-4.2	-4.7	n.a.	-1.4	-1.4	-60.0	-40.0	0.0	0.0
Class 6, farm 189	3.2	-0.8	-0.8	-4.6	n.a.	-1.6	-1.6	-60.0	-40.0	0.0	0.0
Class 7, farm 504	3.1	n.a.	n.a.	-3.3	n.a.	-1.8	-1.8	-60.0	-40.0	0.0	0.0

Note: n.a. is the mitigation option not applicable; TW is the tailwind technology setting; HW is the headwind technology setting.

Table A2.6 Relative change (%) in N_2O emissions for sheep and beef classes under different mitigation options, in % per hectare

Farm class and number	Mitigations										
	Baseline, tCO_2/ha	Forestry	Scrub	Reduction in stock number		Low methane breeding		Bromoform bolus		Nitrification inhibitor	
				Small	Medium	TW	HW	TW	HW	TW	HW
Class 3, farm 12	0.6	-9.1	-9.1	n.a.	n.a	0.0	0.0	0.0	0.0	-1.0	-0.7
Class 4, farm 29	0.7	-2.0	-2.0	-5.0	-9.8	0.0	0.0	0.0	0.0	-7.7	-5.3
Class 4, farm 30	0.5	-8.6	-8.6	n.a.	n.a.	0.0	0.0	0.0	0.0	-0.1	-0.1
Class 4, farm 33	0.8	-4.0	-4.0	-7.7	n.a.	0.0	0.0	0.0	0.0	-2.5	-1.7
Class 5, farm 45	0.7	n.a.	n.a.	-5.2	n.a	0.0	0.0	0.0	0.0	-25.0	-17.0
Class 5, farm 59	1.3	n.a.	n.a.	-9.9	-24.5	0.0	0.0	0.0	0.0	-15.0	-10.2
Class 4, farm 73	0.9	-0.1	-0.1	-15.2	n.a.	0.0	0.0	0.0	0.0	-7.0	-4.8
Class 4, farm 88	0.7	-2.1	-2.1	-7.5	n.a.	0.0	0.0	0.0	0.0	0.0	0.0
Class 4, farm 92	0.8	-7.7	-7.7	-5.2	n.a.	0.0	0.0	0.0	0.0	-2.1	-1.4
Class 3, farm 134	0.8	-4.8	-4.8	-11.5	n.a.	0.0	0.0	0.0	0.0	-2.6	-1.7
Class 5, farm 141	0.8	-1.2	-1.2	-9.8	n.a.	0.0	0.0	0.0	0.0	-10.6	-7.2
Class 3, farm 190	0.9	-8.4	-8.4	-11.6	-22.1	0.0	0.0	0.0	0.0	-0.6	-0.4
Class 1, farm 1	0.1	n.a.	n.a.	-3.8	n.a.	0.0	0.0	0.0	0.0	-2.7	-1.9
Class 2, farm 49	0.4	-3.6	-3.6	-4.6	n.a.	0.0	0.0	0.0	0.0	-17.9	-12.2
Class 6, farm 50	1.0	-2.6	-2.6	-8.6	n.a.	0.0	0.0	0.0	0.0	-10.2	-7.0
Class 7, farm 52	1.0	-3.3	-3.3	-4.8	-16.1	0.0	0.0	0.0	0.0	-1.8	-1.2
Class 6, farm 84	0.8	-2.1	-2.1	-4.3	n.a.	0.0	0.0	0.0	0.0	-5.1	-3.4
Class 6, farm 128	0.5	n.a.	n.a.	-8.9	-15.0	0.0	0.0	0.0	0.0	-9.9	-6.7
Class 2, farm 179	0.3	-4.2	-4.2	-4.7	n.a.	0.0	0.0	0.0	0.0	0	0
Class 6, farm 189	0.7	-0.8	-0.8	-4.4	n.a.	0.0	0.0	0.0	0.0	-12.7	-8.7
Class 7, farm 504	0.8	n.a.	n.a.	-5.2	n.a.	0.0	0.0	0.0	0.0	-25	-17

Note: n.a. is the mitigation option not applicable; TW is the tailwind technology setting; HW is the headwind technology setting.

Appendix 3 Overview of technology mitigation option costs and effectiveness

This appendix documents and summarises the assumptions made by MPI and MfE to construct mitigation technology scenarios when modelling different pricing options for agricultural emissions.

Table A3.1 Overview of the efficacy and cost of mitigation options

Technology	Stock type	Unit	Tail winds		Head winds		Comments
		Efficacy, Cost	Efficacy (% reduction)	Cost ($)	Efficacy (% reduction)	Cost ($)	
CH_4 Inhibitor (Bromoform)	Beef	Per head, per head	60	55	40	95	
CH_4 Inhibitor (Bromoform)	Dairy	Per head, per head	55	55	36	95	
CH_4 Inhibitor (Bromoform)	Sheep	Per head, per head	60	35	40	55	
Low methane breeding (3% weighting)	Dairy	Per head, per tonne CO2e	0.9	78.25	0.9	78.25	
Low methane breeding (10% weighting)	Dairy	Per head, per tonne CO_2-e	1.6	148.31	1.6	148.31	
Low methane breeding	Sheep	Per head, per tonne CO2e	2.06	15	2.06	22.5	
CH_4 Inhibitor (3NOP fed twice a day)	Dairy	Per head, per head	16	15.36	8	28.8	Only systems three to five
EcoPond	Dairy	Per head, per head	8	25	8	25	There is also a per farm capital cost for infrastructure.
Nitrification inhibitor	Flatland	Per hectare, per hectare	25	240	17	360	Only applies to urine and dung applied to pasture

Methane inhibitors

A methane inhibitor is a chemical compound that blocks enzymatic pathways in methanogens (the microbes that live in the rumen of cattle, sheep, and deer, and create methane). A methane inhibitor restricts methanogens growth and ability to produce methane. The methane inhibitor needs to be present in the rumen while the animal is digesting its feed to be effective. Two methane inhibitors are assumed to be available by 2030. A bromoform bolus and 3-Nitooxypropanol (3-NOP).

Bromoform is a chemical compound that can be found in Asparagopsis seaweed. Bromoform has been shown to significantly inhibit methanogenesis, in some cases up to 98%.[15] A bolus

[15] https://researcharchive.lincoln.ac.nz/handle/10182/14753?show=full

is a large pill that sits in the rumen and releases bromoform slowly over a period of 6 months. These are assumed to reduce methane from enteric fermentation from 40 to 60%.[16] A proportion of methane from dairy cows is from effluent ponds so the efficacy per animal has been decreased to reflect this.

Bromoform boluses were assumed to cost $20 for cattle and $10 for sheep about 2.5 times the cost of a zinc bolus (zinc boluses are used to prevent facial eczema). It was assumed that a vet would be required to administer the bolus, and boluses are required twice a year. In the head winds scenario, the cost of the bolus was doubled, assuming that the manufacturer adds a premium to capture more of the benefits from reducing emissions.

3-NOP has been developed, successfully trialled and is being commercialised as Bovaer® in some countries by a Dutch company, DSM Nutritional Products. It achieved reductions in methane emissions of between 22 and 35% in cattle in housed systems, without any detrimental effect on animal productivity or welfare.[17] 3-NOP works better in housed farming systems where it can be continuously fed. As a result, the assumptions for 3-NOP are:

- Only dairy systems three, four, and five utilise the mitigation technology as these farms are already supplementary feeding. These farms use supplementary feed with farms feeding 1–2 kg of meal or grain per cow per day for most of the season best fitting in system three.[18]
- As 3-NOP is better suited to housed farming systems and New Zealand systems are predominantly pastoral, lower rates of efficacy were assumed to be 10% to 20%.
- Dairy cows are fed in the farm dairy shed; this means they are only fed 3-NOP twice daily during lactation (300 days of the year). This assumption is used to adjust both the efficacy and the cost of 3-NOP. The efficacy is adjusted to reflect the proportion of emissions that occur during lactation (August to May at a national level) calculated from the New Zealand Greenhouse Gas Inventory.

Costs of $16 NZD and $30 NZD per kg of Bovaer® were assumed.[19] Trials suggest dosage rates of 1.6 g.[20] When feeding twice daily, 300 days per year, this suggests a dosage rate of 960 g per dairy cow per year.

Low methane breeding

Low methane breeding is where farmers select their animals with an emphasis put on the breeding value for methane emissions. Beef + Lamb genetics has developed a breeding index for low methane, DairyNZ/LIC is also able to give farmers information on the breeding worth of animals for low methane.

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[16] Gerald Rys & John Roche, pers. comms.
[17] https://www.nzagrc.org.nz/domestic/methane-research-programme/methane-inhibitors/
[18] https://www.dairynz.co.nz/business/the-5-production-systems/
[19] Gerald Rys, pers. comm.
[20] https://www.sciencedirect.com/science/article/pii/S0022030218311111

Low methane breeding (Dairy) allows Dairy farmers to put a low weighting (3%) or a higher weighting (10%) on low methane breeding worth using the greenmilk calculator[21] with default gene flow settings to calculate emissions reductions and carbon prices for low methane genetic selection weightings for dairy farmers. The results of this were confirmed by referring to research in the Australian dairy industry,[22] which returned consistent results.

Low methane breeding (Sheep) allows sheep farmers to weight low methane breeding worth when selecting a ram, the low methane genetics will be picked up in their flock over time to reduce the flock's methane breeding value.

The efficacy of low methane breeding was estimated using a simple gene flow model developed by John McEwan (AgResearch). The cost of low methane breeding was adopted from the He Waka Eke Noa Partnership impacts analysis for the tailwinds scenario and increased by 50% for the head winds scenario. Low methane sheep breeding has been found to be positively correlated with several desirable traits for sheep farmers, so we assume that the opportunity cost of selecting for the low methane trait is relatively low. The head winds scenario assumes that ram breeders will charge a premium to capture some benefit from GHG reductions.

EcoPond[23]

A chemical compound that is added to effluent which inhibits the activity of microbes which generate methane in effluent. This has proved to be extremely effective at reducing methane emissions from effluent (by 98%), methane from effluent is on average about 8 per cent of methane emissions from dairy.[24] The cost for EcoPond is approximately $45,000 capital cost for infrastructure to distribute the chemical compound, and $25 per head per year for the chemical compound.[25] It is only applicable to dairy farms as dry stock farms tend not to collect and store effluent.

Nitrification inhibitor

A chemical compound that is applied to flatland to reduce nitrous oxide emissions from agricultural soils. It is 40–60% effective when applied, but only applied 5 months of the year. The cost assumes that cost of application will be similar to DCD, so this cost was adjusted by inflation, increased by 50% to estimate headwinds cost.

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[21] Abacus Bio 2019 https://abacusbio.com/projects/case-study-green-milk-project/

[22] Reducing greenhouse gas emissions through genetic selection in the Australian dairy industry - PubMed (nih.gov)

[23] https://www.youtube.com/watch?v=MCmCWFpz_Io

[24] https://environment.govt.nz/assets/publications/GhG-Inventory/New-Zealand-Greenhouse-Gas-Inventory-1990-2020-Chapters-1-15.pdf

[25] Ravensdown, pers. comms. 2022.

Appendix 4 Modelling results – GHG Emissions

Appendix 4 provides more disaggregated GHG emissions results for the scenarios modelled.

Table A4.1 Relative change (%) in GHG emissions from the 2030 baseline by sector

Scenarios	GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)	Farm LUC – Same Price	Farm LUC – Diff Price
Tailwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable	-1.2%	10.3%	10.6%	10.6%	5.7%	6.2%	6.1%	6.0%	3.6%	2.4%	2.0%
Fruit	11.1%	4.5%	4.7%	4.7%	2.7%	3.4%	3.4%	3.2%	2.1%	0.3%	0.2%
Vegetables	25.3%	7.1%	7.4%	7.4%	4.0%	5.0%	4.9%	4.8%	3.2%	0.3%	0.3%
Dairy	-26.5%	-8.7%	-8.9%	-8.9%	-6.1%	-4.9%	-4.9%	-5.4%	-4.7%	-4.3%	-4.3%
Sheep & Beef	4.2%	-27.2%	-27.2%	-27.2%	-16.9%	-23.3%	-23.3%	-23.9%	-11.9%	6.5%	6.7%
Total	**-10.4%**	**-18.2%**	**-18.3%**	**-18.3%**	**-11.7%**	**-14.4%**	**-14.5%**	**-15.0%**	**-8.4%**	**1.4%**	**1.5%**
Tailwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable		10.3%	10.6%	10.6%	5.7%	6.1%	6.1%	6.0%	3.6%	2.4%	1.9%
Fruit		4.5%	4.7%	4.7%	2.7%	3.4%	3.4%	3.2%	2.1%	0.3%	0.2%
Vegetables		7.1%	7.4%	7.3%	4.0%	5.0%	4.9%	4.8%	3.2%	0.3%	0.3%
Dairy		-8.7%	-8.9%	-8.9%	-6.1%	-4.9%	-4.9%	-5.4%	-4.7%	-4.3%	-4.3%
Sheep & Beef		-27.1%	-27.2%	-27.1%	-16.9%	-23.3%	-23.3%	-23.8%	-11.9%	6.5%	6.7%
Total		**-18.2%**	**-18.3%**	**-18.3%**	**-11.7%**	**-14.4%**	**-14.5%**	**-14.9%**	**-8.4%**	**1.4%**	**1.5%**
Headwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable		10.6%	10.9%	10.9%	6.0%	6.2%	6.1%	6.1%	6.1%	2.5%	2.0%
Fruit		4.6%	4.8%	4.8%	2.8%	3.4%	3.4%	3.4%	3.3%	0.3%	0.2%
Vegetables		7.3%	7.6%	7.5%	4.2%	5.0%	5.0%	4.9%	4.9%	0.3%	0.3%
Dairy		-8.3%	-8.4%	-8.4%	-5.6%	-4.9%	-4.9%	-4.9%	-4.9%	-4.4%	-4.3%
Sheep & Beef		-27.2%	-27.2%	-27.2%	-17.9%	-23.4%	-23.4%	-23.4%	-23.6%	6.6%	6.8%
Total		**-18.0%**	**-18.1%**	**-18.1%**	**-11.9%**	**-14.5%**	**-14.5%**	**-14.5%**	**-14.6%**	**1.4%**	**1.5%**

Headwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable		10.6%	10.9%	10.8%	6.0%	6.2%	6.1%	6.1%	6.1%	2.5%	2.0%
Fruit		4.6%	4.8%	4.8%	2.8%	3.4%	3.4%	3.4%	3.3%	0.3%	0.2%
Vegetables		7.3%	7.5%	7.5%	4.2%	5.0%	5.0%	4.9%	4.9%	0.3%	0.3%
Dairy		-8.3%	-8.4%	-8.4%	-5.6%	-4.9%	-4.9%	-4.9%	-4.9%	-4.4%	-4.3%
Sheep & Beef		-27.2%	-27.2%	-27.2%	-17.8%	-23.4%	-23.4%	-23.4%	-23.6%	6.6%	6.8%
Total		**-18.0%**	**-18.1%**	**-18.1%**	**-11.9%**	**-14.5%**	**-14.5%**	**-14.5%**	**-14.6%**	**1.4%**	**1.5%**

Table A4.2 Relative change (%) in methane emissions from the 2030 baseline by sector

Scenarios	GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)	Farm LUC – Same Price	Farm LUC – Diff Price
Tailwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fruit	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Vegetables	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Dairy	-25.3%	-8.8%	-9.1%	-9.1%	-6.4%	-4.9%	-4.9%	-5.4%	-4.8%	-4.3%	-4.2%
Sheep & Beef	5.0%	-27.1%	-27.2%	-27.2%	-17.0%	-23.2%	-23.2%	-25.0%	-15.4%	6.4%	6.6%
Total	**-8.5%**	**-19.0%**	**-19.1%**	**-19.1%**	**-12.3%**	**-15.0%**	**-15.1%**	**-16.3%**	**-10.7%**	**1.6%**	**1.8%**
Tailwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fruit		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Vegetables		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Dairy		-8.8%	-9.1%	-9.1%	-6.4%	-4.9%	-4.9%	-5.4%	-4.8%	-4.3%	-4.2%
Sheep & Beef		-27.1%	-27.2%	-27.2%	-17.0%	-23.2%	-23.2%	-25.0%	-15.4%	6.4%	6.6%
Total		**-18.9%**	**-19.1%**	**-19.1%**	**-12.2%**	**-15.0%**	**-15.1%**	**-16.3%**	**-10.7%**	**1.6%**	**1.8%**
Headwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fruit		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Vegetables		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Dairy		-8.1%	-8.4%	-8.4%	-5.6%	-4.9%	-4.9%	-4.9%	-4.9%	-4.3%	-4.3%
Sheep & Beef		-27.2%	-27.2%	-27.2%	-17.8%	-23.3%	-23.3%	-23.3%	-23.5%	6.4%	6.6%
Total		**-18.6%**	**-18.8%**	**-18.8%**	**-12.3%**	**-15.1%**	**-15.1%**	**-15.1%**	**-15.2%**	**1.6%**	**1.8%**
Headwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fruit		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Vegetables		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Dairy		-8.1%	-8.4%	-8.4%	-5.6%	-4.9%	-4.9%	-4.9%	-4.9%	-4.3%	-4.3%
Sheep & Beef		-27.1%	-27.2%	-27.1%	-17.8%	-23.3%	-23.3%	-23.3%	-23.6%	6.4%	6.6%
Total		**-18.6%**	**-18.8%**	**-18.7%**	**-12.3%**	**-15.1%**	**-15.1%**	**-15.1%**	**-15.2%**	**1.6%**	**1.8%**

Table A4.3 Relative change (%) in nitrous oxide emissions from the 2030 baseline by sector

Scenario	GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)	Farm LUC – Same Price	Farm LUC – Diff Price
Tailwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable	-1.2%	10.3%	10.6%	10.6%	5.7%	6.2%	6.1%	6.0%	3.6%	2.4%	2.0%
Fruit	11.1%	4.5%	4.7%	4.7%	2.7%	3.4%	3.4%	3.2%	2.1%	0.3%	0.2%
Vegetables	25.3%	7.1%	7.4%	7.4%	4.0%	5.0%	4.9%	4.8%	3.2%	0.3%	0.3%
Dairy	-29.7%	-8.3%	-8.3%	-8.3%	-5.4%	-5.0%	-5.0%	-5.2%	-4.3%	-4.4%	-4.3%
Sheep & Beef	1.1%	-27.3%	-27.1%	-27.1%	-16.7%	-23.7%	-23.8%	-19.3%	2.6%	7.1%	7.2%
Total	**-16.2%**	**-15.9%**	**-15.8%**	**-15.8%**	**-9.9%**	**-12.6%**	**-12.6%**	**-10.9%**	**-1.3%**	**0.6%**	**0.6%**
Tailwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable		10.3%	10.6%	10.6%	5.7%	6.1%	6.1%	6.0%	3.6%	2.4%	1.9%
Fruit		4.5%	4.7%	4.7%	2.7%	3.4%	3.4%	3.2%	2.1%	0.3%	0.2%
Vegetables		7.1%	7.4%	7.3%	4.0%	5.0%	4.9%	4.8%	3.2%	0.3%	0.3%
Dairy		-8.3%	-8.3%	-8.3%	-5.4%	-5.0%	-5.0%	-5.3%	-4.3%	-4.4%	-4.3%
Sheep & Beef		-27.3%	-27.1%	-27.1%	-16.7%	-23.7%	-23.7%	-19.2%	2.6%	7.1%	7.2%
Total		**-15.8%**	**-15.8%**	**-15.7%**	**-9.9%**	**-12.6%**	**-12.6%**	**-10.9%**	**-1.3%**	**0.6%**	**0.6%**
Headwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable		10.6%	10.9%	10.9%	6.0%	6.2%	6.1%	6.1%	6.1%	2.5%	2.0%
Fruit		4.6%	4.8%	4.8%	2.8%	3.4%	3.4%	3.4%	3.3%	0.3%	0.2%
Vegetables		7.3%	7.6%	7.5%	4.2%	5.0%	5.0%	4.9%	4.9%	0.3%	0.3%
Dairy		-8.7%	-8.6%	-8.6%	-5.7%	-5.0%	-5.0%	-5.0%	-4.9%	-4.4%	-4.4%
Sheep & Beef		-27.6%	-27.3%	-27.3%	-18.2%	-23.7%	-23.7%	-23.7%	-23.7%	7.2%	7.4%
Total		**-16.2%**	**-16.1%**	**-16.1%**	**-10.7%**	**-12.6%**	**-12.6%**	**-12.6%**	**-12.5%**	**0.6%**	**0.6%**
Headwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable		10.6%	10.9%	10.8%	6.0%	6.2%	6.1%	6.1%	6.1%	2.5%	2.0%
Fruit		4.6%	4.8%	4.8%	2.8%	3.4%	3.4%	3.4%	3.3%	0.3%	0.2%
Vegetables		7.3%	7.5%	7.5%	4.2%	5.0%	5.0%	4.9%	4.9%	0.3%	0.3%
Dairy		-8.7%	-8.6%	-8.6%	-5.7%	-5.0%	-5.0%	-5.0%	-4.9%	-4.4%	-4.4%
Sheep & Beef		-27.5%	-27.3%	-27.3%	-18.1%	-23.7%	-23.7%	-23.7%	-23.7%	7.2%	7.4%
Total		**-16.2%**	**-16.0%**	**-16.0%**	**-10.7%**	**-12.6%**	**-12.6%**	**-12.6%**	**-12.5%**	**0.6%**	**0.6%**

Appendix 5 Modelling results – Land use change

Appendix 5 provides more disaggregated land use change results for the scenarios modelled.

Table A5.1 Relative change (%) in land use from the 2030 baseline

Scenario	2030 Baseline area ('000 ha)	GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)	Farm LUC – Same Price	Farm LUC – Diff Price
Tailwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector												
Arable	213	-1.2%	10.3%	10.6%	10.6%	5.7%	6.2%	6.1%	6.0%	3.6%	2.4%	2.0%
Fruit	138	11.2%	4.6%	4.7%	4.7%	2.7%	3.4%	3.4%	3.2%	2.1%	0.3%	0.2%
Vegetables	18	20.7%	6.7%	7.0%	6.9%	3.8%	4.6%	4.5%	4.4%	3.0%	0.4%	0.4%
Dairy	2,632	-24.0%	-5.3%	-5.7%	-5.7%	-3.0%	-2.7%	-2.7%	-3.1%	-2.3%	-2.0%	-2.0%
Sheep & Beef	7,564	4.6%	-19.7%	-20.0%	-20.0%	-11.0%	-17.8%	-17.8%	-16.7%	-3.5%	7.8%	8.0%
Forestry	2,986	7.2%	4.9%	5.1%	5.1%	2.8%	3.9%	3.9%	3.7%	2.2%	0.1%	0.1%
Scrub/Indigenous Forest	8,136	0.7%	17.9%	18.2%	18.2%	10.0%	15.8%	15.8%	14.9%	3.1%	-6.7%	-6.9%
Tailwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector												
Arable	213		10.3%	10.6%	10.6%	5.7%	6.1%	6.1%	6.0%	3.6%	2.4%	1.9%
Fruit	138		4.5%	4.7%	4.7%	2.7%	3.4%	3.4%	3.2%	2.1%	0.3%	0.2%
Vegetables	18		6.7%	6.9%	6.9%	3.8%	4.6%	4.5%	4.4%	3.0%	0.4%	0.4%
Dairy	2,632		-5.3%	-5.7%	-5.7%	-3.0%	-2.7%	-2.7%	-3.1%	-2.3%	-2.0%	-2.0%
Sheep & Beef	7,564		-19.6%	-20.0%	-19.9%	-11.0%	-17.7%	-17.8%	-16.7%	-3.5%	7.9%	8.1%
Forestry	2,986		4.9%	5.1%	5.1%	2.8%	3.9%	3.9%	3.7%	2.2%	0.1%	0.1%
Scrub/Indigenous Forest	8,136		17.8%	18.2%	18.2%	9.9%	15.7%	15.7%	14.9%	3.0%	-6.8%	-6.9%

Scenario	2030 Baseline area ('000 ha)	GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)	Farm LUC – Same Price	Farm LUC – Diff Price
Headwind technology setting == <u>No</u> payment for C sequestration for scrub mitigation option for sheep & beef sector												
Arable	213		10.6%	10.9%	10.9%	6.0%	6.2%	6.1%	6.1%	6.1%	2.5%	2.0%
Fruit	138		4.7%	4.8%	4.8%	2.8%	3.4%	3.4%	3.4%	3.3%	0.3%	0.2%
Vegetables	18		6.9%	7.1%	7.1%	3.9%	4.6%	4.5%	4.5%	4.5%	0.5%	0.4%
Dairy	2,632		-5.6%	-6.1%	-6.1%	-3.2%	-2.7%	-2.7%	-2.7%	-2.6%	-2.1%	-2.0%
Sheep & Beef	7,564		-19.7%	-19.9%	-19.9%	-11.2%	-17.7%	-17.7%	-17.7%	-17.7%	8.0%	8.2%
Forestry	2,986		5.0%	5.2%	5.2%	2.9%	3.9%	3.9%	3.9%	3.8%	0.1%	0.1%
Scrub/Indigenous Forest	8,136		17.9%	18.2%	18.2%	10.1%	15.7%	15.7%	15.7%	15.7%	-6.9%	-7.0%
Headwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector												
Arable	213		10.6%	10.9%	10.8%	6.0%	6.2%	6.1%	6.1%	6.1%	2.5%	2.0%
Fruit	138		4.7%	4.8%	4.8%	2.8%	3.4%	3.4%	3.4%	3.3%	0.3%	0.2%
Vegetables	18		6.9%	7.1%	7.1%	3.9%	4.6%	4.6%	4.5%	4.5%	0.5%	0.4%
Dairy	2,632		-5.6%	-6.1%	-6.1%	-3.2%	-2.7%	-2.7%	-2.7%	-2.6%	-2.1%	-2.0%
Sheep & Beef	7,564		-19.6%	-19.9%	-19.9%	-11.1%	-17.7%	-17.7%	-17.8%	-17.8%	8.0%	8.2%
Forestry	2,986		5.0%	5.2%	5.2%	2.9%	3.9%	3.9%	3.9%	3.8%	0.1%	0.1%
Scrub/Indigenous Forest	8,136		17.8%	18.2%	18.2%	10.1%	15.7%	15.7%	15.7%	15.7%	-6.9%	-7.1%

Appendix 6 Modelling results – Uptake of mitigation options

Table A6.1 Uptake of mitigation options (ha) for tailwind technology setting and no payment for new C sequestered by the scrub mitigation option

	Mitigation Options	Area adopted for each mitigation option (ha) for each scenario										
		GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm LUC – Same Price	Farm LUC – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)
	No mitigation options	25,259,156	25,148,077	25,403,682	25,403,637	25,384,273	25,494,147	25,493,971	25,507,777	25,500,969	25,064,535	24,332,908
Dairy Management	Output app 5% red	13,778	13,156	10,697	10,697	11,047	11,486	11,511	11,478	11,456	11,340	11,334
	Output app 10% red	12,932	11,419	7,504	7,504	7,682	7,912	7,938	7,986	7,971	7,890	7,840
	Output app 15% red	11,599	9,885	5,110	5,110	5,196	5,308	5,331	5,402	5,392	5,330	5,264
	Output app 20% red	10,277	8,568	3,615	3,615	3,646	3,688	3,706	3,781	3,775	3,727	3,662
	Fert 5% red	10,715	11,054	8,766	8,766	8,987	9,257	9,278	9,264	9,248	9,155	9,142
	Fert 10% red	12,015	10,202	6,308	6,308	6,426	6,562	6,586	6,617	6,606	6,528	6,479
	Fert 15% red	12,776	9,397	4,706	4,706	4,760	4,814	4,836	4,888	4,880	4,817	4,756
	Fert 20% red	12,960	8,404	3,490	3,490	3,502	3,503	3,522	3,584	3,578	3,529	3,465
	Ch supp feed – 50% low protein	9,296	10,930	10,993	10,993	11,399	11,906	11,916	11,800	11,778	11,640	11,696
	Ch supp feed – 100% low protein	8,666	9,453	9,322	9,322	9,691	10,145	10,158	10,061	10,042	9,913	9,957
	Ch supp feed – red 50% import feed & red SR	7,989	12,025	10,819	10,819	11,065	11,425	11,423	11,361	11,341	11,236	11,267
	Ch supp feed – red all import feed & red SR	6,245	11,735	8,907	8,907	9,055	9,340	9,334	9,302	9,285	9,160	9,148
	Red 5% SR & red prod	7,896	10,399	7,640	7,640	7,809	8,045	8,054	8,047	8,032	7,949	7,935
	Red 10% SR & red prod	6,843	8,856	4,691	4,691	4,753	4,853	4,863	4,893	4,885	4,824	4,781
	Red 15% SR & red prod	5,169	7,298	2,740	2,740	2,763	2,809	2,816	2,845	2,840	2,797	2,755
	Red 20% SR & red prod	3,718	5,705	1,529	1,529	1,531	1,545	1,550	1,573	1,571	1,541	1,508
	OAD half season	8,212	10,344	10,319	10,319	10,609	10,979	10,990	10,936	10,915	10,801	10,837
	OAD all season	9,065	11,727	11,447	11,447	11,733	12,116	12,125	12,061	12,039	11,927	11,966
Dairy Technology	Bromoform bolus	411	64,348	67,056	67,054	63,290	6,933	6,768	7,721	11,575	20,001	25,944
	3NOP fed twice a day	2,835	16,044	16,385	16,385	16,696	8,720	8,656	9,019	10,266	12,051	13,012
	Ecopond	4,004	10,563	10,743	10,743	11,063	8,453	8,428	8,530	9,031	9,638	10,001
	Low dairy CH_4 genetics	9,444	12,561	12,774	12,774	13,176	13,218	13,218	13,138	13,202	13,203	13,324
	Dairy N inhibitor	8,647	4,507	4,579	4,579	4,741	3,680	3,704	3,998	3,991	3,955	3,834
SNB Mgt	Scrub mitigation[a]	9,850	11,103	6,882	6,884	7,772	9,294	9,324	7,471	7,468	7,400	7,738
	Reduce Stock – Small	41,760	111,314	31,653	31,650	29,860	30,962	31,048	26,490	26,479	24,688	25,049
	Reduce Stock – Med	217,961	133,823	5,433	5,432	4,649	3,576	3,627	4,779	4,777	3,226	2,736
SNB Tech	SNB N inhibitor	11,997	9,706	10,135	10,136	10,565	10,562	10,600	9,650	9,647	9,039	9,336
	Low CH_4 SNB Genetics	28,601	37,343	38,683	38,690	42,755	40,373	40,334	31,121	32,514	32,499	35,019
	SNB Bolus	379	25,211	28,570	28,613	44,702	379	379	379	398	431,615	1,153,286

Mgt	10% red in N fert – hort	772	772	772	772	772	46	46	47	47	47	46
Mgt	15% red in fert – arable	1,050	1,091	1,069	1,069	1,050	983	979	1,020	1,020	1,019	994

a: the area of scrub mitigation for sheep and beef does not reflect the total area of scrub, rather the area where a portion of the land is in scrub. The portion differs between farm systems.

Table A6.2 Uptake of mitigation options (ha) for tailwind technology setting and a payment for new C sequestered by the scrub mitigation option

	Mitigation Options	Area adopted for each mitigation option (ha) for each scenario										
		GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm LUC – Same Price	Farm LUC – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)
	No mitigation options		25,120,583	25,391,262	25,005,243	25,370,322	25,477,067	25,476,929	25,496,518	25,489,715	25,053,398	24,319,998
Dairy Management	Output app 5% red		13,155	10,697	10,697	11,047	11,486	11,511	11,478	11,456	11,340	11,333
	Output app 10% red		11,418	7,504	7,504	7,682	7,912	7,938	7,986	7,971	7,890	7,839
	Output app 15% red		9,884	5,110	5,110	5,196	5,308	5,331	5,402	5,392	5,330	5,263
	Output app 20% red		8,567	3,615	3,615	3,646	3,688	3,706	3,781	3,775	3,727	3,661
	Fert 5% red		11,053	8,766	8,766	8,987	9,257	9,278	9,264	9,247	9,154	9,142
	Fert 10% red		10,201	6,308	6,308	6,426	6,562	6,586	6,617	6,605	6,528	6,479
	Fert 15% red		9,396	4,706	4,706	4,760	4,814	4,836	4,888	4,879	4,817	4,756
	Fert 20% red		8,403	3,490	3,490	3,502	3,503	3,522	3,584	3,578	3,529	3,465
	Ch supp feed – 50% low protein		10,929	10,993	10,993	11,398	11,907	11,916	11,800	11,777	11,640	11,696
	Ch supp feed – 100% low protein		9,452	9,322	9,322	9,690	10,146	10,158	10,061	10,042	9,913	9,956
	Ch supp feed – red 50% import feed & red SR		12,024	10,819	10,819	11,065	11,425	11,424	11,361	11,341	11,236	11,267
	Ch supp feed – red all import feed & red SR		11,734	8,906	8,906	9,054	9,340	9,334	9,301	9,284	9,160	9,148
	Red 5% SR & red prod		10,398	7,639	7,639	7,809	8,045	8,054	8,047	8,032	7,948	7,935
	Red 10% SR & red prod		8,855	4,690	4,690	4,753	4,853	4,863	4,893	4,885	4,824	4,781
	Red 15% SR & red prod		7,298	2,740	2,740	2,763	2,809	2,816	2,845	2,840	2,797	2,755
	Red 20% SR & red prod		5,704	1,529	1,529	1,531	1,545	1,550	1,573	1,570	1,541	1,508
	OAD half season		10,344	10,318	10,318	10,608	10,979	10,990	10,935	10,915	10,800	10,836
	OAD all season		11,726	11,447	11,447	11,733	12,116	12,125	12,061	12,039	11,926	11,966
Dairy Technology	Bromoform bolus		64,343	67,052	67,049	63,287	6,932	6,767	7,721	11,574	20,000	25,950
	3NOP fed twice a day		16,042	16,384	16,384	16,695	8,720	8,656	9,019	10,266	12,050	13,013
	Ecopond		10,563	10,743	10,743	11,062	8,453	8,429	8,530	9,031	9,638	10,000
	Low dairy CH_4 genetics		12,561	12,774	12,774	13,175	13,218	13,219	13,137	13,202	13,203	13,323
	Dairy N inhibitor		4,507	4,579	4,579	4,741	3,680	3,704	3,998	3,991	3,955	3,834
SNB Mgt	Scrub mitigation[a]		39,964	19,458	19,461	21,892	26,527	26,520	18,825	18,819	18,740	20,612
	Reduce Stock – Small		110,966	31,623	31,620	29,828	30,919	31,004	26,463	26,451	24,661	25,019
	Reduce Stock – Med		133,299	5,429	5,428	4,646	3,574	3,624	4,776	4,773	3,224	2,734
SNB Tech	SNB N inhibitor		9,656	10,112	10,112	10,539	10,529	10,567	9,632	9,630	9,022	9,314
	Low CH_4 SNB Genetics		37,202	38,624	38,630	42,685	40,299	40,259	31,080	32,472	32,454	34,964
	SNB Bolus		24,929	28,541	28,585	44,673	379	379	379	398	431,509	1,153,431
Mgt	10% red in N fert – hort		772	772	772	772	46	46	47	47	47	46
Mgt	15% red in fert – arable		1,091	1,069	1,069	1,050	983	979	1,020	1,020	1,019	994

a: the area of scrub mitigation for sheep and beef does not reflect the total area of scrub, rather the area where a portion of the land is in scrub. The portion differs between farm systems.

Table A6.3 Uptake of mitigation options (ha) for headwind technology setting and no payment for new C sequestered by scrub mitigation option

	Mitigation Options	Area adopted for each mitigation option (ha) for each scenario										
		GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm LUC – Same Price	Farm LUC – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)
	No mitigation options		25,210,643	25,477,412	25,476,917	25,467,717	25,502,908	25,502,635	25,495,879	25,492,256	25,486,961	25,442,190
Dairy Management	Output app 5% red		13,489	10,975	10,975	11,307	11,534	11,559	11,533	11,524	11,510	11,466
	Output app 10% red		11,737	7,665	7,665	7,846	7,946	7,972	8,024	8,018	8,008	7,980
	Output app 15% red		10,259	5,210	5,210	5,305	5,332	5,355	5,428	5,423	5,417	5,398
	Output app 20% red		9,021	3,681	3,681	3,720	3,705	3,723	3,799	3,796	3,792	3,779
	Fert 5% red		11,353	8,956	8,956	9,184	9,295	9,317	9,307	9,300	9,290	9,257
	Fert 10% red		10,852	6,438	6,438	6,565	6,590	6,615	6,648	6,643	6,635	6,613
	Fert 15% red		10,479	4,796	4,796	4,859	4,835	4,858	4,910	4,907	4,901	4,885
	Fert 20% red		9,938	3,553	3,553	3,572	3,519	3,538	3,601	3,598	3,594	3,582
	Ch supp feed – 50% low protein		11,180	11,284	11,285	11,687	11,954	11,964	11,856	11,847	11,833	11,787
	Ch supp feed – 100% low protein		9,668	9,570	9,570	9,938	10,186	10,198	10,109	10,101	10,089	10,050
	Ch supp feed – red 50% import feed & red SR		12,311	11,063	11,063	11,311	11,472	11,470	11,415	11,406	11,393	11,352
	Ch supp feed – red all import feed & red SR		12,129	9,134	9,134	9,287	9,379	9,373	9,345	9,338	9,327	9,292
	Red 5% SR & red prod		10,724	7,805	7,805	7,979	8,079	8,088	8,085	8,079	8,070	8,041
	Red 10% SR & red prod		9,298	4,782	4,782	4,853	4,874	4,884	4,916	4,913	4,907	4,890
	Red 15% SR & red prod		7,954	2,791	2,791	2,822	2,821	2,829	2,858	2,856	2,853	2,843
	Red 20% SR & red prod		6,881	1,556	1,556	1,564	1,552	1,557	1,580	1,579	1,578	1,572
	OAD half season		10,581	10,564	10,564	10,864	11,024	11,035	10,988	10,980	10,967	10,926
	OAD all season		11,984	11,709	11,709	12,004	12,166	12,175	12,118	12,109	12,095	12,051
Dairy Technology	Bromoform bolus		15,386	15,747	15,747	16,214	3,994	3,931	4,260	5,524	7,681	15,506
	3NOP fed twice a day		9,358	9,551	9,551	9,844	7,176	7,154	7,280	7,745	8,375	9,817
	Ecopond		10,799	11,005	11,006	11,353	8,489	8,464	8,570	9,083	9,771	11,320
	Low dairy CH_4 genetics		12,390	12,637	12,637	13,024	12,481	12,477	12,432	12,572	12,747	13,089
	Dairy N inhibitor		2,176	2,211	2,211	2,304	1,937	1,946	2,036	2,034	2,032	2,026
SNB Mgt	Scrub mitigation[a]		11,147	6,915	6,917	7,826	9,306	9,337	29,091	29,086	29,079	29,057
	Reduce Stock – Small		111,940	31,934	31,933	30,800	31,008	31,093	26,455	26,447	26,436	26,383
	Reduce Stock – Med		146,480	5,651	5,653	5,404	3,582	3,632	4,779	4,777	4,774	4,745
SNB Tech	SNB N inhibitor		7,874	8,229	8,231	8,757	8,653	8,668	7,712	7,710	7,708	7,695
	Low CH_4 SNB Genetics		36,743	51,973	52,461	50,618	39,818	39,771	30,559	31,919	33,748	37,740
	SNB Bolus		379	379	379	6,665	379	379	379	379	379	30,620
Mgt	10% red in N fert – hort		772	772	772	772	46	46	47	47	47	47
Mgt	15% red in fert – arable		1,093	1,071	1,071	1,050	983	979	1,020	1,020	1,020	1,019

a: the area of scrub mitigation for sheep and beef does not reflect the total area of scrub, rather the area where a portion of the land is in scrub. The portion differs between farm systems.

Table A6.4 Uptake of mitigation options (ha) for headwind technology setting and a payment for new C sequestered by the scrub mitigation option

	Mitigation Options	Area adopted for each mitigation option (ha) for each scenario										
		GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm LUC – Same Price	Farm LUC – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)
	No mitigation options		25,182,642	25,464,933	25,467,300	25,453,715	25,485,798	25,485,565	25,506,069	25,502,444	25,497,144	25,452,358
Dairy Management	Output app 5% red		13,488	10,974	10,974	11,307	11,534	11,559	11,533	11,524	11,510	11,466
	Output app 10% red		11,736	7,665	7,665	7,846	7,946	7,972	8,024	8,018	8,009	7,980
	Output app 15% red		10,258	5,210	5,210	5,304	5,332	5,355	5,428	5,424	5,417	5,398
	Output app 20% red		9,020	3,680	3,680	3,719	3,705	3,723	3,799	3,796	3,792	3,779
	Fert 5% red		11,352	8,956	8,956	9,184	9,295	9,317	9,307	9,301	9,290	9,257
	Fert 10% red		10,851	6,438	6,437	6,565	6,590	6,615	6,648	6,643	6,636	6,613
	Fert 15% red		10,478	4,796	4,796	4,859	4,835	4,857	4,910	4,907	4,901	4,885
	Fert 20% red		9,937	3,553	3,552	3,572	3,519	3,538	3,601	3,598	3,594	3,583
	Ch supp feed – 50% low protein		11,179	11,284	11,284	11,687	11,954	11,964	11,856	11,847	11,833	11,787
	Ch supp feed – 100% low protein		9,667	9,570	9,570	9,937	10,186	10,199	10,109	10,101	10,089	10,050
	Ch supp feed – red 50% import feed & red SR		12,310	11,063	11,063	11,311	11,472	11,470	11,415	11,407	11,393	11,353
	Ch supp feed – red all import feed & red SR		12,128	9,134	9,134	9,287	9,379	9,373	9,346	9,339	9,328	9,292
	Red 5% SR & red prod		10,723	7,804	7,804	7,979	8,079	8,088	8,085	8,079	8,070	8,041
	Red 10% SR & red prod		9,297	4,782	4,782	4,853	4,874	4,884	4,916	4,913	4,907	4,890
	Red 15% SR & red prod		7,954	2,791	2,791	2,822	2,821	2,829	2,858	2,856	2,853	2,843
	Red 20% SR & red prod		6,880	1,556	1,556	1,564	1,552	1,557	1,580	1,579	1,578	1,572
	OAD half season		10,580	10,563	10,563	10,864	11,025	11,035	10,989	10,980	10,967	10,926
	OAD all season		11,984	11,708	11,708	12,003	12,166	12,175	12,118	12,109	12,095	12,051
Dairy Technology	Bromoform bolus		15,385	15,746	15,746	16,214	3,993	3,931	4,260	5,525	7,681	15,507
	3NOP fed twice a day		9,357	9,551	9,551	9,844	7,176	7,154	7,280	7,745	8,375	9,817
	Ecopond		10,798	11,005	11,005	11,353	8,489	8,464	8,570	9,083	9,771	11,320
	Low dairy CH_4 genetics		12,389	12,637	12,637	13,024	12,481	12,477	12,432	12,572	12,747	13,089
	Dairy N inhibitor		2,176	2,211	2,211	2,304	1,937	1,946	2,036	2,034	2,032	2,026
SNB Mgt	Scrub mitigation[a]		40,224	19,515	19,519	21,966	26,566	26,558	18,829	18,825	18,819	18,802
	Reduce Stock – Small		111,581	31,903	31,892	30,768	30,964	31,049	26,475	26,467	26,455	26,402
	Reduce Stock – Med		145,975	5,647	5,636	5,400	3,579	3,630	4,780	4,778	4,775	4,747
SNB Tech	SNB N inhibitor		7,826	8,207	8,204	8,732	8,621	8,637	7,727	7,726	7,724	7,711
	Low CH_4 SNB Genetics		36,603	51,914	49,571	50,550	39,745	39,697	30,593	31,955	33,787	37,785
	SNB Bolus		379	379	379	6,665	379	379	379	379	379	30,624
Mgt	10% red in N fert – hort		772	772	772	772	46	46	47	47	47	47
Mgt	15% red in fert – arable		1,093	1,071	1,071	1,050	983	978	1,020	1,020	1,020	1,019

a: the area of scrub mitigation for sheep and beef does not reflect the total area of scrub, rather the area where a portion of the land is in scrub. The portion differs between farm systems.

Appendix 7 Modelling results – Net revenue

Table A7.1 Relative change (%) in net revenue from the 2030 baseline by sector for the tailwind technology setting

Scenario	GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)	Farm LUC – Same Price	Farm LUC – Diff Price
Tailwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable	-1.2%	10.2%	10.5%	10.5%	5.7%	5.5%	5.4%	5.3%	3.0%	33.3%	17.5%
Fruit	11.0%	4.4%	4.5%	4.5%	2.5%	3.3%	3.3%	3.2%	2.0%	8.1%	4.7%
Vegetables	23.7%	6.8%	7.0%	7.0%	3.7%	4.8%	4.8%	4.7%	3.1%	5.6%	3.3%
Dairy	-19.2%	-10.4%	-10.7%	-10.7%	-6.8%	-7.4%	-7.4%	-7.4%	-6.8%	-26.8%	-18.8%
Sheep & Beef	-3.4%	-34.8%	-35.5%	-35.5%	-21.7%	-30.0%	-30.0%	-28.5%	-12.1%	58.2%	40.1%
Forestry[a]	2.6%	1.0%	1.2%	1.1%	-1.1%	-0.1%	-0.1%	-0.3%	-1.7%	-3.6%	-3.7%
Total	**-4.2%**	**-5.8%**	**-5.9%**	**-5.9%**	**-4.5%**	**-5.1%**	**-5.1%**	**-5.0%**	**-3.9%**	**-2.8%**	**-2.8%**
Tailwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable		10.2%	10.5%	10.5%	5.7%	5.4%	5.4%	5.3%	2.9%	33.2%	17.4%
Fruit		4.4%	4.5%	4.5%	2.5%	3.3%	3.3%	3.2%	2.0%	8.1%	4.7%
Vegetables		6.8%	7.0%	7.0%	3.7%	4.8%	4.8%	4.7%	3.1%	5.6%	3.3%
Dairy		-10.4%	-10.8%	-10.7%	-6.8%	-7.5%	-7.4%	-7.4%	-6.8%	-26.8%	-18.8%
Sheep & Beef		-34.8%	-35.5%	-35.4%	-21.7%	-29.9%	-29.9%	-28.4%	-12.1%	58.2%	40.1%
Forestry[a]		1.0%	1.1%	1.1%	-1.1%	-0.1%	-0.1%	-0.3%	-1.7%	-3.6%	-3.7%
Total		**-5.8%**	**-5.9%**	**-5.9%**	**-4.5%**	**-5.1%**	**-5.1%**	**-5.0%**	**-3.9%**	**-2.8%**	**-2.8%**

a: For some scenarios, forestry revenue declines despite the increase in area. This is because the scenarios include the National Environmental Standards for Plantation Forestry (NESPF), a complementary environmental policy. The inclusion of the NESPF is modelled by removing 10 m riparian areas from exotic forestry production, which may lead to an overall decrease in net revenue for the forestry sector in some scenarios.

Table A7.2 Relative change (%) in net revenue from the 2030 baseline by sector for the headwind technology setting

Scenario	GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)	Farm LUC – Same Price	Farm LUC – Diff Price
Headwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable		10.5%	10.8%	10.8%	5.9%	5.5%	5.4%	5.4%	5.4%	33.3%	17.5%
Fruit		4.5%	4.6%	4.6%	2.7%	3.3%	3.3%	3.3%	3.3%	8.1%	4.7%
Vegetables		7.0%	7.2%	7.2%	3.9%	4.8%	4.8%	4.8%	4.7%	5.6%	3.3%
Dairy		-10.7%	-11.1%	-11.1%	-7.2%	-7.4%	-7.4%	-7.4%	-7.3%	-26.9%	-18.8%
Sheep & Beef		-34.7%	-35.4%	-35.4%	-21.8%	-29.7%	-29.7%	-29.7%	-29.7%	58.7%	40.4%
Forestry		1.1%	1.2%	1.2%	-1.0%	-0.1%	-0.1%	-0.1%	-0.2%	-3.6%	-3.7%
Total		**-5.8%**	**-5.9%**	**-5.9%**	**-4.6%**	**-5.1%**	**-5.1%**	**-5.1%**	**-5.0%**	**-2.8%**	**-2.8%**
Headwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector											
Arable		10.5%	10.8%	10.8%	5.9%	5.5%	5.4%	5.4%	5.4%	33.3%	17.5%
Fruit		4.5%	4.6%	4.6%	2.7%	3.3%	3.3%	3.3%	3.3%	8.1%	4.7%
Vegetables		7.0%	7.2%	7.2%	3.9%	4.8%	4.8%	4.8%	4.7%	5.6%	3.3%
Dairy		-10.7%	-11.1%	-11.1%	-7.2%	-7.4%	-7.4%	-7.4%	-7.3%	-26.9%	-18.8%
Sheep & Beef		-34.6%	-35.4%	-35.4%	-21.8%	-29.8%	-29.8%	-29.8%	-29.8%	58.7%	40.5%
Forestry		1.1%	1.2%	1.2%	-1.0%	-0.1%	-0.1%	-0.1%	-0.2%	-3.6%	-3.7%
Total		**-5.8%**	**-5.9%**	**-5.9%**	**-4.6%**	**-5.1%**	**-5.1%**	**-5.1%**	**-5.0%**	**-2.8%**	**-2.8%**

Appendix 8 Modelling results – commodity outputs

Table A8.1 Relative change (%) in production from the 2030 baseline by commodity

	Scenarios										
Production (t)	GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)	Farm LUC – Same Price	Farm LUC – Diff Price
Tailwind technology setting == <u>No</u> payment for C sequestration for scrub mitigation option for sheep & beef sector											
Milk solids	-29.1%	-9.3%	-9.5%	-9.5%	-6.2%	-5.3%	-5.3%	-5.6%	-4.6%	-4.5%	-4.4%
Lamb	4.7%	-23.3%	-23.6%	-23.6%	-14.7%	-21.4%	-21.4%	-24.4%	-18.9%	-3.2%	-2.6%
Beef	1.8%	-62.0%	-60.8%	-60.8%	-36.9%	-36.7%	-36.7%	-0.7%	80.2%	47.8%	45.2%
Wool	7.0%	-21.9%	-22.0%	-22.0%	-13.9%	-21.1%	-21.1%	-24.3%	-19.3%	-1.8%	-1.1%
Venison	-1.5%	-45.7%	-45.6%	-45.6%	-27.6%	-22.3%	-22.3%	-21.3%	-12.8%	-2.8%	-2.1%
Wheat	-1.2%	10.3%	10.6%	10.6%	5.7%	6.2%	6.1%	6.0%	3.6%	2.4%	2.0%
Barley	-1.2%	10.3%	10.6%	10.6%	5.7%	6.2%	6.1%	6.0%	3.6%	2.4%	2.0%
Maize	-1.2%	10.3%	10.6%	10.6%	5.7%	6.2%	6.1%	6.0%	3.6%	2.4%	2.0%
Berryfruit	11.0%	4.4%	4.5%	4.5%	2.5%	3.4%	3.4%	3.2%	2.1%	0.3%	0.2%
Kiwifruit	11.0%	4.4%	4.5%	4.5%	2.5%	3.4%	3.4%	3.2%	2.1%	0.3%	0.2%
Vegetables	18.8%	6.4%	6.6%	6.6%	3.5%	4.4%	4.4%	4.3%	2.9%	0.5%	0.4%
Tailwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector											
Milk solids		-9.3%	-9.5%	-9.5%	-6.2%	-5.3%	-5.3%	-5.6%	-4.6%	-4.5%	-4.4%
Lamb		-23.2%	-23.6%	-23.6%	-14.7%	-21.4%	-21.4%	-24.4%	-18.8%	-3.2%	-2.5%
Beef		-62.0%	-60.8%	-60.8%	-36.9%	-36.7%	-36.7%	-0.7%	80.2%	47.7%	45.1%
Wool		-21.8%	-22.0%	-22.0%	-13.9%	-21.1%	-21.1%	-24.2%	-19.3%	-1.8%	-1.0%
Venison		-45.6%	-45.6%	-45.6%	-27.6%	-22.3%	-22.3%	-21.3%	-12.7%	-2.7%	-2.1%
Wheat		10.3%	10.6%	10.6%	5.7%	6.1%	6.1%	6.0%	3.6%	2.4%	1.9%
Barley		10.3%	10.6%	10.6%	5.7%	6.1%	6.1%	6.0%	3.6%	2.4%	1.9%
Maize		10.3%	10.6%	10.6%	5.7%	6.1%	6.1%	6.0%	3.6%	2.4%	1.9%

	Scenarios										
Production (t)	GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)	Farm LUC – Same Price	Farm LUC – Diff Price
Berryfruit		4.4%	4.5%	4.5%	2.5%	3.4%	3.4%	3.2%	2.1%	0.3%	0.2%
Kiwifruit		4.4%	4.5%	4.5%	2.5%	3.4%	3.4%	3.2%	2.1%	0.3%	0.2%
Vegetables		6.4%	6.6%	6.6%	3.5%	4.4%	4.4%	4.3%	2.9%	0.5%	0.4%
Headwind technology setting == No payment for C sequestration for scrub mitigation option for sheep & beef sector											
Milk solids		-9.6%	-9.8%	-9.8%	-6.4%	-5.3%	-5.3%	-5.3%	-5.2%	-4.5%	-4.5%
Lamb		-22.8%	-23.1%	-23.0%	-13.1%	-21.4%	-21.4%	-21.4%	-21.4%	-3.2%	-2.5%
Beef		-65.4%	-64.7%	-64.7%	-52.2%	-36.7%	-36.7%	-36.7%	-36.3%	48.5%	45.9%
Wool		-21.4%	-21.5%	-21.4%	-12.2%	-21.0%	-21.0%	-21.0%	-21.1%	-1.8%	-1.0%
Venison		-45.9%	-45.9%	-45.9%	-28.2%	-22.3%	-22.3%	-22.3%	-22.3%	-2.8%	-2.1%
Wheat		10.6%	10.9%	10.9%	6.0%	6.2%	6.1%	6.1%	6.1%	2.5%	2.0%
Barley		10.6%	10.9%	10.9%	6.0%	6.2%	6.1%	6.1%	6.1%	2.5%	2.0%
Maize		10.6%	10.9%	10.9%	6.0%	6.2%	6.1%	6.1%	6.1%	2.5%	2.0%
Berryfruit		4.5%	4.6%	4.6%	2.7%	3.4%	3.4%	3.4%	3.3%	0.3%	0.2%
Kiwifruit		4.5%	4.6%	4.6%	2.7%	3.4%	3.4%	3.4%	3.3%	0.3%	0.2%
Vegetables		6.6%	6.8%	6.8%	3.7%	4.4%	4.4%	4.4%	4.3%	0.5%	0.4%
Headwind technology setting == Payment for C sequestration for scrub mitigation option for sheep & beef sector											
Milk solids		-9.6%	-9.8%	-9.8%	-6.4%	-5.3%	-5.3%	-5.3%	-5.2%	-4.5%	-4.5%
Lamb		-22.8%	-23.0%	-23.0%	-13.0%	-21.4%	-21.4%	-21.4%	-21.5%	-3.2%	-2.5%
Beef		-65.4%	-64.7%	-64.5%	-52.2%	-36.7%	-36.7%	-36.7%	-36.3%	48.4%	45.8%
Wool		-21.3%	-21.4%	-21.4%	-12.2%	-21.1%	-21.1%	-21.1%	-21.1%	-1.7%	-1.0%
Venison		-45.9%	-45.9%	-45.8%	-28.2%	-22.3%	-22.3%	-22.3%	-22.3%	-2.7%	-2.1%
Wheat		10.6%	10.9%	10.8%	6.0%	6.2%	6.1%	6.1%	6.1%	2.5%	2.0%
Barley		10.6%	10.9%	10.8%	6.0%	6.2%	6.1%	6.1%	6.1%	2.5%	2.0%

	Scenarios										
Production (t)	GHG Target	Processor ETS – All Mit	Processor ETS – Tech Mit	Processor Hybrid – Same Price	Processor Hybrid – Diff Price	Farm Split Gas Levy (x1)	Farm Split Gas Levy (x 5)	Farm Split Gas Levy (x10)	Farm Split Gas Levy (x20)	Farm LUC – Same Price	Farm LUC – Diff Price
Maize		10.6%	10.9%	10.8%	6.0%	6.2%	6.1%	6.1%	6.1%	2.5%	2.0%
Berryfruit		4.5%	4.6%	4.6%	2.7%	3.4%	3.4%	3.4%	3.3%	0.3%	0.2%
Kiwifruit		4.5%	4.6%	4.6%	2.7%	3.4%	3.4%	3.4%	3.3%	0.3%	0.2%
Vegetables		6.6%	6.8%	6.8%	3.7%	4.4%	4.4%	4.4%	4.3%	0.5%	0.4%

8 ANNEX: Additional scenario modelling

8.1 Overview

Scenarios additional to the modelling results for the primary scenarios provided in the main body of this report (hereafter 'main report') were requested by MPI and MfE. These scenarios are a refinement of the primary scenarios in the main report and compare between processor-based and Farm Split Gas Levy scenarios using similar emissions and incentive price settings. The Farm Split Gas Levy scenarios include 3 methane emissions prices to determine how this price affects the uptake of climate mitigation options and land use change. This Annex describes these additional scenarios and the modelling results.

For these scenarios, the elasticity parameters for the CET function were modified. The CET function specifies the rate at which land cover, enterprises, and management practices can be transformed across the array of available options. As suggested in the review by Dorner (2022), the CET elasticities for these scenarios are specified to allow greater management change while reducing land cover change in response to the different policy settings in the scenarios.[26] The elasticities used in the modelling for the additional scenarios are as follows: land cover ($\sigma L = -1.5$), enterprise ($\sigma E = -3$), and land management ($\sigma M = -15$). These elasticities were chosen as they produce a similar degree of historic land use change for the sheep and beef sector over the 5-year period representing 2025 to 2030.[27]

The modification of the CET elasticity parameters does result in small changes in the 2030 baseline area for some land uses. The elasticity parameters are used in the baseline calibration process, hence there being a small change in baseline areas. The total 2030 baseline land area remains the same, however. With the modified CET elasticity parameters, the 2030 baseline area reduces by less than 0.5% for all land uses except for dairy where the area is around 1.3% greater compared with the scenarios in the main report. The modification of the CET elasticity parameters means the additional modelling results outlined in this Annex and the modelling results in the main report are not directly comparable.

8.2 Description of additional scenarios

Five additional scenarios to the main report are included in this Annex: Processor ETS scenario, a Processor Hybrid scenario, and three Farm Split Gas Levy scenarios. The Processor Hybrid and Farm Split Gas Levy scenarios use a different pricing structure to those in the main report and all scenarios use the new CET elasticity parameters within the modelling framework. In all scenarios, only the uptake of technology mitigation options are rewarded

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[26] The CET elasticity parameters can theoretically range from 0 to infinity, where 0 indicates the input is fixed, while infinity indicates the inputs are perfect substitutes (i.e. no implicit cost from switching from one land use or enterprise activity to another).

[27] StatsNZ data shows land use change out of sheep and beef has been 1.8% per annum or 8.9% for a 5-year period.

and the tailwind technology setting is used. The carbon sequestered in the scrub mitigation option on sheep and beef land is also rewarded through incentive payments, and exotic forestry receives a carbon payment through the ETS. All other aspects of the scenarios remain the same as the initial scenarios modelled.

The Farm Split Gas Levy scenarios cover three methane emissions prices – low ($2.86/tCO_2e$), medium ($3.93/tCO_2e$), and high ($5/tCO_2e$) after accounting for a 90% price discount. The nitrous oxide emissions price is held constant across the scenarios ($10/tCO_2e$) after accounting for a 90% price discount.[28]

The Processor Hybrid scenario uses the medium methane emissions price of $3.93/tCO_2e$ and $10/tCO_2e$ for nitrous oxide emissions, which also accounts for a 90% price discount. For these scenarios the incentive price for the reduction in methane and nitrous oxide emissions is around $50/tCO_2e$.

The Processor ETS scenario uses the estimated 2030 NZU price of $10.86/tCO_2e$ (which includes 90% free allocation) for methane and nitrous oxide emissions. The incentive price for reductions in methane and nitrous oxide emissions are $108.62/tCO_2e$.

Across all scenarios, the payment for carbon sequestered by forestry is the estimated 2030 NZU price of $108.62/tCO_2e$. Only the carbon sequestered by scrub in the sheep and beef scrub mitigation option is rewarded and is priced at 75% of the estimated 2030 NZU price or $81.47/tCO2e.

The prices used for each of the scenarios are provided in Table AA1. In terms of the prices being modelled, the $108.62/tCO_2e$ roughly corresponds to The Treasury's mid-price projection for the NZU in 2030. The methane emissions price aligns with the Partnership's recommended price of 11 cents/kg CH_4 which equates to $3.93/tCO_2e$.[29] A high (14 cents/kg CH_4) and low (8 cents/kg CH_4) methane emissions price scenario are also modelled.

[28] A 90% discount is equivalent to the price being 10% of the full price for emissions. For example, the full price for nitrous oxide emissions is $100/tCO_2e$, but farmers receive a 90% discount on this price and only pay $10/tCO_2e$ (or 10% of the full price) for their nitrous oxide emissions.

[29] Note the 11 cents/kg CH_4 price was also modeled for the Farm Split Gas Levy scenarios in the main report, but this price was considered as the 2022 price and was inflated to a 2030 price in the main report.

Table AA1 GHG emissions and incentive prices for the additional agricultural climate policy scenarios

	Processor ETS – Tech Mit	**Processor Hybrid (Medium CH_4 price)**	**Farm Split Gas Levy (Low CH_4 price)**	**Farm Split Gas Levy (Medium CH_4 price)**	**Farm Split Gas Levy (High CH_4 price)**
Mitigation options rewarded	*Technology: tailwind setting*	*Technology: tailwind setting*	*Technology: tailwind setting*	*Technology: tailwind setting*	*Technology: tailwind setting*
CH_4 emissions price[a]	$10.86/tCO_2e$	$3.93/tCO_2e$	$2.86/tCO_2e$	$3.93/tCO_2e$	$5/tCO_2e$
N_2O emissions price[b]	$10.86/tCO_2e$	$10/tCO_2e$	$10/tCO_2e$	$10/tCO_2e$	$10/tCO_2e$
CH_4 reduction incentive price	$108.62/tCO_2e$	$50/tCO_2e$	$50/tCO_2e$	$49.11/tCO_2e$	$50/tCO_2e$
N_2O reduction incentive price	$108.62/tCO_2e$	$50/tCO_2e$	$50/tCO_2e$	$50/tCO_2e$	$50/tCO_2e$
C sequestered by exotic forestry price[c]	$108.62/tCO_2e$	$108.62/tCO_2e$	$108.62/tCO_2e$	$108.62/tCO_2e$	$108.62/tCO_2e$
C sequestered by scrub price[d]	$81.47/tCO_2e$	$81.47/tCO_2e$	$81.47/tCO_2e$	$81.47/tCO_2e$	$81.47/tCO_2e$

a. All methane emissions prices account for a 90% payment discount.
b. All nitrous oxide emissions prices account for a 90% payment discount of the full GHG price in 2030. The full price for the Processor ETS scenario is $108.62/tCO_2e$ while the full price for the other scenarios is $100/tCO_2e$.
c. Aligns with ETS payment for exotic forestry; price is 1 NZU/tCO_2e sequestered by forestry. The estimated 2030 NZU price for the carbon sequestered is $108.62/tCO_2e$.
d. Only for the scrub mitigation option on sheep and beef land; aligns with the Partnership's proposal that carbon sequestration from scrub receives 75% of NZU/tCO_2e. The estimated 2030 NZU price for the carbon sequestered is $108.62/tCO_2e$.

8.3 Modelling results

The modelling results outlined in this section cover the key impacts of the additional agricultural climate policy scenarios assessed – GHG emissions, land use, net revenue, agricultural production, uptake of mitigation options, and emissions payments and incentive payments.

8.3.1 GHG emissions

The modelling of the change in GHG emissions is compared with 2030 baseline emissions, not with 2017 emissions, on which the CCRA target is based. Using the 2020 baseline emissions as a proxy for the CCRA target, a reduction in methane emissions of 8.5% and GHG emissions of 10.4% equates to meeting the GHG targets.[30]

[30] The methane reduction target is a requirement in the CCRA while the overall GHG emissions reduction target was specified by MPI and MfE.

All scenarios are estimated to achieve the methane reduction target, with reductions in methane emissions ranging between 9 and 17% across the scenarios (Table AA2). The modelling, however, shows the Processor Hybrid and low methane emissions price Farm Split Gas Levy scenarios as not meeting the GHG reduction target, with reductions in GHG emissions of 9 and 10%, respectively. The processor ETS scenario shows the largest decrease in emissions at around 16% for total GHG emissions and 17% for methane emissions and 13% for nitrous oxide emissions. These results are primarily driven by the higher emissions pricing, especially for methane.

Table AA2 Relative Change (%) in GHG emissions compared to the 2030 Baseline for the additional policy scenario (shading indicates the GHG targets are not achieved)

	GHG emissions[b]	Methane emissions[b]	Nitrous Oxide emissions
2030 Baseline (tCO_2e)[a]	50,889,072	38,437,940	12,451,132
Scenarios (percent change)			
Processor ETS – Tech Mit	-15.7%	-16.7%	-12.6%
Processor Hybrid – split gas price (Medium CH_4 Price)	-9.1%	-9.4%	-8.1%
Farm Split Gas Levy (Low CH_4 Price)	-10.1%	-11.2%	-6.5%
Farm Split Gas Levy (Med CH_4 Price)	-11.2%	-12.4%	-7.5%
Farm Split Gas Levy (High CH_4 Price)	-12.3%	-13.6%	-8.2%

a: The 2030 baseline GHG emissions differ to the main report as the CET elasticity parameters were modified. These elasticity parameters are used to calibrate the baseline, hence there are small changes in baseline land use area compared to the main report resulting in differences in GHG emissions.
b: A reduction in 2030 methane emissions of 8.5% and GHG emissions of 10.4% equates to meeting the GHG targets (based on a 2020 base year).

8.3.1.1 Land use

The changes in land use area exhibit a similar trend as the changes in GHG emissions across the scenarios (Table AA3). Sheep and beef area decreases between 7% for the Processor Hybrid scenario and 16% in the Processor ETS scenario. The scenarios estimated to achieve the GHG and methane reduction targets have reductions in sheep and beef area of at least 10%. The modelled decrease in dairy area ranges from just under 2% to 4%. The area in forestry is estimated to increase between 2 and 4% depending on the scenario, and a 6 to 14% increase in scrub and indigenous forest area is also estimated. The increase in scrub and indigenous forest reflects the area of agricultural pastoral land that is no longer profitable when GHG emissions are priced. There is no payment for any carbon being sequestered on this land and thus the land is effectively being retired. The scrub mitigation option for sheep and beef land which does receive a carbon sequestration payment is captured in the sheep and beef land use area.

Table AA3 Relative change (%) in land use from the 2030 baseline by sector for the additional policy scenarios

Scenario	2030 Baseline area ('000 ha)[a]	Processor ETS – Tech Mit	Processor Hybrid – split gas price (Medium CH_4 Price)	Farm Split Gas Levy (Low CH_4 Price)	Farm Split Gas Levy (Medium CH_4 Price)	Farm Split Gas Levy (High CH_4 Price)
Arable	212	7.8%	3.7%	3.1%	3.8%	4.4%
Fruit	138	3.5%	1.8%	1.7%	2.0%	2.3%
Vegetables	18	5.1%	2.5%	2.4%	2.8%	3.2%
Dairy	2,666	-4.0%	-1.9%	-1.9%	-2.1%	-2.4%
Sheep & Beef	7,557	-15.6%	-7.1%	-8.2%	-10.2%	-12.0%
Forestry	2,980	3.8%	1.9%	2.0%	2.3%	2.7%
Scrub/Indigenous Forest	8,115	14.2%	6.5%	7.5%	9.2%	10.8%

a: The 2030 baseline land use area differs to the main report as the CET elasticity parameters were modified. The elasticity parameters are used to calibrate the baseline, hence there are small changes in baseline land use area compared to the main report. The total 2030 baseline area remains the same.

8.3.2 Net revenue

The changes in net revenue also have a similar pattern as the changes in GHG emissions across the scenarios (Table AA4). The reduction in net revenue for the split gas emissions pricing scenarios ranges between 4 and 5%, while the Processor ETS scenario is estimated to decrease net revenue for the agricultural sector by just under 6%.

The modelling shows the sheep and beef sector will experience the biggest decrease in net revenue, ranging from between 17% and 24% for the split gas emissions pricing scenarios to just under 32% for the Processor ETS scenario. Dairy has a similar trend, with ~6 to 7% reduction in net revenue for the split gas emissions pricing scenarios and about a 9.5% reduction for the Processor ETS scenario. Arable and horticultural revenues are estimated to increase between about 1.5 and 8%, depending on sector and scenario.

Table AA4 Relative change (%) in net revenue from the 2030 baseline by sector for the additional policy scenarios

Scenario	2030 Baseline net revenue ($'000)	Processor ETS – Tech Mit	Processor Hybrid – split gas price (Medium CH_4 Price)	Farm Split Gas Levy (Low CH_4 Price)	Farm Split Gas Levy (Medium CH_4 Price)	Farm Split Gas Levy (High CH_4 Price)
Arable	349,855	7.7%	3.7%	2.5%	3.1%	3.8%
Fruit	1,019,966	3.3%	1.6%	1.7%	2.0%	2.3%
Vegetables	197,920	5.1%	2.3%	2.5%	3.0%	3.4%
Dairy	4,359,216	-9.5%	-5.9%	-5.7%	-6.2%	-6.8%
Sheep & Beef	1,358,656	-31.6%	-16.8%	-17.8%	-21.1%	-23.9%
Forestry[a]	5,978,562	-0.1%	-2.0%	-2.0%	-1.6%	-1.3%
Total	**13,264,175**	**-5.9%**	**-4.3%**	**-4.4%**	**-4.7%**	**-4.9%**

a: Forestry revenue declines despite the increase in area because the scenarios include the NESPF, a complementary environmental policy. The inclusion of the NESP is modelled by removing 10 m riparian areas from exotic forestry production, which leads to an overall decrease in net revenue for the forestry sector in some scenarios.

8.3.3 Production levels

The changes in production levels exhibit similar trends to those scenarios in the main report. The smaller decrease in wool production in the Processor Hybrid scenario, compared with the Farm Split Gas Levy, likely reflects wool not being explicitly priced in the processor scenario. This results in a smaller decrease in South Island sheep and beef land area in the Processor Hybrid scenario compared to the Farm Split Gas Levy scenarios.

The difference in beef production between the processor and farm split gas levy scenarios is being driven by the move from North Island sheep and beef systems to a beef-dominated system and the uptake of the bromoform bolus mitigation option on that land (see Table AA6). Bromoform bolus is a relatively expensive, but effective, mitigation option. With emissions pricing, the use of bromoform bolus in this beef-dominated system makes this system more profitable than other sheep and beef systems. This is estimated to lead to an increase in beef production and a subsequent decrease in lamb production.

Table AA5 Relative change (%) in production from the 2030 baseline by commodity for the additional policy scenarios

Production (t)	Processor ETS – Tech Mit	Processor Hybrid – split gas price (Medium CH_4 Price)	Farm Split Gas Levy (Low CH_4 Price)	Farm Split Gas Levy (Medium CH_4 Price)	Farm Split Gas Levy (High CH_4 Price)
Milk solids	-7.6%	-4.8%	-4.3%	-4.5%	-4.7%
Lamb	-18.5%	-8.7%	-15.8%	-17.8%	-20.1%
Beef[a]	-51.4%	-44.4%	11.2%	7.7%	9.7%
Wool	-18.3%	-8.2%	-15.8%	-17.7%	-20.1%
Venison	-37.1%	-19.5%	-12.5%	-14.6%	-16.6%
Wheat	7.8%	3.7%	3.1%	3.8%	4.4%
Barley	7.8%	3.7%	3.1%	3.8%	4.4%
Maize	7.8%	3.7%	3.1%	3.8%	4.4%
Berryfruit	3.3%	1.6%	1.7%	2.0%	2.3%
Kiwifruit	3.3%	1.6%	1.7%	2.0%	2.3%
Vegetables	4.8%	2.2%	2.3%	2.7%	3.1%

a: The beef production quantities do not include the beef from dairy cull cows. The net revenue does, however, include the sale of these cows within each dairy system.

8.3.4 Uptake of mitigation options

The summary of the uptake of mitigation options is outlined in Table AA6. GHG emissions and incentive pricing do affect the uptake of the technology mitigation options. While it is not possible to discern from the results whether emissions pricing or incentive pricing has the biggest impact on technology adoption for dairy, the Processor ETS scenario, which has the highest methane emissions price, does show the largest uptake of dairy mitigation technologies, particularly bromoform bolus. For the sheep and beef sector, the emissions pricing is shown to be driving the uptake of bromoform bolus in the farm split gas levy scenarios. There is a relatively modest uptake of most other technology mitigation options. Low methane sheep and beef genetics are estimated to have a higher uptake than all technology mitigation options, except for bromoform bolus.

Table AA6 Uptake of mitigation options (ha) in the additional policy scenarios

	Mitigation Options	Area adopted for each mitigation option (ha) for each scenario				
		Processor ETS – Tech Mit	Processor Hybrid – split gas price (Medium CH_4 Price)	Farm Split Gas Levy (Low CH4 Price)	Farm Split Gas Levy (Medium CH4 Price)	Farm Split Gas Levy (High CH4 Price)
	No mitigation options	25,207,339	25,458,389	24,997,621	25,021,380	24,987,209
Dairy Management	Output app 5% red	9,704	10,620	10,687	10,672	10,615
	Output app 10% red	5,058	5,413	5,455	5,458	5,446
	Output app 15% red	2,642	2,785	2,792	2,798	2,796
	Output app 20% red	1,614	1,660	1,654	1,661	1,662
	Fert 5% red	6,604	7,085	7,048	7,041	7,016
	Fert 10% red	3,935	4,142	4,096	4,097	4,084
	Fert 15% red	2,600	2,692	2,651	2,654	2,649
	Fert 20% red	1,795	1,828	1,795	1,800	1,799
	Ch supp feed - 50% low protein	10,100	11,195	11,132	11,104	11,035
	Ch supp feed - 100% low protein	7,749	8,598	8,567	8,543	8,484
	Ch supp feed - red 50% import feed & red SR	9,606	10,302	10,202	10,198	10,170
	Ch supp feed - red all import feed & red SR	6,960	7,426	7,252	7,259	7,237
	Red 5% SR & red prod	5,062	5,405	5,360	5,361	5,347
	Red 10% SR & red prod	2,211	2,310	2,273	2,278	2,274
	Red 15% SR & red prod	868	897	872	875	874
	Red 20% SR & red prod	373	377	358	360	360
	OAD half season	9,205	10,121	10,046	10,029	9,985
	OAD all season	11,176	12,145	12,057	12,041	12,000
Dairy Technology	Bromoform bolus	172,781	25,310	29,393	29,583	32,818
	3NOP fed twice a day	22,757	13,381	13,869	13,873	14,183
	Ecopond	9,200	7,484	7,570	7,557	7,600
	Low dairy CH_4 genetics	12,850	13,577	13,575	13,551	13,512
	Dairy N inhibitor	2,119	1,759	1,824	1,817	1,804
SNB Mgt	Scrub mitigation[a]	28,681	32,845	29,010	27,732	26,587
	Reduce Stock - Small	89,148	42,695	31,411	31,143	30,585
	Reduce Stock - Med	4,493	4,143	2,117	2,269	2,212
SNB Tech	SNB N inhibitor	7,764	8,159	7,102	7,011	6,865
	Low CH_4 SNB Genetics	50,623	41,467	38,485	37,671	36,936
	SNB Bolus	60,177	10,986	489,831	468,285	501,951
Mgt	10% red in N fert - hort	772	772	8	8	8
Mgt	15% red in fert - arable	1,050	1050	904	910	916

a: the area of the scrub mitigation option for sheep and beef does not indicate this whole area is scrub. Rather a portion of the area is in scrub and the portion of the area in scrub differs between farm systems.

8.3.5 Emissions and incentive payments

The payments for GHG emissions by the farmer or the processor vary, depending on the emissions prices they face (Table AA7). In all scenarios the emissions price faced by farmers accounts for a 90% discount in price (akin to 90% free allocation). All of the additional scenarios modelled except the Processor ETS scenario have a lower price for methane emissions than for nitrous oxide emissions.

The incentive payments in each scenario are constrained to be equal or less than the total payments made by processors or farmers for their GHG emissions. In most instances, the incentive payment is a fraction of the GHG emissions payments.

The GHG emissions payment for the Processor ETS scenario (~$413million) is higher than the split gas scenarios (~$200–290 million) due to the higher emissions price for this scenario. Despite a smaller uptake in mitigation options in the Processor ETS scenario compared with the farm split gas levy scenarios, the higher incentive price resulted in the highest total incentive payment at around $86 million.

The difference in GHG emissions payments between the Processor Hybrid scenario and the farm split gas levy scenarios reflects the difference in how the emissions payments are levied. The processor scenarios price emissions based on production levels while the farm split gas levy scenarios price emissions based on the methane and nitrous oxides emitted.

The Processor Hybrid scenario has the lowest uptake of technology mitigation options and thus the lowest incentive payments (~$7 million). There is a small difference in the methane incentive price compared with the similar Farm Split Gas Levy scenario – medium methane emissions price scenario. The methane incentive price for the medium methane emissions price Farm Split Gas Levy scenario is $49.11/t$CO_2$e and has a similar methane emissions price to the Processor Hybrid scenario. However, the other farm split gas levy scenarios have a methane incentive price of $50/t$CO_2$e. This difference is likely driving the slightly smaller area increase in the beef-only farm system and the subsequent lower uptake of bromoform bolus in the sheep and beef sector and lower level of incentive payments.

It appears the higher methane emissions price leads to a greater technology mitigation option uptake in the farm split gas levy scenarios. At the low methane emissions price there is greater uptake of the scrub mitigation option on sheep and beef land, which is also being financially rewarded in the modelling.

Table AA7 GHG emissions payments, incentive payments, and the payment for the carbon sequestered in the scrub mitigation option for the sheep and beef sector for the additional policy scenarios

	Processor ETS – Tech Mit	**Processor Hybrid – split gas price (Medium CH_4 Price)**	**Farm Split Gas Levy (Low CH_4 Price)**	**Farm Split Gas Levy (Medium CH_4 Price)**	**Farm Split Gas Levy (High CH_4 Price)**
GHG emissions payments ($)	413,006,300	202,743,407	220,877,053	255,640,602	289,612,884
Incentive payments ($)	86,439,486	6,907,897	70,171,890	66,149,404	72,261,338
SNB scrub carbon sequestration payment[a] ($)	610,112	706,418	591,098	560,195	531,243

a: The scrub payment is associated with the uptake of the scrub mitigation option on sheep and beef land.

8.4 Summary

All the additional scenarios modelled are forecast to achieve the methane reduction target. However, only the Processor ETS scenario and the medium and high methane emissions price for the Farm Split Gas Levy are forecast achieve the GHG emissions target.

The net revenue for the agricultural sector is estimated to decrease in all scenarios, with the biggest percentage reduction in net revenue in the sheep and beef sector, followed by the dairy sector. The sheep and beef sector is also estimated to have the largest decrease in area, with the dairy area also contracting. There is an increase in forestry, arable and horticultural area as well as in land that is being retired as scrub and indigenous forest.

Of the technology mitigation options, bromoform bolus has the largest uptake for the dairy and sheep and beef sectors. There is also a moderate uptake of low methane genetics in the sheep and beef sector. Bromoform bolus uptake is greatest at the highest methane emissions price for the farm split gas levy scenarios.

As with the results in the main report, the processor-based scenarios, which do not explicitly price emissions associated with wool production, are estimated have a smaller impact on South Island sheep and beef systems than the farm split gas levy scenarios. Many South Island sheep and beef systems have greater wool production than the North Island systems.

In the farm split gas levy scenarios, there is also an increase in the North Island beef-only system when it is profitable for bromoform bolus to be adopted. The Farm Split Gas Levy rewards the adoption of technologies like bromoform bolus which reduce GHG emissions without compromising production through lower emissions payments. In the processor-based scenarios, however, there is no change in emissions payment for the adoption of these types of technologies as the emissions pricing is via production which is unchanged for these technologies.

The results provide insights into the estimated impacts of the different scenarios where the emissions and incentive pricing structures are similar, and which prices and scenarios are more likely to achieve the GHG targets. These refinements of the scenarios from the main report should still be used alongside other considerations such as equity implications, administrative costs, and transaction costs, to identify those policy levers that meet GHG targets and minimise the impacts on the agricultural sector.