Resource Economics

Pricing agricultural GHG emissions: *sectoral impacts and cost benefit analysis*

May 2022

Report for *He Waka Eke Noa*

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Cover photo: Werner Sevenster

Disclaimer

Although every effort has been made to ensure the accuracy of the material and the integrity of the analysis presented herein, Resource Economics Ltd accepts no liability for any actions taken on the basis of its contents.

Acknowledgements

This report provides a description of the quantitative analysis used in examining the *He Waka Eke Noa* pricing options and the results of that analysis. It includes quantitative results for dairy farming provided by Graeme Doole, now of AgResearch (for Dairy NZ) and for horticulture and arable land by Stuart Ford, The Agribusiness Group (for Horticulture New Zealand).

The work has benefited from the inputs and advice of the *He Waka Eke Noa* Programme Office (Kelly Forster, Kate Thompson) consultants to the Programme Office (Gus Charteris, Erica van Reenan, Andrew Curtis and Charlotte Glass) and from the members of the *He Waka Eke Noa* Policy and Pricing working groups and the Steering Group.

Phil Journeaux (AgFirst) provided valuable insights and inputs to the analysis, particularly relating to emission factors and technology costs and effectiveness. The report and analysis was improved following formal reviews by Lee Matheson (Perrin Ag Consultants) and Professor Frank Scrimgeour (University of Waikato).

Glossary of Abbreviations

3NOP	3-Nitrooxypropanol
AR4	4th Assessment Report of the IPCC
AR5	5th Assessment Report of the IPCC
BERG	Biological Emissions Research Group
BERSA	Biological Emissions Reductions Science Accelerator
B+LNZ	Beef + Lamb New Zealand
CBA	cost benefit analysis
CCC	Climate Change Commission
CGE	computable general equilibrium
CH_4	methane
CO_2	carbon dioxide
CO_2-e	carbon dioxide equivalent
DCD	dicyandiamide
EBIT	earnings before interest and tax
EBITRm	earnings before interest, tax, rent and manager wages
EF	emission factor
EFW	Essential Freshwater package
EITE	emissions intensive trade exposed
EMC	emissions management contract
ETS	emissions trading scheme
FAR	Foundation for Arable Research
FLL	farm level levy
FPBT	farm profit before tax
GHG	greenhouse gas
GWP_{100}	100-year global warming potential
HWEN	He Waka Eke Noa
ICCC	Interim Climate Change Commission
IPCC	Intergovernmental Panel on Climate Change
kg	kilogrammes
kt	kilotonnes (‘000 tonnes)
LLG	long lived gas
MfE	Ministry for the Environment
MPI	Ministry for Primary Industries
NEFD	national exotic forest description
NES-FW	national environmental standards for freshwater
N_2O	nitrous oxide
NPS-FM	National Policy Statement for Freshwater Management
NPV	net present value

NZAGRC	NZ Agricultural Greenhouse Gas Research Centre
NZU	New Zealand Unit
PH	processor hybrid
PV	present value
R&D	research and development

Contents

Executive Summary

Background

He Waka Eke Noa was launched in 2019 as a partnership between the agriculture and horticulture industries, Māori authorities and the Government, to coordinate a process to develop and analyse emissions pricing options for biological emissions from agriculture. The objective is to identify an alternative to the inclusion of these emissions in the New Zealand Emissions Trading Scheme (ETS). This report summarises the results of analysis of the impacts of identified emissions pricing options on dairy, sheep & beef and horticulture industries. It also includes the results of a national cost benefit analysis (CBA) of a selection of options.

Options Modelled

The baseline for analysis is current policy, which includes:

- the New Zealand Emissions Trading Scheme (ETS) applying to forestry, with increasing prices increasing incentives for more land use change from farming; and
- the implementation of the Essential Freshwater programme, including the National Policy Statement on Freshwater Management 2020 (NPS-FM).

A "backstop" scenario is compared with this baseline. It involves processors of agricultural products (milk, meat and fertiliser production) being included in the ETS. Several pricing options are compared to the backstop.

- They involve a charge rather than a tradable allowance system.
- Charges are levied via a split gas system in which methane (CH_4) is priced independently of long-lived gases (nitrous oxide and CO_2), in recognition of the separate domestic emission reduction targets.
- The inclusion of options for on-farm sequestration of CO_2 additional to those eligible under the ETS.

In addition to the backstop, the options examined are:

- **Farm-level levy** (FLL) with a price on every emission measured at the farm level.
- **FLL** plus a rebate to compensate farmers for costs, either as
    - An **output-based rebate** based on farm output; or
    - A **land-based rebate** based on farm area, adjusted for carrying capacity.
- **Processor hybrid** (PH) which has a charge on emissions at the processor level, with the funds used to pay for on-farm emission reductions via an Emissions Management Contract (EMC).
- **FLL + technology payment** to farmers for emission reductions using mitigation technologies.

Overview of Issues

Analysis of the base case with no additional pricing, suggests responses to freshwater regulation (the NPS-FM) and the extent of land use change expected from the high and rising New Zealand Unit (NZU) price in the ETS encouraging more afforestation, are forecast to produce reductions in methane emissions of over 4%. Based on this, the *He Waka Eke Noa* partners were looking for pricing options that would deliver an additional 4% or greater reduction in methane emissions by 2030, without having a significant impact on agricultural production[1]. There is no specific target for LLG emission reductions, so there has been greater focus on the methane results, but the partners are aware of the expectation of a significant contribution either in gross (emission reductions) or net terms (taking account of sequestration).

Emission Reduction Options

There are three broad approaches to reducing emissions from agriculture and horticulture:

1. Increasing efficiency, ie reducing the inputs of feed or fertiliser per unit of output;

2. Adoption of emission reduction technologies; or

3. Reducing total agricultural production.

Increasing efficiency (beyond any underlying trends) is a desirable option and there are opportunities that have been included in the modelled response in the dairy sector. Fewer opportunities exist in sheep and beef farming and/or they are more difficult to incentivise.

Emission reduction technologies offer greater potential but are still largely experimental rather than available commercially. Although the analysis assumes they will be available soon and will contribute increasingly to emission reductions from 2025, this is uncertain.

Reducing agricultural production provides more emissions reduction certainty, but this is a less desirable option because of the potential for emissions leakage[2] and because the mechanisms to reward these reductions may introduce inequities.[3] In the modelling, when emission costs rise, the least profitable dairy farms or farm areas reduce production. Some areas of sheep and beef farms are projected to convert to forestry in response to NZU prices; additional areas are likely to convert in response to emissions prices, although the extent of this is uncertain.

Pricing Emissions versus Paying for Emission Reductions

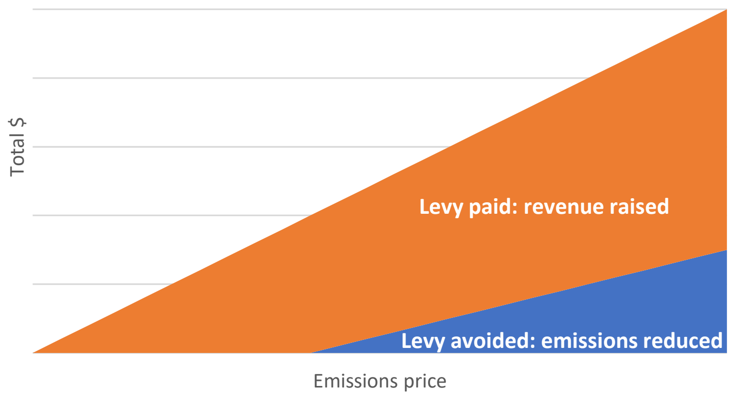
Emissions pricing is an ideal policy tool when there is uncertainty over how best to reduce emissions at the farm level. Emissions pricing rewards all reductions, however they are

[1] It is anticipated that the waste sector could achieve a reduction in biogenic methane of close to 20% by 2030 (or close to 2% of total biogenic methane) (Climate Change Commission 2021c). This alongside the base case and the methane reductions associated with the pricing proposals would achieve the 2030 target for methane of a 10% reduction below 2017 levels.
[2] Global demand is met by production elsewhere if production in New Zealand falls, with a consequent shift in the location of emissions.
[3] Emission payments require changes to be measured relative to an historical benchmark. This will differ with emissions intensity and early adopters of efficiency improvements may not be rewarded.

achieved, and the overall response will be revealed as farmers respond creatively to the new incentives and technologies emerge, some of which are not currently anticipated.

Initially, when there are limited opportunities for emission reductions, an emissions charge will be largely unavoidable (Figure ES1). This means a large effect of emissions charges will be to raise revenue. This has been significant in the partners' consideration of pricing mechanisms that use the revenue to obtain emission reductions and not just the response to the emission price, particularly when the level of charge to encourage emission reductions is likely to have high costs relative to profit.

Figure ES1 Effects of the levy – emission reductions and revenue raised



Theory would suggest the response to paying for an emission reduction will be the same as that to a charge on emissions, although other factors will be at play, including the voluntary nature of the payment compared with the charge. Paying for emission reductions also introduces the potential to use a higher price per kg of emissions reduced than is used in raising the revenue via the initial charge. This is the idea behind the *multiplier* used in some of the pricing options analysed. Emissions are charged at one price but reductions are rewarded at a multiple of that price. Use of a multiplier enables greater levels of emission reduction to be achieved at a given emissions price.

Options Analysis

Processor-Level ETS

The backstop processor-level ETS (PL-ETS) does not provide incentives for the full range of emission reductions because the obligation to surrender NZUs (and the associated cost of their purchase) varies with the level of output rather than with the emissions associated with that output. There is effectively no incentive for farm-level actions, including on-farm efficiency measures or the use of mitigation technologies to reduce the emissions intensity of production.[4] Incentives from the surrender obligation are limited to reducing output.

The positive arguments for the PL-ETS are that it is relatively simple to implement because of the existing system, with low administration costs. And some of the incentives for a

[4] Any farm-level responses would affect national average emission factors used for assessing emissions (when they are regularly updated) with the benefits then shared by the whole sector rather than by the individual farmer bearing the costs of the emission reductions.

wider range of emission reductions might be targeted by paying for emission reductions separately (the PL-ETS could operate similarly to the PH – see below).

Farm-Level Levy

In contrast to the PL-ETS, the FLL can provide incentives for all emission reduction options and disincentives for all emission increases. Achieving this comes with a higher cost for emissions measurement, and a relatively high price is needed to incentivise the full range of mitigation technologies. But high prices are also associated with high impacts on farm profit and in reductions in output. This means additional options considered include:

- using a low price FLL (which limits the emission reductions incentivised);
- using rebates to compensate for costs; and
- addressing the marginal incentives to reduce emissions by paying for emission reductions.

FLL plus Rebates

Rebates can be used alongside a high-priced FLL to redistribute some of the revenue raised from the charge to reduce the overall impacts on farmer or landowner profit. Ideally this is achieved by paying rebates in a way that is related to the costs faced but is not affected by emission reductions.

Two options have been explored by *He Waka Eke Noa* with rebates on the basis of output or land area (adjusted for productive capacity of the land). However, the impacts of the FLL plus rebate options have not been included in the final results because of the implementation and equity challenges perceived by the *He Waka Eke Noa* partners.

Processor Hybrid

The PH enables revenue to be raised at low cost (at the processor level). The incentives to reduce emissions then come via payments for emission reductions under emissions management contracts (EMCs) agreed between farmers and the Government. EMC options considered have included those based on payments for specific actions (use of technologies or identifiable efficiency improvements) or changes in emissions relative to an historical emissions benchmark for a farm.

The results suggest that the PH can produce significant levels of emission reduction when a multiplier is used to raise the price paid for emission reductions above the marginal costs of emission technologies, with significant reductions also associated with payments for livestock reductions under the benchmark approach.

FLL and Technology Payments

Under this option, the FLL provides incentives for emission reductions via the levy, but is reinforced by a multiplier applied to payments for emission reductions using mitigation technologies, and excluding payments for reductions in output. This reduces the potential emission reductions but is consistent with the full set of *He Waka Eke Noa* objectives.

The results suggest that, using a high multiplier, significant reductions can be achieved, although this depends on the technology development and adoption assumptions.

Sequestration and Revenue Sufficiency

Currently, sequestration is incentivised under the ETS. The *He Waka Eke Noa* options have introduced the potential for additional forms of sequestration to be rewarded, including current native forests that are managed to achieve additional growth, eg from livestock exclusion. This additional sequestration can provide compensatory revenue for some farmers, contribute to reducing atmospheric CO_2 and may provide some environmental co-benefits, eg from greater biodiversity. However, not all of it will count towards meeting national emission targets as emission reductions or ETS-eligible forestry do.

The payments for sequestration under *He Waka Eke Noa* compete with other potential uses of the revenue, eg payments for emission reductions.

Faster Technology Uptake Assumptions

The modelling has included the effects of high technology scenarios in which mitigation technologies are lower cost or have greater or earlier availability. As expected, these assumptions result in greater reductions and lower costs. This effect is behind the assumption that some of the revenue raised from an emissions charge would be used to fund additional research, particularly into these mitigation technologies and their implementation.

Quantified Impacts

The quantitative results presented in this report have been compiled from the output of three separate analytical models (for dairy, sheep & beef, and horticulture & arable land uses), operated by different modellers, using different methodologies and some different assumptions. Below we show the estimated effects from the contribution of sheep & beef and dairy farms. The impacts n horticulture and arable farms are shown separately as these land uses are not expected to reduce emissions but will simply pay the charge.

2025 Impacts

Emission reductions are assumed to be very low in 2025, the year in which the pricing system is assumed to start (Table ES1). The results are shown for prices expected under the PL-ETS: a 2025 NZU price of \$85/t CO_2-e[5] and a 95% allocation, equivalent to a net cost of \$4.25/t CO_2-e for long-lived gases (LLGs) or \$0.11/kg of CH_4.[6] They include a multiplier of 2.5 applied to the PH with benchmark (PH-B) option[7] and a higher multiplier of 5 applied to the FLL + technology payments option; the higher rate is applied because there are fewer potential emission reductions.

The baseline effects are the impacts of the freshwater regulations and the existing ETS (for forestry only) relative to the 2017 base. The impacts of the other options are all relative to this baseline. This means the effects are additional, ie the impacts of the PH + benchmark EMCs are an estimated 1% reduction in methane; this adds to the 2% from the baseline, resulting in a total estimate of a 3% reduction in 2025.

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[5] The NZU prices are based on the CCC 'Our Path to 2035' scenario (Climate Change Commission 2021b)
[6] This uses a conversion factor of 25, as used currently in the national emissions inventory and in the ETS.
[7] With a 2.5x multiplier, emission reductions are paid for at \$0.27/kg CH_4 and at \$10.63/t CO_2-e

Table ES1 Summary of Pricing Option Impacts, 2025

	CH₄ price ($/kg CH₄)	LLG Price ($/t CO₂-e)	CH_4	LLG	Milk	Meat	Dairy Profit	Sheep & beef profit	Gross levy revenue ($m)
Baseline			-2.0%	-1.8%	-1.2%	-3.2%	-2.8%	26.2%	$0
PL–ETS	$0.11	$4.25	-0.2%	-0.2%	-0.5%	-0.2%	-1.7%	-4.1%	$140
FLL	$0.11	$4.25	-0.2%	-0.5%	-0.3%	-0.2%	-1.8%	-3.7%	$143
PH–B (2.5x)	$0.11	$4.25	-1.2%	0.0%	-1.7%	0.2%	-2.0%	-3.8%	$141
FLL+Tech (5x)	$0.11	$4.25	-0.2%	-0.5%	-0.3%	-0.2%	-1.8%	-3.7%	$140

Note: PH – B = PH with benchmark-based EMCs

The PH results show how the multiplier can be used to raise the level of emission reduction at a given emissions price, eg methane reductions are approximately one percentage point higher than the FLL using a 2.5x multiplier. The FLL with technology payments has limited impact in 2025 because there are few technologies available.

2030 Results

Table ES2 shows the impacts in 2030.

able ES2 Summary of Pricing Option Impacts, 2030

	CH_4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	Multi-plier	CH_4	LLG	Milk	Meat	Dairy Profit	Sheep & beef profit	Gross levy revenue ($m)	Net ($m)
Base Case				-4.5%	-3.8%	-1.2%	-8.1%	-1.6%	127%	$0	$0
PL–ETS	$0.35	$13.80		-0.8%	-1.5%	-1.3%	-0.1%	-5.8%	-10.9%	$451	?
FLL	$0.05	$13.80		-0.5%	-2.6%	-0.9%	-0.1%	-3.6%	-5.8%	$133	$39
	$0.35	$13.80		-1.0%	-2.9%	-1.6%	-0.2%	-7.2%	-14.5%	$460	$366
	$0.11	$41.40		-0.9%	-3.5%	-1.7%	0.0%	1.6%	-0.5%	$340	$247
	$0.35	$41.40		-3.6%	-6.4%	-7.6%	-0.1%	-1.6%	-5.9%	$607	$513
PH–B	$0.05	$13.80	2.5	-0.9%	-3.5%	-1.7%	0.0%	1.6%	-0.5%	$143	-$59
	$0.11	$41.40	2.5	-3.6%	-6.4%	-7.6%	-0.1%	-1.6%	-5.9%	$497	$163
	$0.35	$41.40	2.5	-4.2%	-6.4%	-7.6%	-0.2%	1.4%	-14.4%	$622	$282
	$0.17	$13.80	7	-4.7%	-9.7%	-7.7%	0.0%	1.9%	-1.0%	$270	-$115
	$0.35	$13.80	2.5	-3.8%	-5.2%	-5.9%	-0.1%	-3.5%	-7.5%	$452	$233
	$0.35	$13.80	5	-6.3%	-9.2%	-10.1%	-0.1%	-0.1%	-6.8%	$441	$24
	$0.35	$13.80	7	-9.4%	-12.5%	-14.0%	-0.1%	3.2%	-6.2%	$431	-$225
PH–AB	$0.17	$13.80	7	-1.5%	-0.6%	-1.0%	0.0%	-3.5%	-1.0%	$278	$171
	$0.35	$13.80	2.5	-1.7%	-1.2%	-1.8%	-0.1%	-5.8%	-7.5%	$460	$356
	$0.35	$13.80	5	-2.2%	-1.3%	-1.8%	-0.1%	-5.7%	-6.8%	$460	$343
	$0.35	$13.80	7	-3.0%	-1.5%	-5.7%	-6.2%	-1.8%	-0.1%	$460	$312
	$0.35	$13.80	10	-5.1%	-2.0%	-5.1%	-5.2%	-1.7%	-0.1%	$460	$210
FLL+	$0.05	$13.80	5	-0.2%	-1.4%	-0.3%	0.0%	-1.4%	-0.5%	$129	$27
tech	$0.11	$41.40	5	-0.5%	-3.0%	-0.9%	-0.1%	-3.6%	-5.8%	$340	$238
	$0.35	$41.40	5	-2.6%	-3.5%	-1.6%	-0.2%	-7.0%	-14.2%	$585	$477
	$0.35	$13.80	2.5	-2.5%	-2.4%	-1.4%	-0.1%	-5.8%	-7.4%	$456	$339
	$0.35	$13.80	5	-2.8%	-2.2%	-1.4%	-0.1%	-5.8%	-7.3%	$455	$343
	$0.35	$13.80	7	-4.0%	-2.9%	-1.4%	-0.1%	-5.6%	-7.2%	$449	$295
	$0.35	$13.80	10	-6.0%	-3.3%	-1.2%	-0.1%	-4.7%	-7.2%	$441	$189

Note: PH–B = PH with benchmark-based EMCs; Note: PH–AB = PH with action-based EMCs

The results show the expected reductions under the base case (no additional pricing) of a 4.5% reduction in methane and close to a 4% reduction in LLGs. The pricing options include those based on an assumed NZU price in 2030 of $138/t CO_2-e and 90% free allocation in the PL-ETS backstop, resulting in a net cost of $13.80/t CO_2-e and $0.35/kg CH_4. Pricing options are highlighted that result in methane reductions of 4% or more, profit impacts of under 10% and with positive net revenue. This includes examples from PH and FLL + technology payment options.

High Technology Scenario

Table ES3 provides a limited set of 2030 results using high technology assumptions, ie assuming greater availability and/or lower costs. If these improvements are obtainable, it suggests value in efforts to rapidly advance the technologies and in pricing options that incentivise them. The high technology results show greater emission reductions and more pricing options that are forecast to achieve significant reductions with low profit impacts and positive net revenue.

Table ES3 Summary of Pricing Option Impacts, 2030 with high technology assumptions

	CH_4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	Multi-plier	CH_4	LLG	Milk	Meat	Dairy Profit	Sheep & beef profit	Gross levy revenue ($m)	Net ($m)
Base Case				-4.5%	-3.8%	-1.2%	-8.1%	-1.6%	127%	$0	$0
PL–ETS	$0.35	$13.80		-0.8%	-0.6%	-1.8%	-0.1%	-5.5%	-14.7%	$451	?
FLL	$0.35	$13.80		-2.1%	-0.9%	-1.1%	-0.1%	-5.7%	-10.9%	$452	$358
PH–B	$0.35	$13.80	2.5	-4.3%	-2.8%	-5.5%	-0.1%	-3.9%	-7.3%	$450	$232
	$0.35	$13.80	5	-11.3%	-7.9%	-9.6%	-0.1%	0.0%	-6.4%	$439	-$71
	$0.35	$13.80	7	-15.2%	-11.5%	-13.1%	-0.1%	4.5%	-5.8%	$430	-$385
PH–AB	$0.35	$13.80	2.5	-2.2%	-1.4%	-1.8%	-0.1%	-5.7%	-7.3%	$460	$351
	$0.35	$13.80	5	-7.9%	-2.8%	-1.7%	-0.1%	-5.0%	-6.4%	$460	$229
	$0.35	$13.80	7	-11.5%	-3.3%	-3.4%	-5.8%	-1.3%	-0.1%	$461	$72
	$0.35	$13.80	10	-13.2%	-4.2%	-0.2%	-4.7%	-1.0%	-0.1%	$462	-$125
FLL+ tech	$0.35	$13.80	2.5	-4.8%	-3.0%	-1.4%	-0.1%	-5.7%	-7.5%	$446	$177
	$0.35	$13.80	5	-10.6%	-4.6%	-1.2%	-0.1%	-4.3%	-7.3%	$421	$173
	$0.35	$13.80	7	-12.8%	-4.9%	-0.8%	-0.1%	-2.4%	-7.3%	$412	$11
	$0.35	$13.80	10	-13.8%	-5.5%	-0.5%	-0.1%	0.9%	-7.2%	$408	-$163

Note: PH–B = PH with benchmark-based EMCs; Note: PH–AB = PH with action-based EMCs

Impacts on Horticulture and Arable

The impacts on horticulture and arable farming are estimated to be limited to increases in the price of fertiliser (processor level) or to emissions from fertiliser (farm-level). The prices modelled are sufficiently low to have little impact and only a small reduction in profit (Table ES4). The only significant impacts are for arable farmers at the highest cost options (no discount to NZU price).

These results are assumed to apply to all pricing options.

Table ES4 Estimated impacts of long-lived gas emissions prices ($/t CO_2-e) on cash operating surplus

	2025			2030		
Land use	**$4.25**	**$21.25**	**$85.00**	**$13.80**	**$41.40**	**$138.00**
Apple	0.00%	0.01%	0.03%	0.00%	0.01%	0.05%
Kiwifruit	0.00%	0.02%	0.07%	0.01%	0.03%	0.11%
Vegetables, Auckland	0.05%	0.25%	1.00%	0.16%	0.48%	1.62%
Vegetables, Canterbury	0.03%	0.16%	0.62%	0.10%	0.30%	1.01%
Arable	0.16%	0.81%	3.24%	0.53%	1.58%	5.26%

Source: Stuart Ford, The Agribusiness Group

Cost Benefit Analysis

Unlike the sectoral analysis above, a CBA estimates costs to the nation and compares these with the benefits estimated in monetary terms.

- The costs of paying the charge or the rewards paid for reducing emissions are treated as transfer payments.
- Costs that are counted include those for mitigation actions, reduced revenue from lower production (offset by reduced production costs when there is less feed or fertiliser used), and costs for fencing, weed and pest control for sequestration.
- The benefits are the avoided costs of having to reduce emissions elsewhere in the economy (to meet net emission targets) when agriculture reduces emissions or sequesters more. We use NZ Treasury shadow values of emission reductions.[8]

The overall results for the different options are shown in Table ES5, as the net present value (NPV) to 2030 using a 5% discount rate. The results are for prices that are the same as expected under the PL-ETS, ie \$0.11/kg CH_4 and \$4.25/t CO_2-e in 2025 rising in a straight line to \$0.35/kg CH_4 and \$13.80/t CO_2-e in 2030.

Table ES5 Summary of Impacts: PV (to 2030) in 2022 $ values ($ million) – 5% discount rate

Base Option:	**Processor ETS**	**FLL + Tech payments (2025 start)**	**FLL + Tech payments (2026 start)**	**Processor Hybrid + Benchmark EMCs**	**Processor Hybrid + Action-based EMCs**
Multiplier assumed	na	10	10	5	10
Costs					
Admin costs	-$56	-$280	-$263	-$319	-$197
Emission reduction costs	$32	-$232	-$233	-$246	-$184
Sequestration costs	-$33	-$149	-$154	-$145	-$145
Total costs	**-$58**	**-$661**	**-$649**	**-$710**	**-$526**
Costs per tonne					
$/t CO_2-e (excl admin costs)	-$37	$52	$52	$35	$52
$/t CO_2-e (incl admin costs)	$29	$114	$110	$80	$108
Benefits					
Emission Benefits	$109	$584	$575	$896	$458
Sequestration Benefits	$217	$252	$232	$236	$235
Total Benefits	**$326**	**$836**	**$806**	**$1,132**	**$693**
Net Costs/Benefits	**$268**	**$175**	**$157**	**$422**	**$167**

[8] NZ Treasury (2021)

All options have positive net benefits by 2030. This is particularly because the prices provide incentives for emission reductions that are lower cost than the national benefits of emission reductions. In addition, there is an overall surplus from the benefits of sequestration. The surpluses from emission reductions and sequestration are greater than the estimated administrative costs for the options.

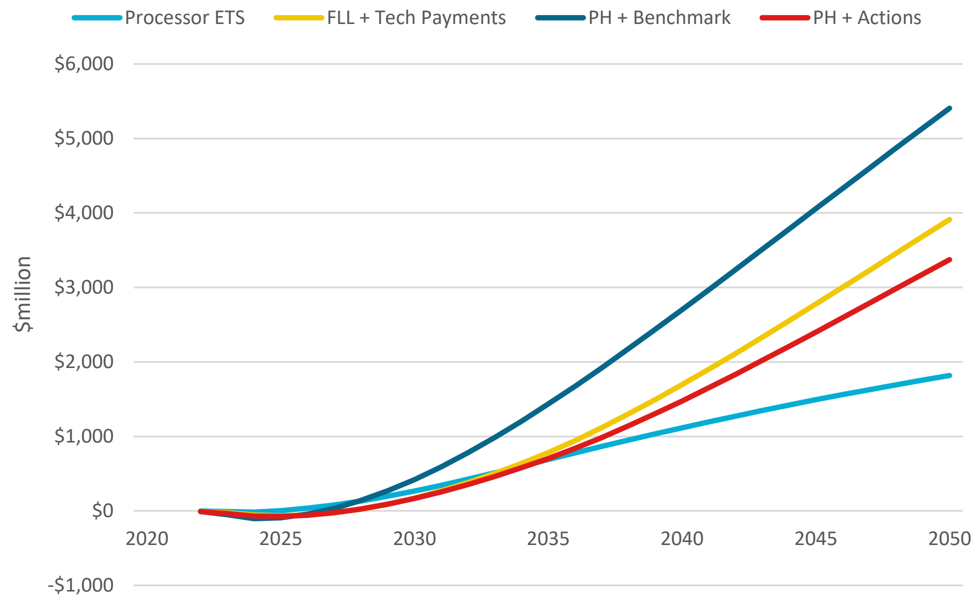
The PL-ETS option has low costs because it has a simple measurement and revenue collection system at the processor level and has no additional element used to measure and incentivise emission reductions at the farm level. It also has little emissions impact benefit but larger sequestration benefits because of the impact of emission prices on the relative profitability of sheep & beef farming and forestry.

The greatest net benefits are estimated for the PH + benchmark EMC option. It has relatively high administration costs (particularly for operating the EMC system) but produces the largest estimated emission reductions. However, these are associated with reductions in production (with leakage risk).

The NPVs for the other options are quite similar, with the FLL + technology payments options having higher administration costs than the PH + actions-based EMCS, but higher estimated emission reductions also.

The analysis has been limited to 2030 reflecting the period used for the sectoral analysis. Extending the analysis beyond 2030 is expected to raise the benefits more than costs for all options. Figure ES2 demonstrates this using some simple assumptions of annual emission reductions continuing to increase at the same level as the annual average between 2025 and 2030. It shows the NPV from 2022 to the year in the x-axis, eg the NPV for the FLL + Technology Payments is approximately $800 million if the analysis is to 2035 but increases to close to $4 billion if extended to 2050.

Figure ES2 Potential NPV for pricing options if analysis is extended to different end years



The NPV for the PL-ETS is initially similar to the others initially but performs worse over time because of the limited incentives for emission reductions. The PH + benchmark option increases relative to the others but is based on falling agricultural production in New Zealand and (assumed) higher emissions leakage.

Conclusions

The results of analysis suggest the following.

- Regardless of the design of a *He Waka Eke Noa* pricing system, the high and expected rising price of NZUs in the ETS is expected to provide a strong incentive for land use change from farming to forestry. Exotic planting to gain NZUs will be largely on sheep & beef farms.

- *He Waka Eke Noa* pricing introduces a value for additional sequestration to that included in the ETS. Only a small percentage (estimated at 25%) of this sequestration will contribute to achievement of national emission targets; at the time of writing this report, work is continuing within *He Waka Eke Noa* considering what price to pay for it.

- The analysis has identified options that can reduce emissions to a level consistent with domestic targets, taking account of expected change under the base case. These include options using prices at levels anticipated under the PL-ETS, or even slightly lower. These options include the PH and FLL + technology payment options, both using multipliers to amplify the signal to reduce emissions. The analysis has raised several issues that need to be weighed in making a choice of preferred option.

    - **Where to place the charge**, weighing the costs of the measurement system versus the incentive effects. Processor level charges are lower cost but provide incentives themselves for very few emission reductions. In contrast, farm-level charges require higher cost farm-level measurement but provide incentives for the full range of emission reductions.

      A FLL on its own would need to be set at a high price to provide incentives for emission reductions, with significant impacts on farm profit, particularly for sheep & beef farms. It has greater advantages when there are more farm-level mitigation options and when greater use can be made of the charge than payments to reduce emissions.

    - Providing the **main incentives for emission reduction via charges or payments**. Charges are simplest but payments combined with a multiplier enable an amplified incentive at a lower emissions price. This is particularly attractive when there are few potential emission reductions and the charge is largely unavoidable (Figure ES1). As the emission reduction potential rises, multipliers will need to fall as there is greater risk of exhausting the available revenue and the relative role of the charge in achieving emission reductions will rise.

    - Limiting incentives for emission reductions to **mitigation technologies and efficiencies or including reductions in production**. This weighs up risks of emissions leakage (from production loss which is also somewhat at odds with the *He Waka Eke Noa* objectives) with those of potential slow development of technology, which risks falling short of targeted reductions. Providing incentives for reductions in production provides greater emissions reduction certainty but also requires the use of a benchmark against which emission reductions can be measured, and this raises equity issues from differences in starting levels of emissions intensity.

1 Introduction

1.1 Background and Objective

1.1.1 Background

He Waka Eke Noa was launched in 2019 as a partnership between the agriculture and horticulture industry, Māori authorities and the Government, to coordinate a process to develop and analyse emissions pricing options for biological emissions from agriculture. The aim is to identify an alternative to the inclusion of these emissions in the New Zealand Emissions Trading Scheme (ETS), while meeting the objectives as set out in Box 1.

Box 1 *He Waka Eke Noa* Objectives

Design a farm-level pricing mechanism, that forms part of a broader behaviour change framework within He Waka Eke Noa, that:

- Incentivises farmers and growers to reduce greenhouse gas emissions within New Zealand's agricultural sector
- Contributes to reducing greenhouse gas emissions from the agricultural sectors towards meeting New Zealand's targets under the Climate Change Response Act
- Enables New Zealand farmers and growers to understand and be recognised for the sequestration that is happening on their farms and incentives prevention of carbon losses
- Is workable and cost effective to comply with and administer
- Supports farm systems to align with wider government and industry objectives
- Supports productive, internationally competitive and sustainable New Zealand agricultural and horticultural sectors
- Gives affected parties an appropriate amount of time to modify practices and transition to the new system

Source: *He Waka Eke Noa*

This report summarises the results of analysis of the impacts of identified emissions pricing options on dairy, sheep & beef and horticulture industries. It is not a comprehensive assessment of all possible options and pricing levels. Rather it has been developed in response to requests for analysis by the project partners and the *He Waka Eke Noa* programme office as their policy preferences have developed over the project period.

This report summarises and aggregates the impact assessments of industry-specific (dairy, sheep & beef and horticulture) models on emissions, land use change, production and farm-level profit; these results are then used to develop an overall assessment of national costs and benefits. A separate report for *He Waka Eke Noa* has assessed the macro-economic impacts.[9] This report uses this analysis to draw out conclusions on the merits of the different pricing approaches in reducing emissions to achieve targets, set against the *He Waka Eke Noa* objective of not leading to a significant reduction in agricultural output.[10]

1.1.2 Agricultural Emissions and Emission Reductions

Agricultural emissions include methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2).

[9] Infometrics (2022)
[10] The *He Waka Eke Noa* objectives include supporting productive, internationally competitive and sustainable New Zealand agricultural and horticultural sectors

Agricultural CH_4 emissions are very largely from the digestive system of ruminant animals and the quantity of emissions reflects the quantity of food intake; much smaller amounts are derived from manure. Reducing methane emissions involves either a reduction in the number of animals or in the emissions intensity of production. Reducing emissions intensity is the preferred option because, in the absence of a reduction in global demand for agricultural products, reducing animal numbers in New Zealand can simply result in agricultural production increasing in another country without a reduction in global emissions.[11] Reductions in emissions intensity can result from improved farm management systems, and in the future, it is expected that mitigation technologies will be available also, including genetics (low methane livestock), vaccines and inhibitors.

N_2O is largely the result of microbial processes in the soil acting on urine and fertilisers. Emissions are reduced from a reduction in animal numbers or in fertiliser inputs, or in more efficient feed regimes. And as with methane, there is an expectation of technologies being developed to address these emissions more directly. CO_2 emissions result from the application of urea, lime and dolomite.[12]

1.1.3 Current Policy

In addition to economy-wide, all sectors and all gases targets, the Government has adopted separate (split-gas) targets for methane and long-lived gases (CO_2 and N_2O), including a required 10% reduction in biogenic methane[13] by 2030 (see Box 2), approximately 90% of which is from agriculture.

Box 2 New Zealand's Emission Targets

New Zealand's Nationally Determined Contribution under the Paris Agreement is to "reduce net greenhouse gas emissions to 50 per cent below gross 2005 levels by 2030" (New Zealand Government, 2021), with net emissions including all gases based on 100-year Global Warming Potentials (GWP_{100}) from the IPCC 5th assessment report.[14]

National emission objectives set in the Climate Change Response (Zero Carbon) Amendment Act 2019 require reductions in agricultural emissions. These are:

- Net zero emissions of all greenhouse gases (GHGs) other than biogenic methane (CH_4), but including nitrous oxide (N_2O), by 2050; and
- 24 to 47 per cent reduction of biogenic methane emissions below 2017 levels by 2050, including a 10 per cent reduction below 2017 by 2030.

To achieve emission reductions, agricultural emissions will be included in the emissions trading scheme (ETS) from 2025 under the Climate Change Response (Emissions Trading Reform) Amendment Act 2020, unless an alternative pricing regime is developed and agreed to. This alternative pricing regime is the task of *He Waka Eke Noa*.

This report summarises the analysis of the pricing options in comparison to the ETS 'backstop'. It includes their expected effectiveness in reducing emissions, the costs to the agriculture sector, the impacts on farm profitability and the impacts on output. It also includes a cost benefit analysis (CBA) of the options.

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[11] Denne (2022)
[12] Gibbs (2019)
[13] Biogenic methane is produced from biological (plant and animal) sources and includes emissions from livestock and from waste decomposition.
[14] The GWPs are 28 for CH_4 and 265 for N_2O (Box 3.2 in IPCC, 2014)

1.2 Pricing Options

1.2.1 The ETS 'Backstop'

In the absence of an alternative pricing system being developed and agreed, the Government can bring the agriculture sector into the NZ ETS at a processor level by 2025.[15] This is the backstop option in our analysis. The ETS option would be an obligation on processors of agricultural products (milk and meat) and manufacturers of fertiliser to surrender New Zealand Units (NZUs)[16] equal to estimates of the biological emissions from the production of those products. The level of obligation is calculated from the quantity of output multiplied by emission factors designated in kg of carbon dioxide equivalents per kg of product (kg CO_2-e/kg). The emission factors are estimates of the average downstream on-farm emissions for each product.[17]

The processors would start with an annual allocation of 95% of their NZU requirement and must purchase NZUs for the shortfall. This allocation percentage is assumed to reduce annually, in the same way as allocation for emissions intensive trade exposed (EITE) industries under the ETS. The initial effective price faced by processors per tonne of output is thus equal to 5% of the NZU price. It is assumed that this would be passed on to farmers supplying the processors as a reduction paid for farm outputs (milk, meat etc) and an increase in the price charged for fertiliser.[18]

Although the backstop option ensures the agriculture industry bears the costs of its emissions, placing obligations upstream at the processor level provides incentives for a very limited number of potential emission reduction options. The processor faces costs based on a national average emission factor per unit of output and would be expected to pass costs on in the same way.

- This does not provide any incentive for individual farms to increase the efficiency of production, eg via alternative feed regimes, or to use any new technologies (low emission animals, vaccines or emission inhibitors), which are currently at various stages of development. These farm-level responses would affect national average emission factors (when they are regularly updated) with the benefits then shared by the whole sector rather than by the individual farmer bearing the costs of the emission reductions.

- It does provide incentives for:
    - Greater efficiency in the use of fertiliser because of the price increase; and
    - Reduced output (of milk, meat etc), including via lower animal numbers.

In addition to biological emissions, the backstop also includes the rewards for sequestration that currently exist in the ETS. Afforestation of at least one hectare on previously non-forest land, can be used to earn NZUs based on growth in carbon stocks.

1.2.2 *He Waka Eke Noa* Pricing Options

The pricing options developed by *He Waka Eke Noa* partners aim to ensure farmers have incentives to reduce on-farm emissions and are rewarded for emission reductions. The options are characterised by the following:

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[15] He Waka Eke Noa (2022a); Climate Change Commission (2021a)
[16] An NZU is an allowance to emit one metric tonne of carbon dioxide equivalent (CO_2-e). Obligated parties in the ETS must surrender units equal to their emission obligations.
[17] The main source of emission factors in this report is Journeaux (2019)
[18] The extent of pass through will reflect the price elasticity of demand and supply and the relative market power of the processors and farmers.

- The pricing regime involves a charge rather than a tradable allowance system. Farm-level trading regimes were examined by the partners, but ultimately rejected largely for their perceived complexity. Using a charge provides greater certainty over cost, but some uncertainty over the emission outcome.

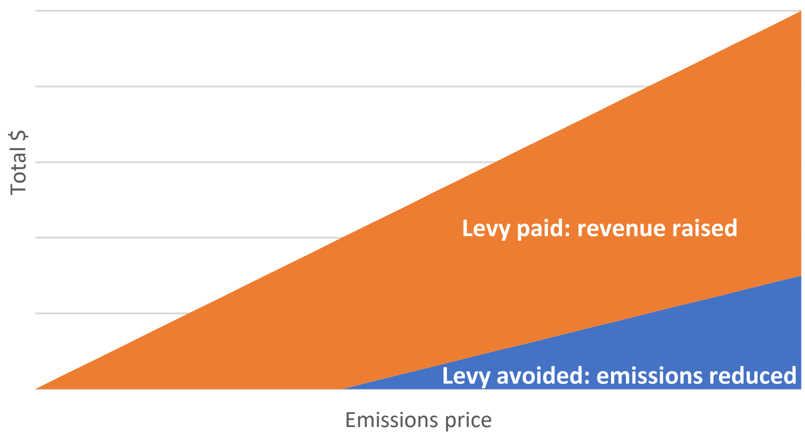
- Farmers are provided price incentives for a full range of options to reduce emissions, including mitigation technologies, farm-level innovations and farm management optimisation.

- Charges are levied via a split gas system in which methane (CH_4), as a short-lived gas, is priced differently from long-lived gases (N_2O and CO_2), in recognition of the separate domestic targets (Box 2) and the different impacts on the atmosphere.

- The inclusion of additional options for on-farm sequestration of CO_2 to those eligible under the ETS. This would offset emissions and provide revenue to offset some of the costs of the charge payments.

The simplest form of pricing system is a **farm level levy (FLL)** in which emissions measured for individual farms (using a farm-level emissions calculator) face an emissions charge, with a separate price for the individual gases. The analysis suggests that, although there will be incentives for efficiency improvements, including in fertiliser use, initially and while emission reduction technologies are still under development, the FLL will be largely unavoidable without farmers reducing output (Figure 1).

Figure 1 Effects of emission charge with few abatement options



Often when an economic instrument is used for environmental policy purposes this outcome is desirable. The price on residual emissions can reduce the profitability of emissions-intensive industries and encourage a shift in economic activity and in economic structure. However, this is not compatible with the *He Waka Eke Noa* objective of supporting "*productive, internationally competitive and sustainable New Zealand agricultural and horticultural sectors*" (Box 1). However, where the levy is still paid, the revenue can be used to mitigate the impacts on farm profitability for options which include:

1. displacing other (distortionary) sources of government revenue. However, this would benefit all taxpayers so the effects on agriculture would be limited, and the Government has

announced that any revenue would be recycled to the agriculture sector;[19]

2. providing rebates to compensate those who face costs under the system (in a way that does not reduce the incentive to reduce emissions);

3. to fund additional expenditure on related matters, including research and development (R&D) on emission reduction technologies; and/or

4. paying for emission reductions or sequestration, including at a higher price that the emissions price. This can enable a greater level of emission reduction and charge avoidance at a lower price.

Early analysis suggested pricing levels expected to drive the adoption of emission technologies (when available) and other emission reductions would mean farmers faced a total cost that represented a high proportion of profit, particularly in the sheep and beef sector. Some change in activity levels would be expected as a result, particularly via land use change to forestry. However, additional exotic forestry is not necessarily desirable[20] and the potential 'leakage' of livestock emissions to other agriculture commodity producing countries meaning global emissions might not fall.[21]

This analysis led to the identification of alternative pricing options in which the emissions charge functioned largely as a revenue raising tool, with the money raised being used to fund additional research and development (R&D) in emission reduction technologies, sequestration by native vegetation and payments for emission reductions using a multiplier of the emissions price (and potentially limited to options that would reduce emissions intensity of production rather than on reductions in output). The options considered are broadly categorised as follows.

- **FLL** with prices set at a relatively low level, consistent with the effective price faced under the ETS, eg initially 5% of the projected NZU price, but with the percentage rising over time. This might also be defined as a high emissions price with a high discount.

- **FLL plus rebate** options. These could include a high emissions price at the farm level, and with (some of) the revenue raised from the emissions charge being returned to farmers as a rebate to protect their profit (in a similar way to NZU allocation under the ETS option). This would retain the full marginal incentive to reduce emissions as with the FLL and potentially at the full NZU price, while redistributing money to the farmers in a way that, ideally, did not distort the incentives for emissions intensity reduction. Two rebate options were considered:
  (1) Output-based, with an amount distributed per unit of output (eg of milk or meat); and
  (2) Land-based, providing a rebate based on land area, adjusted for carrying capacity.[22]

- **Emission reduction payment** options which include a levy with the primary objective of raising revenue, with some of the revenue then used to purchase emission reductions. This is similar to a feebate, such as the Clean Car Discount: there is an incentive provided by the

[19] Office of the Minister for Climate Change (2019)
[20] See Climate Change Commission (2021a) and MPI and MfE (2022)
[21] See discussion and analysis in Denne (2022)
[22] Without the carrying capacity adjustment, the rebates would go largely to extensive farms.

charge and the payment of the rebate.[23] Two main approaches were considered.

- **Processor level charge** based on a similar calculation to that which would be used for the ETS option. Farmers would then be able to sign a voluntary emissions management contract (EMC) in which they would agree to reduce emissions for an agreed price per tonne. Options examined included those in which emission reductions are measured relative to an historical benchmark or based on an agreed set of actions that excludes reduced production.

- **FLL** with revenue paid back to the farmers based on the implementation of agreed emission reduction actions, most likely limited to the adoption of technologies when available (technology support).

The price options analysed and discussed in this report are shown in Table 1. Further detail is provided when we discuss the analysis of each option.

Table 1 Price options analysed

Option	**Charge or Obligation**	**Rebates or Payments**	**Sequestration**
Processor-level ETS	NZU surrender obligations for processors based on emissions of all GHGs ($/t CO_2-e)	Allocation of NZUs to processors to offset costs based on output.	Current ETS only
***He Waka Eke Noa* Pricing Options**			
Farm Level Levy (FLL)	Emissions charge on farmers with separate prices for CH_4 ($/kg of CH_4) and long-lived gases in ($/t CO_2-e)	No rebates	Additional options available
FLL + output-based rebate	As for FLL	Rebates based on average national emissions per unit of output	As for FLL
FLL + land-based rebate	As for FLL	Rebates based on average emissions per hectare for land of equivalent carrying capacity	As for FLL
Processor hybrid (PH)	Charge applied to processors (with percentage discount).	Emission reduction payments under EMC.	As for FLL
FLL + technology support	As for FLL	Emission reduction payments under a reduced-form EMC.	As for FLL

1.3 Background Data

1.3.1 Baseline Emissions

Emissions from agriculture in 2017 are shown in Table 2. This year is used because it is the year from which measured reductions in biogenic methane are counted towards the split gas target.

The table summarises emissions as tonnes of methane (CH_4) and tonnes of CO_2 equivalents (CO_2-e) for both CH_4 and nitrous oxide (N_2O) based on global warming potentials (GWP_{100}) of 25 and 298 for CH_4 and N_2O respectively.[24] This uses the GWPs based on the IPCC 4th Assessment Report (AR4),[25] rather than the updated GWPs in AR5[26] as recently adopted for New Zealand's updated NDC target

[23] https://www.nzta.govt.nz/vehicles/clean-car-programme/clean-car-discount/
[24] For example, 1 tonne of CH_4 is estimated to have the same global warming effect as 25 tonnes of CO_2.
[25] See Table 2.14 in Forster *et al* (2007)
[26] See Box 3.2 in IPCC (2014)

(see Box 2). The AR4 values are used in the current national inventory and for calculating CO_2-e in the ETS. We have thus retained AR4 GWPs for analysis in this report. The estimates of emission reductions in this report are relative to the values in Table 2.

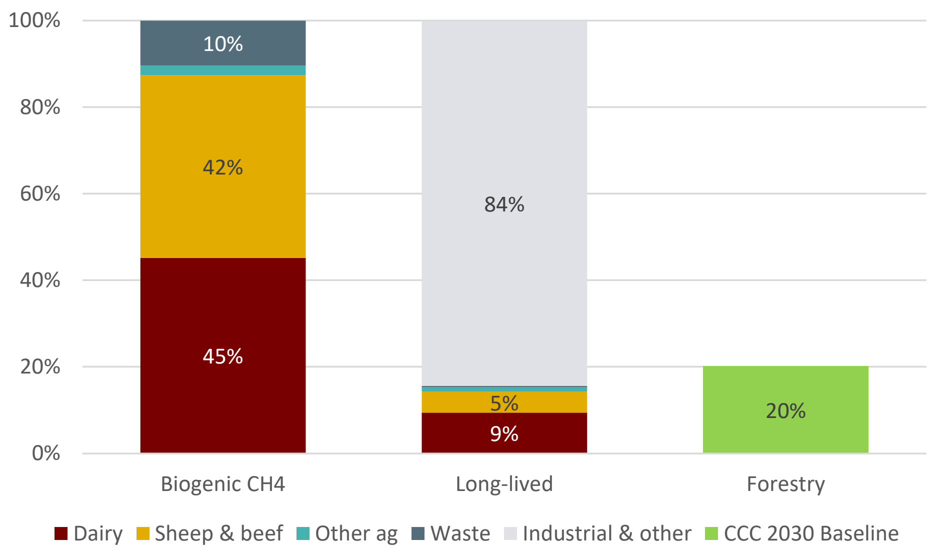
Table 2 Agriculture Sector emissions 2017

Total	**Enteric kt CH_4**	**Manure kt CH_4**	**Enteric kt CO_2-e**	**Manure kt CO_2-e**	**Soils N_2O kt CO_2-e**	**Other kt CO_2-e**	**Total kt CO_2-e**
Dairy cattle	542.9	50.3	13,572	1,257			14,829
Sheep	334.2	3.5	8,356	87			8,443
Other cattle	213.3	2.9	5,332	72			5,404
Deer	19.5	0.2	487	6			493
Other CH_4	2.1	2.3	51	57		23	131
Total CH_4	1,111.9	59.1	27,798	1,478	-	23	29,300
Fertiliser					1,444		1,444
Urine & dung					3,810		3,810
Other N_2O		4.9		122	1,696		1,817
Total N_2O				122	6,949		7,071
CO_2						1,048	1,048
Total	1,112	59	27,798	1,600	6,949	1,071	37,419
% as CO_2-e			74%	4%	19%	3%	100%

Source: MfE New Zealand Greenhouse Gas Inventory

Figure 2 shows agricultural emission relative to other emissions across New Zealand relevant to the split-gas targets. Biogenic methane emissions, for which there are 2030 and 2050 targets, are dominated by dairy (45% of total) and sheep and beef (42%), with smaller contributions from other agriculture, eg other animals (3%) and the waste sector (10%). Agriculture is assumed to be the main source of emission reductions to achieve current biogenic methane targets.

Figure 2 Agricultural emissions in context of national emissions (2017)



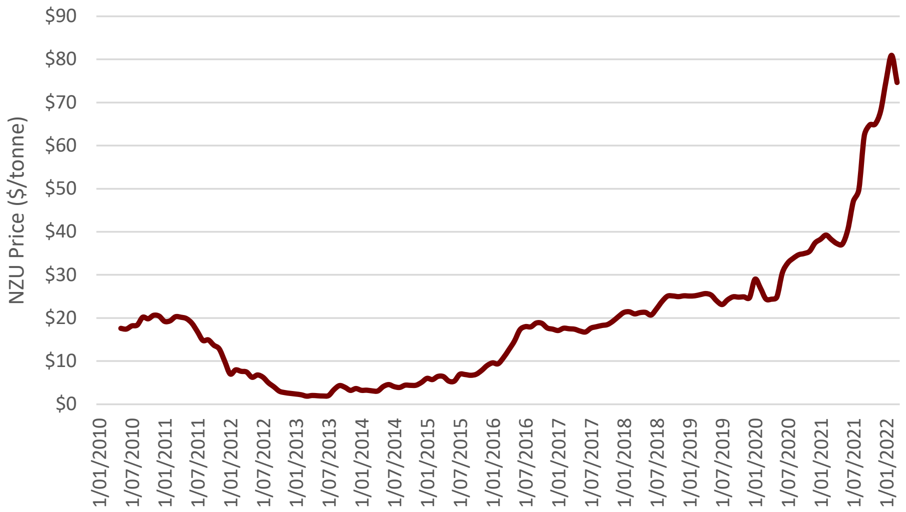
Source: MfE New Zealand Greenhouse Gas Inventory and Climate Change Commission (2021b)

The long-lived gas (LLG) emissions (N_2O and CO_2) from agriculture are placed in the context of total national gross emissions in 2017; agriculture contributed approximately 15% to the total. The Climate Change Commission (CCC) baseline projection of sequestration by forestry in 2030 is included; it is approximately 20% of gross emissions. Agriculture is expected to contribute to the 2030 and 2050 net emission targets.

1.3.2 Emissions Prices

The study was undertaken over a period in which NZU prices have changed significantly. In the first half of 2021 NZUs were trading for less than \$40/t CO_2-e, but by early 2022, NZU prices had peaked at over \$80/t CO_2-e (Figure 3).

Figure 3 Monthly average NZU prices



Source: Data from https://github.com/theecanmole/nzu; https://carbonmatch.co.nz/

Previous studies which have examined the expected response of primary sectors to emission prices under the ETS have generally assumed lower prices. For example, the CCC assumed a price of \$35/t to 2050 in its Reference Case,[27] and Motu's analysis for the Biological Emissions Reference Group (BERG) assumed an emissions price of \$25/t CO_2-e in 2018 rising to \$31/t in 2030 and to \$44/t in 2050.[28]

For analysis of *He Waka Eke Noa* pricing options, a range of prices have been used and the analysis presented in this report varies the prices, partly as assumptions on the underlying NZU price have changed during the analytical phase. The NZU price assumptions are based on the CCC 'Our Path to 2035' scenario,[29] as discussed in the final advice to the Government (Table 3).[30]

Table 3 Climate Change Commission NZU Values

Year	NZU Price (\$/t CO_2-e)
2020	\$30
2025	\$84
2030	\$138
2035	\$160
2050	\$250

Source: Climate Change Commission (2021b)

[27] Scenarios dataset for the Commission's 2021 Draft Advice for Consultation (output from ENZ model)
[28] Dorner *et al* (2018)
[29] Climate Change Commission (2021b)
[30] See Box 7.1 in Climate Change Commission (2021a)

These start from an estimate of the price ($250/t CO_2-e) required in 2050 to eliminate fossil fuel emissions from those sectors where there are low-emission alternatives. The price path then assumed a 3% annual price increase from 2030 to 2050 and a straight-line increase from 2020 to 2030.[31] The CCC notes that this is not a price projection. Rather it is a modelled result for 2050 and an assumption of a rational market response. The approach is consistent with assumptions about optimal pricing of depletable resources[32] and is what might be expected given the ability to trade over time (eg banking NZUs) and on an assumption of a fully informed market regarding future supply and demand for NZUs.

Because of the adoption of a split gas approach and an intent to treat methane differently from long-lived gases (LLGs), the price applied to methane is generally presented in $/kg of CH_4 rather than in $/t CO_2-e. For readers unfamiliar with this presentation, using AR4 GWP_{100} conversion factors, $1/kg CH_4 is equivalent to $40/t CO_2-e.

1.3.3 Afforestation

The analysis of responses to emission prices in this report includes shifts towards forestry from sheep & beef farming. This occurs currently because of the relative values of these activities, including the incentive effect provided by the ETS.

A recent report for Beef + Lamb New Zealand (B+LNZ) examined the amount of land that has been or is expected to be planted into exotic plantation species in the near future that is likely to take land out of pastoral production.[33] The results summarised in Table 4 suggest that:

- The gross land area of whole farms purchased for planting in calendar years 2017 to 2020 inclusive is estimated at 92,118 ha, of which 66,665 ha is estimated as 'plantable (effective) area'.
- Between 2018 and December 2020 an additional 47,382 ha of land within existing farms was approved for planting, funded by the One Billion Trees programme[34] or as part of the Crown Forestry Joint Ventures scheme.[35]
- 19% of the total identifiable land conversion is likely to be planted with mānuka or indigenous species.
- In total, it is estimated that 139,500 hectares of land has been or will be planted in the near future, taking this land predominantly out of sheep and beef production.

[31] This is set out in Climate Change Commission (2021c)
[32] Hotelling (1931); Pearce and Turner (1990)
[33] Orme and Orme (2021)
[34] A Government goal of planting one billion trees between 2018 and 2028. See: https://www.mpi.govt.nz/forestry/funding-tree-planting-research/one-billion-trees-programme/
[35] An agreement for Crown Forestry entering into new commercial forestry joint ventures to build the forestry sector, boost the One Billion Trees programme, and contribute to Māori and regional development.

Table 4 Conversion of pasture to forestry

Whole of Farm Purchase	Year 2017	2018	2019	2020	Grand Total (Hectares)	Percentage by Conversion
Honey (Manuka)	3039	7340	1678	2281	14338	10.3%
NZ Sales	2510	11245	26198	11881	51834	37.2%
OIO	1455	8982	10626	4883	25946	18.6%
Total Whole of Farm	7004	27567	38502	19045	92118	66.0%
Partial farm plantings by Landowner through 1BT/JV						
1BT Landowner Grant		12,124 Indigenous + 13,434 Exotic			25560	18.3%
Crown Forestry JV		21822			21822	15.6%
Total Partial farm funded			47382		47382	34.0%
Totals					139500	100.0%

Source: Orme and Orme (2021)

This suggests approximately 28,000 ha per annum being converted from pasture to exotic forestry on average in the four years to the end of 2020, during a period when NZU values increased from under \$20/t CO_2-e to approximately \$30/t (Figure 3). This is more than suggested by the total new planted area statistics published by MPI in the National Exotic Forest Description (NEFD) (Figure 4). It records 6,000 and 7,000 ha respectively for 2017 and 2018, with a preliminary estimate of 19,000ha for 2019. Orme and Orme tried cross-checking their numbers with other data sources, but were unable to find compatible datasets.[36] These data are thus somewhat uncertain but do suggest potentially significant levels of land use shift compared with much of the historical record in the NEFD, eg between 40,000 and 50,000 ha in 2019 including whole-of-farm purchases not used for mānuka and the exotics component of partial farms funded planting (Table 4).

Figure 4 New land planted ('000 ha)

Note: 2019 data are provisional
Source: MPI (2020)

1.3.4 Baseline Projections of Land Use Change to Forestry

Land use change, particularly from sheep & beef farming to forestry, has been a significant component of the modelled response in many studies. However, predicting rates of land use change is not straightforward because analysis of the relative profitability of sheep & beef farming and forestry suggests that it would be financially rational to change land use currently, and that there are

[36] Orme and Orme (2021)

many reasons why a landowner may not convert or may delay conversion even when it would appear profitable to do so.[37]

Dorner and Hyslop (2014) suggest this includes: option value – the value of delaying a decision given the costs and risks of the decision; risk aversion – the land owner may wish to reduce risks of conversion not paying off by maintaining current use; the human capital of land manager – the land manager may not have the skills to successfully run a new type of farm; preferences or status quo bias of the land manager to keep the land in current use; and liquidity constraints when conversion has costs. They also note land sales have the potential to reduce some or all of these barriers to conversion. Using econometric analysis of historical land use change they found recent profitability data (and commodity prices) had little predictive power for aggregate rural land use change and was only moderately successful at predicting land use transitions out of pasture and into forestry or scrub.

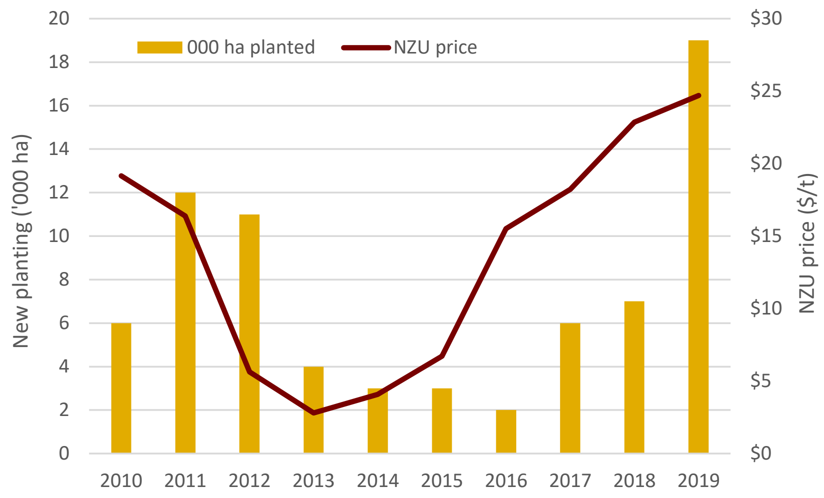
Bruce Manley has projected land use change to forestry in response to the NZU price and log prices. He developed a model that estimates the future afforestation rate from the NZU price, A grade log price and land value.[38] Using his equations and coefficient values, alongside current and projected NZU prices suggests very high planting rates, significantly in excess of historical rates of planting (Figure 4), eg an estimated 286,000 ha per annum in 2030 at an NZU price of \$138/t CO_2-e and a conservative assumed log price of \$125/m^3.[39] More recently, Manley has provided afforestation estimates using 60% of the area of afforestation suggested by the model equation.[40] This would reduce the forecast area to 172,000 ha per annum.

In contrast, the CCC has assumed limits to afforestation, consistent with the recently released Government discussion paper.[41] This partly reflects the assumptions of significant cuts in gross emission such that large areas of new exotic forestry are not required to meet targets, in addition to concerns over the risks of climate change for forestry. The CCC uses scenarios with a total of 570,000–760,000 ha of new exotic forests planted from 2021 to 2050, ie an average of 20-26,000 ha per annum. The discussion paper suggests one approach to limiting further afforestation is to prevent exotic forestry from registering in the permanent post-1989 category in the ETS.

Given these uncertainties, an alternative projection has been developed using a simple relationship between afforestation and the NZU price. In Figure 5 we note that the amount of new planting appears to have shifted with the price of NZUs, although the response is somewhat lagged, eg the increase in planting is delayed following an increase in price, whereas reductions in afforestation appear to be closely linked.

[37] Journeaux *et al* (2017)
[38] Manley (2018)
[39] Current prices for A-grade logs are approximately \$164/t (Ministry of Primary Industries, 2021)
[40] Manley (2019)
[41] MPI and MfE (2022)

Figure 5 New forestry planting and NZU price (2010 to 2019)



Source: MPI (2020); NZU prices – see Figure 3

In analysis we tested various econometric models to relate MPI planting rates to the NZU price and log prices (see Table 5). The NZU prices use a one-year price lag for falling prices and a three-year lag for rising prices (see Figure 6). This assumes that the market responds relatively quickly to a falling price but is delayed in its confidence that a rising price will persist.

Table 5 Afforestation rates econometric results

	Model 1	Model 2
Constant	1.328 (1.692)	
NZU price	0.725 (0.161) ***	0.682 (0.148) ***
A grade log price		0.014 (0.011)
Adjusted R^2	0.71	0.77

Standard errors in brackets
*** Significant at the 1% level

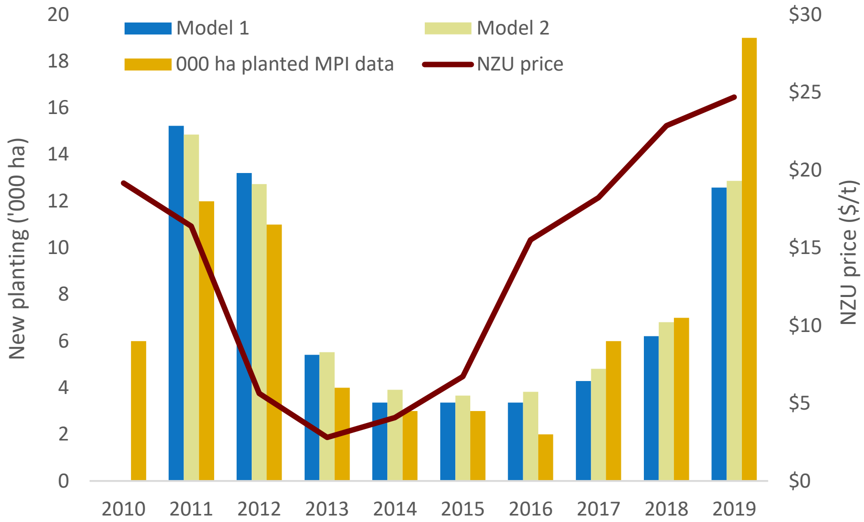
The two models suggest a highly statistically significant relationship between the NZU price and the afforestation rate but with low levels of significance for the constant (model 1), ie the planting rate with a zero NZU price, or the coefficient on log price (model 2). The coefficient on log price suggests a very small effect, eg a $100/m^3 change in price would result in a predicted 1,400 ha of additional afforestation. This is not unexpected, as the log price of more relevance is that expected in 30 years' time.

For simplicity, and because the coefficients on NZU price are similar, we have used model 1 which relates the change in afforestation rate simply to the NZU price. This is an equation of the form:

$$\text{Planted area} = \alpha + \beta \cdot P_{NZU}$$

Where: α = a coefficient for afforestation (in '000 ha) at a zero P_{NZU} ($\alpha = 1.328$)
β = a coefficient used as a multiplier on the NZU price ($\beta = 0.725$)
P_{NZU} = the NZU price ($/t CO_2-e)

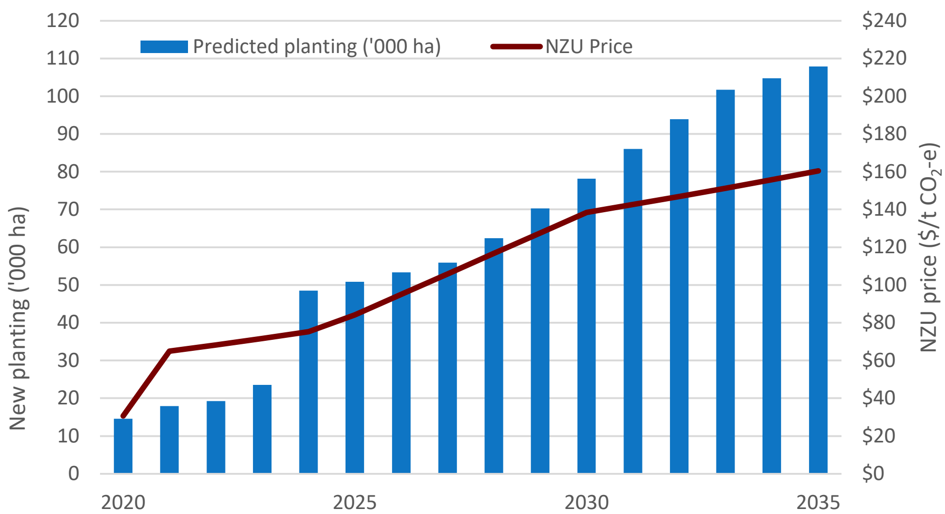
Figure 6 Predicted vs actual new planting



This is used to estimate exotic afforestation rates (Figure 7), assuming a three-year lag in the price response. In analysis it is assumed that it is all from conversion of sheep & beef farms. Using this equation, an emissions price of \$100/t CO_2-e would result in an additional 74,000 ha of new afforestation per year.

In addition to the NZU price directly, the impact of emissions price on farming is used to estimate the equivalent impact on the value of forestry. For example, the average sheep and beef farm emissions per ha (2059 kg CH_4 and 293 kg N_2O per ha, both in CO_2-e) would mean a cost of \$23/ha from a \$10/t CO_2-e charge. With a weighted average sequestration rate on sheep & beef farms (based on the distribution of existing exotic forest) of 21.2 t CO_2/ha, the emissions price would improve the relative value of forestry replacing farming equivalent to an increase in the NZU price of \$1.10/t CO_2-e.[42] This is added to the NZU price in estimating the afforestation rate.

Figure 7 Projected new exotic afforestation



[42] (2.059 + 2.93) x \$10 = \$23.34/ha. \$23.34/21.2 = \$1.10/t increase

All these numbers are highly uncertain as current and projected future NZU prices are higher than we have a historical record for. In addition, there is some uncertainty in the underlying data, given the recent BakerAg (Orme and Orme 2021) results.

Time Delays

The impacts of land use change and afforestation are modelled as happening instantaneously. In practice there may be some delay before the benefits of forestry (sequestration revenues) eventuate, because of the time taken for land preparation and planting. In contrast the removal of livestock, with associated emission benefits may be earlier. To complicate further, some farmers will sell land for forestry, such that the sequestration benefits to the farmer (reflected in the land price) are effectively instantaneous. The modelling assumptions are thus a simplification of a complex set of real-world responses.

1.3.5 Additional Sequestration: Natives and Riparian Planting

Under the *He Waka Eke Noa* pricing options it is proposed that additional sequestration options are available, beyond those currently included in the ETS. This includes:

- Existing pre-2008 native forest that is managed to obtain additional sequestration, including via new fencing of some areas to exclude stock;
- Existing, post-2007 native forest that is counted in the same way as post-1989 forestry is in the ETS (the 2007/08 date is used because of data availability); and
- Planting of riparian areas, eg areas from which stock is required to be excluded under existing freshwater regulations. For these areas it is assumed fencing is not required but that the areas need to be planted.

The maximum quantity assumptions are shown in Table 6 for existing forest areas that are assumed to qualify, along with estimates of the maximum total additional annual sequestration from these areas. Additional new planting of natives will also be eligible, but it is not intended that the *He Waka Eke Noa* pricing system rewards exotic planting. Actual quantities will be determined by the value of this sequestration (affected by assumed price to be paid for sequestration) and the costs to make it available, which include fencing and pest control. In addition, new areas of native forest might be planted that are not included in Table 6, but the costs of planting are estimated to be sufficiently high that this potential is ignored in the modelled response to prices.

Table 6 Maximum estimated sequestration for HWEN pricing

	Pre-2008 native	Post-2007 native	Riparian	Perennial cropland	Total
Area on dairy land (ha)	84,558	2,866	28,700		116,124
Area on sheep & beef farms (ha)	270,780	90,260	8,717		369,757
Additional from S&B Survey (ha)	153,522				153,522
Other (ha)				4,000	4,000
Total (ha)	508,860	93,126	37,417	4,000	643,403
Sequestration rate (t CO_2/ha)	1.83	6.5	3.4	1.3	
Maximum sequestration (t CO_2)	931,213	605,317	130,960	5,200	1,672,691

Source: Pamu, QEII, Nga Whenua Rahui, Fonterra and some Regional Councils (Erica van Reenen, pers comm); Beef + Lamb New Zealand

2 Previous Studies – Implications for Modelling

2.1 Scope of Analyses

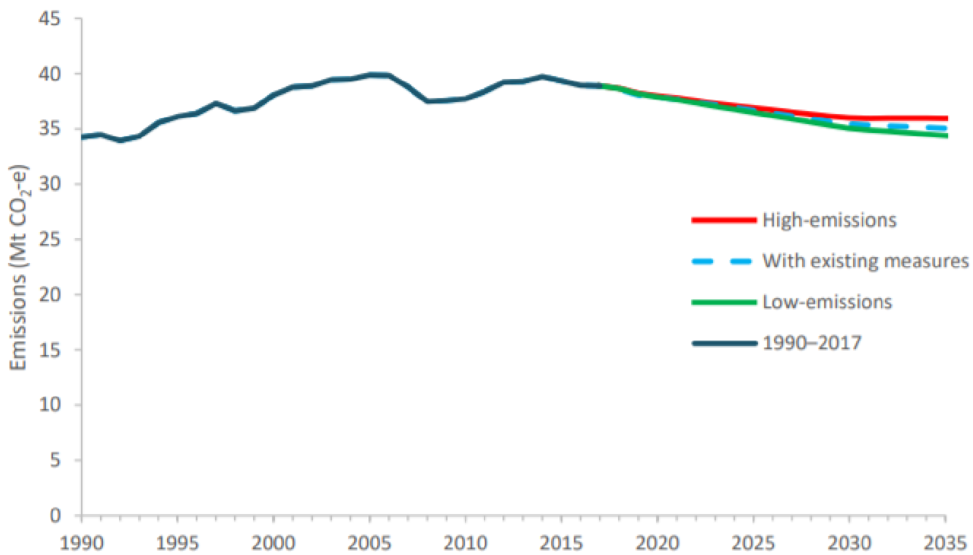
Several previous studies have analysed the expected impacts of pricing agricultural emissions. These studies have been used to assess:

- The response to price, including emission reductions at different pricing levels and using different pricing models;
- Mitigation technologies available, their effectiveness and availability;
- The potential for efficiency gains; and
- The role of land use change in emission reductions.

2.2 Existing Measures

Projection of future agricultural emissions are included in NZ's Biennial Report under the United Nations Framework Convention on Climate Change (UNFCCC). The projections in the 2019 report are shown in Figure 8. With existing measures, ie the ETS applying to forestry but not to agriculture, total emissions are projected to be 9% lower than 2017 in 2030 and 10% lower in 2035.

Figure 8 Projections of NZ agricultural emissions 'with existing measures', high- and low-emissions scenarios



Source: Ministry for the Environment (2019)

The drop in emissions is projected based on the following assumptions:

- a continued decline in the amount of land used for agriculture, including a decrease in the dairy cow population and a continued decline in the sheep and beef populations;
- an increased focus on afforestation, and reduced incentive to deforest, in response to government schemes and policies (such as the One Billion Trees Programme and changes to the ETS);

- changes in farm management practices due to improving environmental outcomes and the implementation of the National Policy Statement for Freshwater Management (NPS-FM); and

- continued reductions in emissions intensity (emissions per unit of product) from ongoing improvements in animal productivity and on-farm efficiency.

The changes forecast for the individual agricultural sectors are shown in Table 7. The largest emission reductions (72% of the total reductions) are forecast for sheep & beef. A 16% and 19% reduction in beef cattle and sheep numbers respectively, results in slightly lower projected 15% and 16% reductions in emissions; the emissions reductions are lower because of the offsetting increases in production per animal. These issues are discussed in more detail in Section 2.6.

Table 7 Projected change in emissions, production and animal numbers 'with existing measures'

	Projected change in emissions by activity (kt CO2-e)		
	Dairy	**Beef**	**Sheep**
2017	18,199	6,563	10,288
2035	17,215	5,588	8,673
Change 2017–35 (%)	−5.4	−14.8	−15.7
	Projected change in total production		
	Total dairy milk production (million litres)	**Total beef meat production (million kg)[1]**	**Total sheep meat production (million kg)[2]**
2017	20,700	417	475
2035	20,420	379	406
Change 2017–35 (%)	−1.4	−9.2	−14.4
	Projected change in animal numbers (thousands)		
	Dairy cattle	**Beef cattle**	**Sheep**
2017	6,530	3,616	27,527
2035	5,887	3,054	22,356
Change 2017–35 (%)	−9.8	−15.5	−18.8

Note: [1] includes meat from adult beef cattle, heifers, steers and bulls; [2] includes mutton and lamb
Source: Ministry for the Environment (2019)

The Biennial report included an analysis using different NZU price assumptions and suggested that agricultural emissions are relatively unresponsive to changes in prices when they apply to sequestration only.[43] The highest price ($62.50/t CO_2-e), resulted in a 10.5% reduction by 2035, only slightly higher than the 9.6% reduction at a price of $25/t CO_2-e.

2.2.1 Climate Change Commission

The CCC has also provided projections of future agricultural emissions under a reference scenario with existing policy (Table 8) based on estimates made by MPI. The existing policy measures included are the Essential Freshwater (EFW) package including the NPS-FM and the national environmental standards for freshwater (NES-FW), the ETS applying to forestry and the inclusion of agricultural emissions in the ETS at the processor level. Methane emissions are projected to be 7% below 2017 levels by 2030 and 13% lower by 2050.

[43] Ministry for the Environment (2019)

Table 8 Climate Change Commission projected agricultural GHG emissions (kt CO_2-e)

	CH_4	N_2O & CO_2	GHG
2017	29,363	8,142	37,505
2030	27,185	7,762	34,947
2035	26,844	7,685	34,529
2040	26,448	7,601	34,049
2050	25,562	7,410	32,972
% below 2017 by 2030	7.4%	4.7%	6.8%
% below 2017 by 2050	12.9%	9.0%	12.1%

Source: Climate Change Commission (2021)

The impacts of the NPS-FM were based on analyses for MfE;[44] these were undertaken prior to the finalisation of the policy and the effects based on the final specification are included in this analysis for *He Waka Eke Noa*.

The assumptions underlying the CCC's baseline projections are shown in Table 9. These include a constant real \$35/t CO_2-e NZU price, reductions in land area and animal numbers for dairy cattle, sheep and beef cattle, increases in forestry and horticulture land area and reductions in emissions intensity of output.

Table 9 Assumptions underlying CCC Baseline Projections

Factor	Unit	2017	2025	2030	2035	% change 2017 to 2030
NZU Price (real 2021 values)	\$/t CO_2-e	\$12	\$35	\$35	\$35	193%
Land area in dairy	M ha	1.76	1.72	1.71	1.70	-2.6%
Land area in sheep & beef	M ha	8.33	7.47	7.41	7.28	-11.0%
Land area in exotic forestry	M ha	1.76	1.93	2.05	2.20	16.5%
Land area in horticulture	M ha	0.10	0.12	0.12	0.12	14.3%
Milk solids	M t	1.85	1.81	1.81	1.83	-2.3%
Meat	M t	1.06	1.11	1.15	1.18	8.6%
Dairy milking cows	Number	4,993	4,617	4,454	4,379	-10.8%
Sheep and beef stock units	Number	47,267	44,567	43,936	43,081	-7.0%
Dairy emissions intensity	kg CO_2-e/kg MS	10.7	10.3	10.1	9.9	-6.2%
Sheep & beef emissions intensity	kg CO_2-e/kg meat	15.4	14.1	13.5	12.9	-12.8%

Source: Climate Change Commission (2021)

The modelling work in this analysis uses different baseline assumptions, which we discuss in Section 4.1.

2.3 Potential Impacts of Land Use Change

Dorner *et al* (2018) explore the potential contribution of land use change to GHG emission reductions.[45] The analysis was of reductions relative to a reference case which assumed the ETS operating with a price of \$25/t CO_2-e from 2018 increasing at real interest rate annually thereafter (approx. 1.8% pa). The main scenarios examined are described in Table 10. They differ in terms of the level of emission reduction ambition and underlying assumptions relating to horticulture

[44] Denne (2020)

[45] This was prior to separate targets being set for methane

expansion. The scenarios included LA and HA (with horticulture modelled endogenously) and with combinations (eg LALH, LAHH etc).

Table 10 Scenarios used to model land use change effects

Scenario	GHG reduction by 2030[a]	GHG reduction by 2050 [a]	Horticulture expansion by 2030	Horticulture expansion by 2050
Reference	Existing ETS[b]	Existing ETS[b]		
Low ambition (LA)	15%	25%	0%	0%
High ambition (HA)	30%	50%	0%	0%
Low Horticulture (LH)			20%	40%
High Horticulture (HH)			100%	200%
Mitigation technology breakthrough (Mit)	Dairy 30% Sheep & beef 20%			

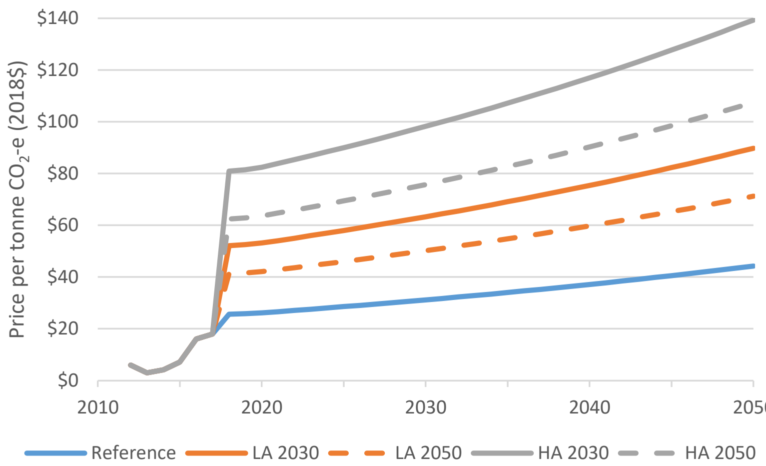
[a] Percentage emission reductions are relative to the reference case [b] Prices under the ETS were assumed to be $25/t from 2018 (in 2018$), increasing by 1.8% per annum in real terms
Source: Dorner *et al* (2018)

The modelling of the scenarios seeks to achieve one of the targets in the most efficient way. This requires an emissions price to be introduced immediately (in 2018) and to then rise steadily from that point. Because the annual rate of reduction required is higher for the 2030 target than the 2050 target, the emissions price required is higher also (Figure 9). The emissions pricing assumes that these prices apply to sequestration but that the price applied to biological emissions from agriculture is only 5% of the ETS price, starting in 2020, rising 3 percentage points annually until 2030, and 5 percentage points annually thereafter.

- The HA scenario requires an emissions price of $80/tCO_2$-e immediately, rising to $98/t by 2030 to meet the 2030 target, but only $60/t (rising to $76/t in 2030) to meet the 2050 target.

- Under the LA scenario, prices rise immediately to approximately $52/t CO_2-e for the 2030 target and to $63/t in 2030.

Figure 9 Prices used to achieve LA and HA emission targets in 2030 and 2050



Source: Dorner *et al* (2018) and Zack Dorner, *pers. comm.*

The prices required under the individual targets to meet the 2030 target are shown in Table 11, including their assumed rise beyond 2030.

Table 11 Prices required ($/t CO_2-e) to meet 2030 target under the different scenarios

	Emissions prices for sequestration				Agricultural emission prices			
	2018	2025	2030	2050	2018	2025	2030	2050
Reference	$26	$29	$31	$44	$0	$0	$0	$0
LA	$53	$58	$63	$90	$3	$12	$22	$90
HA	$82	$90	$98	$139	$4	$18	$34	$139
LALH	$51	$55	$60	$85	$3	$11	$21	$85
HALH	$80	$87	$95	$135	$4	$17	$33	$135
HAHH	$69	$75	$82	$116	$3	$15	$29	$116
HAMit	$82	$90	$98	$139	$4	$18	$34	$139

Source: Estimated from Dorner *et al* (2018) and Zack Dorner, *pers. comm.*

The results using these different prices are shown in Table 12 as changes in land area in 2030. Significant increases in forestry are required to meet emission targets in all scenarios.

Table 12 Results for 2030 - percentage change in land area

Scenario	Dairy	Sheep	Forestry	Scrub	Horticulture
Reference (relative to 2012)	10%	-9%	29%	-2%	0%
Relative to reference					
LA	0.4%	-0.7%	5.1%	-5.9%	0.0%
HA	0.9%	-1.5%	11.3%	-11.8%	0.0%
HAMit	0.4%	-1.1%	7.8%	-8.2%	0.0%
LALH	-1.7%	-1.1%	4.3%	-4.7%	19.1%
HALH	-1.3%	-1.9%	10.5%	-11.2%	19.1%
HAHH	-12.2%	-3.1%	7.8%	-8.2%	95.7%

Source: Dorner *et al* (2018)

The Dorner *et* al analysis suggests the low ambition 2030 target (15% reduction from the reference case), requires a price of just over $60/t CO_2-e (similar to the current ETS market price) for sequestration and $3/t CO_2-e rising to $22/t by 2030 for agricultural emissions.

Motu used the Land Use in Rural New Zealand (LURNZ) model to assess the impacts of emissions pricing on land use change and the wider social impacts of those changes.[46] The emissions pricing used is not very transparent in the report but is assumed to be that used in the Productivity Commission report cited,[47] ie rising from 2018 levels to between $30 and $80/t CO_2-e in 2030 and to between $75 and $150/t CO_2-e by 2050.

They analysed the impacts using two scenarios: with pricing on sequestration only and with extension to agricultural emissions. The price on forestry had the most significant effect, with only a small additional effect of emissions pricing. In comparison with other studies, eg Djanibekov *et al* (2019) discussed below, their analysis suggests a much more significant reduction in dairy land use (largely to horticulture) in addition to the shift from sheep & beef to forestry.

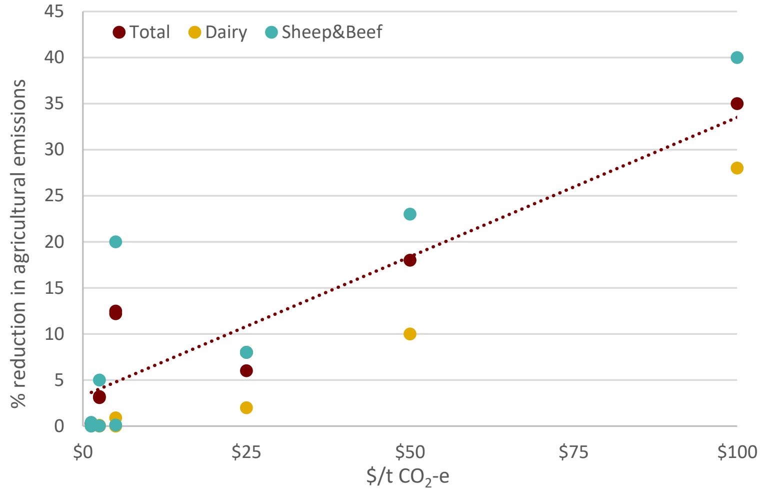
[46] Motu (2019)
[47] New Zealand Productivity Commission (2018); Concept Consulting *et al* (2018)

2.4 Response to Pricing Agricultural Emissions

Several published studies have identified the expected response of agricultural emissions to pricing being extended to biological emissions.

Djanibekov *et al* (2019) analyse prices of \$25, \$50 and \$100/t CO_2-e and different specifications of a pricing regime: processor level ETS, farm level ETS, a decoupled rebate (as with the output and land-based options described above, it provides a rebate that is decoupled from the emissions) and with technological innovation. The analysis uses a 2020 baseline for farm data and measures the effects as a new equilibrium position with the same activity levels but different prices. The results are shown in Figure 10, including a trend line for total agricultural GHGs. Emissions reduce by 18% compared with a 2020 baseline with a marginal price of \$50/t CO_2-e.

Figure 10 Impacts of emissions price on agricultural emissions (% reduction from 2020)



Source: Estimated from data in Djanibekov *et al* (2019)

As suggested by the theoretical position (see Section 1.2), the decoupled rebate approach provides incentives for significant reductions in gross emissions and protects farm net revenues. However, in their analysis this was not paid directly back to individual farmers. There is a payment back to the agricultural sector as a whole and the modelling does not specify how this payment is returned to individual farmers.

As with other modelling exercises, much of the emission reduction response is associated with stock reduction as land shifts from farming to forestry.

2.5 Mitigation Technologies

Mitigation technologies have been assessed in several studies led by the NZ Agricultural Greenhouse Gas Research Centre (NZAGRC) and more recently in the work by the Biological Emissions Reductions Science Accelerator (BERSA).[48] Reisinger and Clark (2016) estimate the potential emission reductions from mitigation options rather than predicting responses to price. They include estimates of potential emission reductions from the following options:

- Reduction in nitrogen inputs.
- Introduction of additional technologies: Vaccine (+ inhibitor), Selective breeding and the nitrification inhibitor dicyandiamide (DCD) (dairy only).
- Partial animal housing and enhanced waste management systems.
- Accelerating animal/farm system performance.

[48] Leahy *et al* (2021)

Table 13 summarises their estimates of potential changes under different scenarios and assumptions; they include results expressed as changes in absolute emissions and in emission intensities. Relative to a 2008-12 baseline, without mitigation, emissions are forecast to increase by 11-17% by 2030. With a high level of adoption of new technologies, emissions could be 18-19% lower in 2030 than without, and 6-7% lower with a low adoption of new technologies.

Table 13 Total mitigation outcomes (emission reductions and intensity improvements) under different assumptions and scenarios

	Absolute emissions		Emissions intensity	
	2030 vs 2008-2012	**2030 vs 2030 baseline**	**2030 vs 2008-2012**	**2030 vs 2030 baseline**
Baseline	+10.9% to +16.7%	NA	-5.1% to -9.4%	NA
High adoption of new technologies	-4.9% to -8.5%	-17.7% to -18.7%	22.2% to 28.4%	18.3% to 21.2%
Low adoption of new technologies	4.2% to 9%	-6.3% to -6.8%	11.8% to 18.4%	7.3% to 10.2%

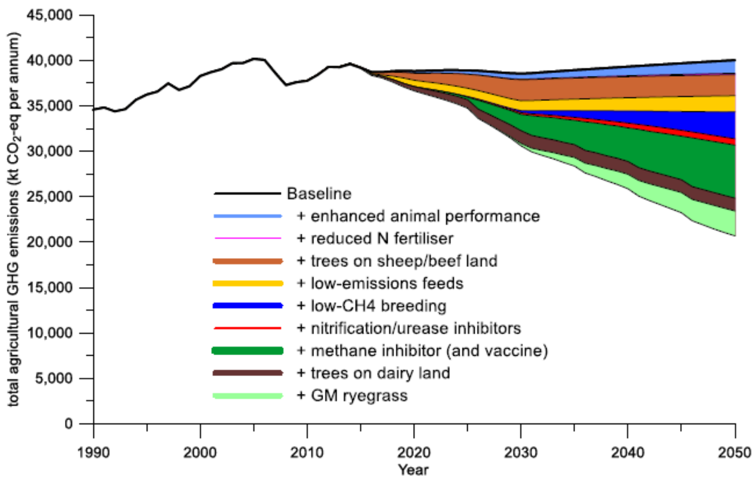
Source: Table 12 in Reisinger and Clark (2016)

The analysis suggests there is significant potential for emission reductions in agriculture via technologies and intensity improvements.

Reisinger *et al* (2017) provide an overview of currently available options to mitigate biological GHG emissions and the impacts of different assumptions for afforestation. They note that there are various options that would reduce biological GHG emissions moderately in both the dairy and sheep & beef sectors without reducing farm profitability, even though some options reduce total production. Other interventions, especially those resulting in deep emission reductions, would have significant negative impacts on both production and profitability.

Reisinger *et al* (2018) evaluate mitigation options that may be available in the future (by 2030 and 2050) to reduce biological GHG emissions on-farm. This includes their confidence that the various options would be technically available, the drivers and barriers to uptake of each option and a quantification of how much each option might reduce GHG emissions below baseline projections, considering both efficacy and potential adoption rates. The possible effects on emissions from a comprehensive package of mitigation measures are illustrated in Figure 11.

Figure 11 Effects of comprehensive package of measures



Source: Reisinger *et al* (2018)

We use estimates of the costs, expected effectiveness, availability and adoption rates that builds on these analyses and provided by one of the authors (see Section 3.6.3).

High Technology Assumptions

In sensitivity analysis we have provided an alternative set of high technology assumptions which uses a combination of faster implementation rates and lower costs. The assumptions are noted for the individual models in Section 3.5.3 and 3.6.3.

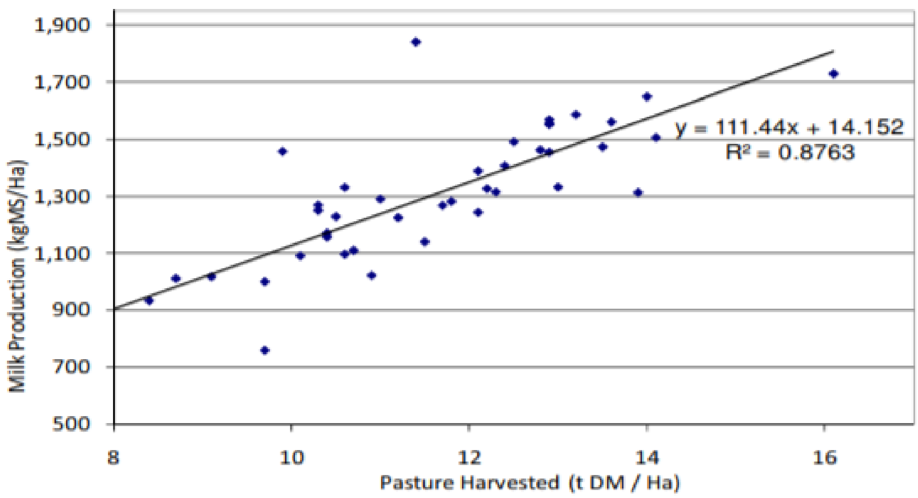
2.6 Effects of Productivity Improvements

One of the issues for modelling is the extent to which there are incentives for farms shifting towards less intensive forms, including lower stocking rates or lower emissions intensity of output. In this section we briefly review published analyses and historical data to understand the trends; we then examine any estimates of financial incentives that might influence the outcomes.

2.6.1 Historical Data

In general, if productivity (output production) per animal increases, so do the emissions per animal because increased productivity requires higher feed intakes (Figure 12) and emissions are a function of dry matter consumption.[49] Thus, agricultural emission projections show a smaller reduction in emissions than the projected reduction in animal numbers because increases in productivity per animal are offsetting some of the emission loss from reduced stock numbers.[50]

Figure 12 Relationship between feed intake (pasture harvested) and milk production



Source: Newman and Savage (2009)

Reisinger *et al* (2018) include increasing animal productivity (output of milk or meat per animal) as a mitigation technique, while noting that, for it to be successful in reducing emissions, per animal productivity must be accompanied by reductions in stock numbers. Journeaux and Kingi (2020) express this differently, suggesting farmers that reduce stocking rates to reduce emissions, need to improve per animal productivity to maintain financial viability. For modelling the impacts, Reisinger *et al* (2018) assume reductions in animal numbers such that total production (of milk or meat) remains at the same levels, although they do not describe any policies that might produce this outcome.

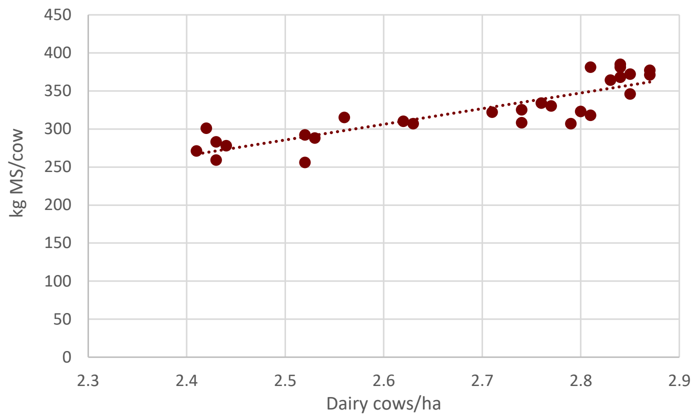
[49] Pickering *et al* (2021)

[50] Ministry for the Environment (2019)

In contrast to this outcome, the historical data suggest there is a positive correlation between productivity (kg of output per animal) and stocking rate, ie increased per animal productivity is associated with increased stocking rates because farms have not reduced their production of food (grass). Figure 13 shows the national average dairy data for which increases in intensity of production (kg milk solids per cow) are correlated with increasing stocking rates. This suggests an historical trend of increasing stocking rates and increasing production per cow, and because production per hectare is a multiplier of these two factors, production per hectare increases at an even greater rate (Figure 14).

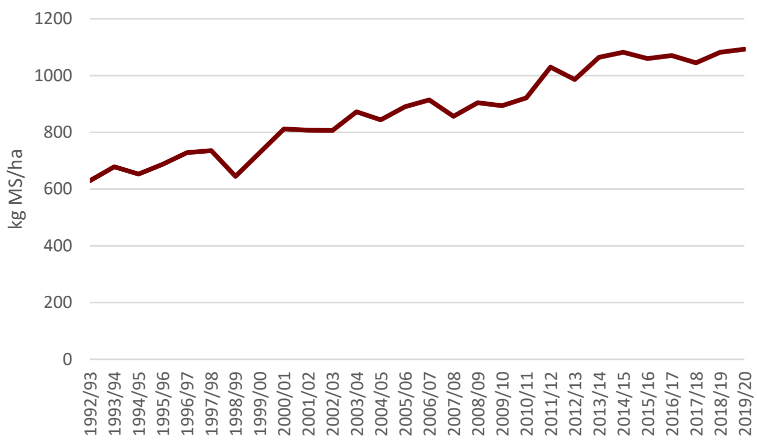
The historical data show there is a trend towards reduced emissions intensity measured as emissions per unit of product. According to Agmatters,[51] emissions intensity of production has been reducing at close to 1% per annum over the last two decades. It notes that contributory factors include improvements in plant and animal genetics, grassland management and animal health, and better optimised fertiliser applications.

Figure 13 Dairy cow production and stocking rates (1992/93 to 2019/20)



Source: Livestock Improvement Corporation Limited & DairyNZ Limited (2020)

Figure 14 Milk solids production (kg MS/ha) per year



Source: Livestock Improvement Corporation Limited & DairyNZ Limited (2020)

Reisinger and Clark (2016) note that the emissions intensity of animal products has declined historically from factors that include increased lambing percentages, weight gain of lambs until slaughter, milk yield per cow, and weight gain of finishing beef cattle. Between 1990 and 2012

[51] Ag Matters is funded by the Ministry for Primary Industries' Sustainable Land Management and Climate Change programme (SLMACC) and managed by the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC).

intensity decreased by 0.8%, 1.1% and 1.0% per annum for dairy, beef and sheep respectively based on emissions per litres of fat and protein corrected milk, beef (growing animals plus cull beef and dairy cows) and total sheep meat slaughtered (lambs plus cull ewes). They assume intensity continues to fall but at a declining rate (Table 14).

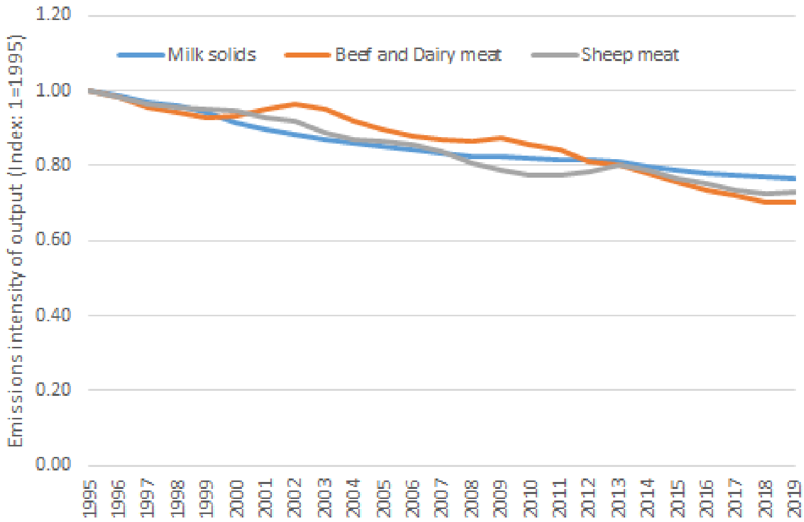
Table 14 Historical and projected emissions intensity trends (for the maximum and minimum efficiency scenarios)

Sector	Dairy	Beef	Sheep	total
1990-2012	-0.80%	-1.10%	-1.30%	-1.00%
2015-2030	-0.3 to-0.60%	-0.5 to -0.70%	-0.2 to -0.50%	-0.3 to -0.60%
2030-2050	-0.3 to -0.50%	-0.5 to -0.70%	-0.2 to -0.40%	-0.3 to -0.50%

Source: Reisinger and Clark (2016)

Figure 15 shows emissions intensity changes over time for dairy, beef and sheep meat in New Zealand using MPI data. The values are expressed as an index relative to 1995 using five year moving averages of kg CO_2-e/kg of product (milk solids or meat). Between 1990 and 2019, emissions intensity has been falling at average rates equivalent to 1.2% per annum (for milk and cattle meat) and 1.3% per annum (sheep meat).[52]

Figure 15 Emissions intensity of agricultural output (1995 - 2019) as five-year moving average



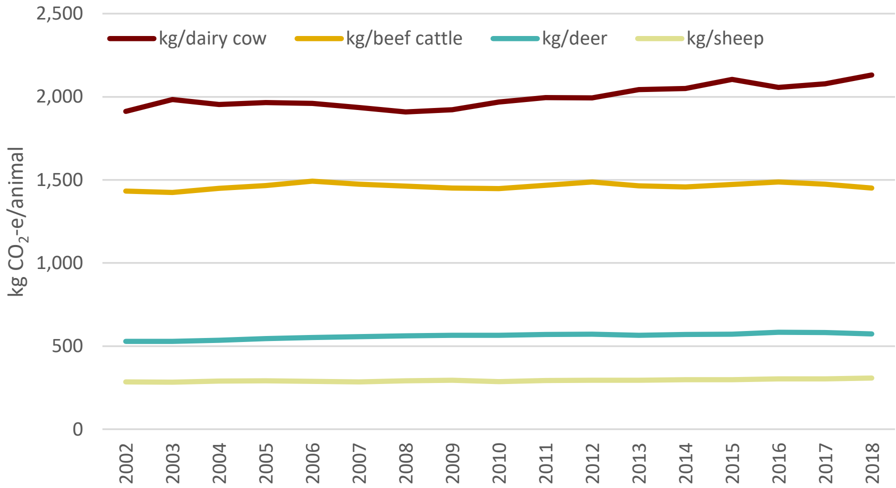
Source: Data from MPI

So, there are two factors at play. Production intensity (kg of product per animal) rises over time, but emissions intensity of production (kg CH_4/kg of product) falls. Combining the two produces a small but increasing emissions intensity per animal over time (Figure 16), which is greatest for dairy cows (11.4 kg CO_2-e/animal/yr) and smallest for sheep (1.3 kg/animal/ yr).[53]

[52] This uses a constant annual growth rate (CAGR) formula

[53] Corresponding rates of increase for beef cattle and deer are 1.6 kg and 3.1 kg CO2-e/animal/yr respectively.

Figure 16 Emissions per animal



Source: emissions data from MfE National Greenhouse Gas Inventory; animal numbers from Statistics NZ (https://www.stats.govt.nz/indicators/livestock-numbers)

2.6.2 Financial Incentives

Dairy-NZ provides the results from several case study farms which demonstrate how reductions in inputs or lower stocking rates can result in lower emissions and higher profits.[54] However, these are usually comparisons between lower input outcomes and the status quo rather than against a profit maximising outcome. For Owl Farm in the Waikato, analysis suggested that deintensification could reduce emissions (-13%) and increase profits (+21%) but an alternative intensification strategy was even more profitable (+41%) while leading to increased emissions (+2%). The market response is thus not obvious.

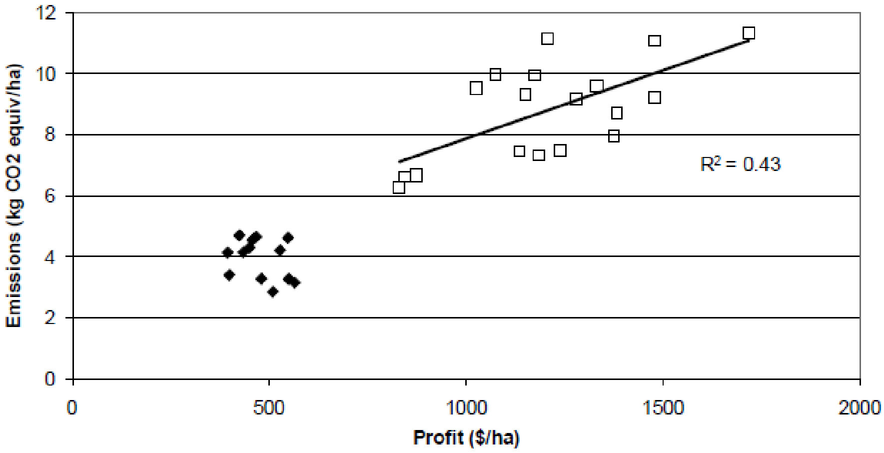
Smeaton *et al* (2011) analysed model farms using farm systems models (FARMAX and FARMAX Pro), along with GHG emissions estimated using *Overseer*, to estimate the relationships between productivity, profitability, nitrogen leaching and GHG emissions. They found a positive but limited relationship between profitability and emissions for dairy (greater profit per hectare is associated with greater emissions, although this relationship could only explain some of the differences). In contrast there was no observable relationship between profit and emissions per hectare for sheep and beef farms (Figure 17). An analysis of the relationship between emissions intensity of products and profit per hectare did not find any significant relationship.

The review above suggests the following.

- There is a trend over time towards more output per animal.
- There is also a trend towards lower emissions intensity of output.
- However, the greater output per animal tends to produce more emissions per animal.
- Some farm case studies have shown the potential for increased profit from de-intensification but it is not clear that this strategy is the most profitable.

[54] https://www.dairynz.co.nz/environment/dairy-sector-progress/greenhouse-gas-partnership-farms-project/

Figure 17 Relationship between per hectare profit and GHG emissions



◆ = sheep; ☐ = dairy farms
Source: Smeaton *et al* (2011)

This does not provide clear guidance for modelling purposes. Because of the uncertainty over the direction and size of market response, we have not included any efficiency response as an option in the sheep & beef model. We have tested the potential (see Section 3.6.5) and we note that there may be additional emission reductions to those included in the model resulting from on-farm efficiencies, without knowing how these might change in response to emission price increases. The dairy model does include some efficiency improvements (see Section 3.5.4).

2.7 Combined Water and Emissions Policy

Policy to reduce nitrogen leaching from farms is expected to also reduce greenhouse gas emissions, particularly of N_2O.[55] Daigneault *et al* (2017a) estimate that without land use change, agricultural GHGs could be reduced by 2.4% from planting riparian buffers
and pole planting for erosion control. In a separate study, Daigneault *et al* (2017b) estimate the impacts of independent and combined policies to address GHG emissions and water quality from nutrient leaching. They use GHG prices of \$0-\$30/t CO_2-e and simulate water quality policy via the NPS-FM 2014 as a price on N leaching (measured via *Overseer*) of \$0-\$30/kg N.[56] All input assumptions are for 2012; the timeframe for the analysis is not stated but the results appear to be the equilibrium position that would result following introduction of the price-based policies.

The results of their analysis of price scenarios on emissions and land area in individual land uses is shown in Table 15. This suggests a \$30/t CO_2-e price on emissions with no new water quality policy (and thus \$0/kg N) would result in a 6% reduction in agricultural GHG emissions and a 23% increase in sequestration.[57] It would be associated with a 4% and 7% reduction in dairy and sheep & beef land respectively, and a 31% increase in the forested area. Water quality policy has a significant effect on GHG emissions; a \$30/kg N price which would reduce N leaching by 30% if introduced alone, would reduce agricultural GHG emissions by 19%

[55] Lou (2017)
[56] They note this is based on economic analyses that have estimated the marginal cost of N leaching abatement ranges from \$5 to \$30/kg
[57] The analysis appears to assume a sequestration rate of 8.9t CO2-e/ha. This is based on the \$30/\$30 scenario in which a 40% increase in sequestration from 24.3Mt (0.4 x 24.3 = 9.72Mt) is from a 53% increase in forested area (0.53 x 2,055 = 1,089)

Table 15 Percentage change in net revenue, emissions and area under different price scenarios

$/t CO_2-e	$/kg N	Net revenue ($m)	GHG (Mt)	Carbon sequest (Mt)	Net GHG (Mt)	N Leach ('000t)	Dairy ('000 ha)	Sheep & beef ('000 ha)	Arable ('000 ha)	Hort.('000h a)	Fores-try ('000 ha)
2012 Baseline:		$11.3	34.6	−24.3	10.3	216	1,705	8,701	204	150	2,055
$10	$0	-1%	-2%	8%	-26%	-1%	-1%	-3%	1%	1%	11%
$20	$0	-1%	-4%	15%	-50%	-2%	-2%	-5%	3%	2%	21%
$30	$0	-2%	-6%	23%	-75%	-3%	-4%	-7%	5%	4%	31%
$10	$10	-1%	-4%	15%	-50%	-4%	-4%	-7%	3%	4%	21%
$20	$20	-6%	-18%	31%	-134%	-20%	-12%	-37%	2%	1%	42%
$30	$30	-13%	-36%	40%	-215%	-37%	-22%	-63%	-14%	-7%	53%
$0	$10	0%	-1%	7%	-16%	-3%	-5%	0%	1%	3%	11%
$0	$20	-5%	-7%	12%	-50%	-17%	-11%	-25%	0%	1%	16%
$0	$30	-11%	-19%	15%	-102%	-30%	-16%	-47%	-7%	0%	19%

Source: Daigneault *et al* (2017b)

They use the analysis to suggest there is a real benefit to considering a combined water quality and climate policy rather than assessing these policies in isolation. In this report we assess the impact of current freshwater policy in our baseline analysis.

3 Models and Assumptions

3.1 Introduction

In this section we describe the three separate models used to estimate effects. These are models for (1) dairy, (2) sheep & beef and (3) horticulture and arable. Below we outline the individual models and the key assumptions. First, we set out the way in which the pricing options have been characterised for modelling.

3.2 Charge Options

Table 16 summarises the equations used to model the individual charging options.

Table 16 Equations used to represent pricing methods in modelling

Method	Equations
Processor ETS	Surrender obligation = O_p x EF_0 Allocation = O_p x $EF_{0\text{-}G}$ x AR Where: O_p = output from processor (kg of milk, meat or fertiliser) $EF_{0\text{-}G}$ = emission factor per unit of output (all gases based on GWP_{100}) AR = allocation rate (95% in 2025, falling 1 percentage point per year)
Farm-Level Levy (FLL)	Charge paid = A + B − C Where: A = emissions of methane (kg CH_4) x charge rate (\$/kg CH_4) B = emissions of long-lived gases (kg CO_2-e) x charge rate (\$/kg CO_2-e) C = eligible sequestration (kg CO_2) x payment rate (\$/kg CO_2-e)
FLL + Output-based Rebate	Charge paid = A + B − C Rebate = O_f x $EF_{o\text{-}s}$ x RR x P_e Where: O_f = output from farm $EF_{o\text{-}s}$ = emission factor per unit of output (for CH_4, N_2O and CO_2) RR = rebate rate P_e = emissions price (separate for CH_4 and long-lived gases)
FLL + Land-based Rebate	Charge paid = A + B − C Rebate = L x EF_{cc} x RR x P_e Where: L = land area in ha EF_{cc} = emission factor specific to a given carrying capacity and gas (CH_4 and long-lived gases) (kg/ha)
Processor hybrid	Charge paid = O_p x ($EF_{o\text{-}s}$ x P_e) x (1 − DR) Emission reduction payment = ER x (P_e x (1 − DR)) x M_E + S x P_s Where: ER = measured emission reductions (separately for CH_4 and LLG) DR = discount rate (95% in 2025 falling by 1 percentage point per year) M_E = multiplier applied to the discounted price for emissions S = measured sequestration P_s = price paid for sequestration (P_s may be different from any P_e)
FLL + technology support	Charge paid = A + B − C Emission reduction payment = ER x (P_e x (1 − DR)) x M_E

3.3 Administration Costs

Administration costs differ between the options and with respect to how they are paid. The assumptions used are shown in Table 17 (these are equivalent to the administrator costs in *He Waka Eke Noa*, 2022b). In addition, some option-specific revenue requirements will be paid for by direct charges to farmers under the processor hybrid option. Given the uncertainty, over the levels of costs and how they will be allocated we have estimated the revenue raised by the different pricing options, noting administration costs may need to be paid out of this revenue.

Table 17 Administration costs and assumed sources of revenue ($ million per annum)

Option	Scenario	Government funding	Levy Revenue	Total
Processor ETS		$5.0	$0.0	$5.0
Farm Level Levy	High	$14.0	$31.0	$45.0
	Low	$13.0	$28.0	$41.0
Processor Hybrid	High	$7.5	$35.5	$43.0
	Low	$7.5	$19.0	$26.5
FLL + technology support	High	$15.5	$31.0	$46.5
	Low	$14.5	$28.0	$42.5

Source: He Waka Eke Noa (2022b); Andrew Curtis, Primary Insight, pers comm

3.4 *He Waka Eke Noa* Sequestration

The estimated level of available sequestration from existing areas in Table 6 has been split into that available rapidly and that available later (the additional areas identified in the Beef + Lamb New Zealand survey and assumed to be un-fenced pre-2008 natives). It is assumed that:

- 50% of the rapidly available opportunities are taken up in 2025 and 100% by 2030;
- of the 'available later' areas, 50% is assumed to be taken up by 2030 and 100% by 2035.

From these assumptions we show estimates of the potential revenue requirement if this is funded by revenue raised by the *He Waka Eke Noa* pricing options in Table 18. Additional sequestration may result from new native planting but this has not been estimated.

Table 18 Maximum estimated sequestration for HWEN pricing and implications for revenue (2021 prices)

	Pre-2008 native	Post-2007 native	Riparian	Perennial cropland	Total
Maximum sequestration (t CO_2)	931,213	605,317	130,960	5,200	1,837,700
Assumed in 2025 (t CO_2)	325,134	302,659	65,480	2,600	695,873
Value @ $85/t CO_2-e ($m)	$27.6	$25.7	$5.6	$0.2	$59.1
Assumed in 2030 (t CO_2)	790,741	605,317	130,960	5,200	1,532,217
Value @ $138/t CO_2-e ($m)	$109.1	$83.5	$18.1	$0.7	$211.4

The estimates are sensitive to the assumptions on the price paid for sequestration and the assumed uptake rates. In addition, these are further modified by estimates of the costs (for fencing, pest & weed control).

Sequestration in He Waka Eke Noa Pricing Options

Pre-2008 and post-2007 natives are assumed to have costs associated with fencing (which will often be fencing repairs rather than new fencing) plus weed and pest control. Riparian planting will require planting but these areas are assumed to be already fenced under existing stock exclusion regulations.

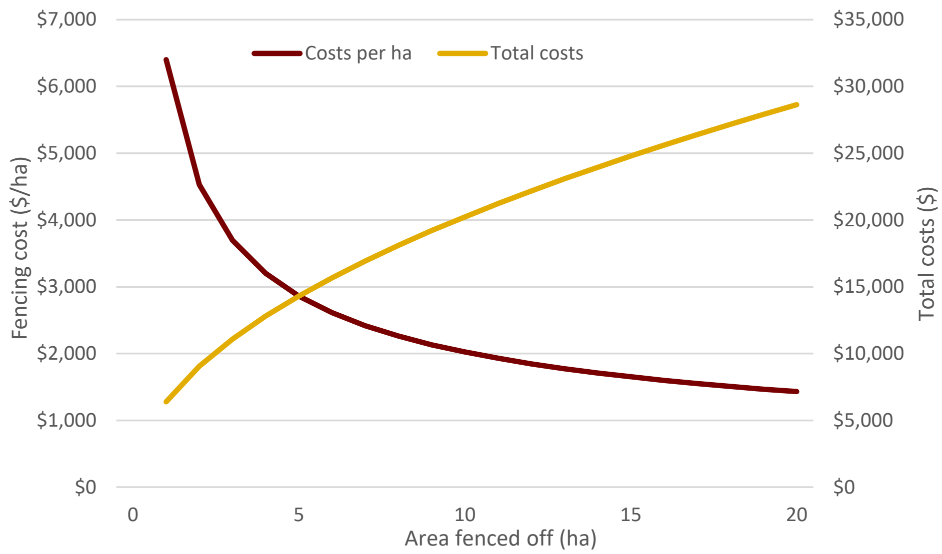
Davis *et al* (2009)[58] estimate fencing costs at $4,000/ha. However, the per hectare costs will decline with the area. For simplicity, we assume a square area, for which the formula is:

$$FC = \frac{(A \times 10000)^{1/2} \times 4}{A} \times P_f$$

Where: FC = fencing cost ($/ha)
A = area in ha
P_f = price of fencing ($/metre)

We use fencing costs of $16/m assumed by PerrinAg,[59] which results in costs as shown in Figure 18. This is a one-off cost and we spread it over 15 years at 5% to produce an annual fencing cost of $1.54/m and costs per ha estimated using the formula above. The area estimates are explained in more detail under the separate dairy and sheep+beef models below.

Figure 18 Relationship between area and fencing cost



Note: assumes $16/m of fencing and a square area

Weed and pest control is estimated to cost $1,125 per hectare for the first three years,[60] but we spread this annually over 15 years at an estimated cost of $295/ha.

Given the size of the combined costs of fencing and weed/pest control, the analysis suggests that, because of the low sequestration rate (1.83 t CO_2/ha), it will not be cost-effective for farmers to register pre-2008 natives in the *He Waka Eke Noa* system, but because of the higher rate (6.5t/ha), it will be for post-2007 natives. In practice, we would expect costs to differ more than those modelled such that a mix of areas will be included.

[58] Cited on p9 in Carver and Kerr (2017)
[59] John Stantiall, PerrinAg, pers comm
[60] Erica van Reenen, AgFirst, pers comm

Riparian planting is assumed to cost $10,000/ha for planting (annual costs of $963) and with annual costs of both weed and pest control of $666/ha.[61] These costs are high compared with estimated rewards for sequestration (3.4t/ha) so very little is assumed to be incentivised by the pricing system.

3.5 Dairy Model

3.5.1 Description

The dairy farm sector model was developed by Graeme Doole for DairyNZ. A more detailed description of the model and assumptions is provided in Annex 2.

- It includes detailed information on 11,590 individual farms, including production, financial and environmental (GHG emissions and nitrogen leaching) data. Key differences with respect to farm debt, GHG emissions, management efficiency, pasture production, production level, supplement intensity, and nitrogen leaching are considered between farms. Each farm is modelled individually to understand how different policy mechanisms will impact different farm types across the sector.

- It is an optimisation model. It seeks to maximise farm-profit, given production rates, costs of inputs and values of outputs. In response to emissions prices and changes in other inputs, it will re-optimise to produce changes in activity levels, emissions, revenues and profits.

- The model simulates each year in the period from 2017 to 2035.

3.5.2 Land Use Change Assumptions

The model is only of the dairy industry, so if the analysis suggests farms become unprofitable the dairy industry shrinks in size with reductions in animal numbers and in milk production. The model does not differentiate between reductions in stocking rates (with fewer cows spread over the same area) and reductions in area farmed (with stocking rates retained). If the latter response occurs, the model effectively assumes the land is idle, rather than assuming a change in land use with any associated emissions (eg in horticulture) or revenue impacts (eg from production of different commodities or sale of land).

In the model, a farm is unprofitable and unviable if it has negative profit and the farm has a debt to asset ratio above 95%. However, the model assumes land continues in dairy if expected revenues exceed operating costs, ie if a farm is unprofitable because debt cannot be paid, it effectively assumes the farm changes ownership.[62]

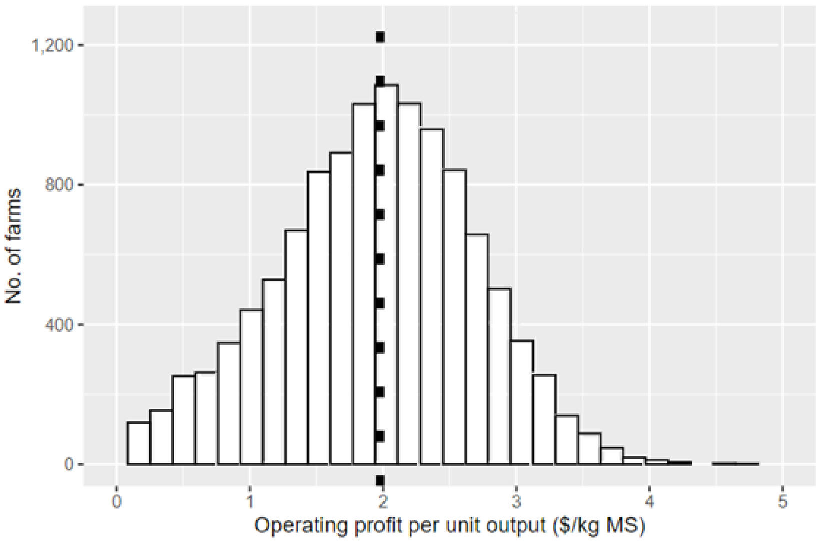
Figure 19 shows the distribution of profit across all dairy farms; those with low profit levels are vulnerable to emissions pricing. The average emissions per kg of milksolids (MS) is currently approximately 10.5 kg CO_2-e/kg MS.[63] An emissions price of $85/t CO_2-e (the predicted NZU price for 2025) would be equivalent to $0.89/kg MS.

[61] Assumptions from Erica van Reenen, pers comm

[62] Effectively this assumes the policy costs are absorbed by a change in land value. In practice, this may involve a change in ownership when debt levels are high. The extent of cost absorption (and change in land price) will be limited by the value of land in the next best use, eg other farm types, although these will also be changing in response to emissions prices.

[63] Climate Change Commission (2021b)

Figure 19 Distribution of profit levels in the dairy sector



Source: Graeme Doole, pers comm

3.5.3 Mitigation Technologies

A single abatement technology is included in the analysis: a methane inhibitor, 3-Nitrooxypropanol (3NOP). 3NOP inhibits the reduction of CO_2 to CH_4 in the terminal step of methanogenesis in the rumen. It is typically given to cows through its addition to feed while in the milking shed. The following assumptions have been developed through expert assumption, following consideration of published and unpublished research pertaining to the use of 3NOP both in NZ and overseas.[64]

- It is assumed that 3NOP is available from 2025.
- Lactation length varies by farm and is affected by mitigation; for example, a reduction in fertiliser use may require a subsequent strategic limiting of days in milk. Thus, 3NOP use is defined across lactation for each farm individually.
- Additional supplement cost is incurred for those farms that feed imported supplement below the level required to deliver the 3NOP to the herd, both without or with mitigation. Half a kg DM per day is used as the carrier feed.
- 3NOP is fed using an in-shed feeder. The cost of an in-shed feeder is annualised using a 10-year time frame and an interest rate of 6%. In-shed feeders are more expensive for herringbone sheds; thus, costs are higher in some regions in which these types of sheds are more prevalent than rotary milking dairies.
- The cost of 3NOP is determined assuming that 150 g of 3NOP is fed per kg DM intake across lactation. Different levels of intake are represented per farm, thus together with diversity of lactation length, the model represents significant variation in the potential value of 3NOP to dairy farms.

The efficacy of 3NOP on each farm is determined through multiplying the maximum proportional reduction achieved in methane emissions if fed continuously (0.3), the proportion of the year for

[64] Graeme Doole, pers comm

which it is fed (the ratio of days in milk and 365), and 0.5 (given that 3NOP is fed twice daily). Average baseline estimated costs are shown in Table 19. Because of the uncertainty in costs, we also estimate the response with higher 3NOP prices of $25 and $60/kg, corresponding to mitigation costs of $58/t CO_2-e ($1.45/kg CH_4) and $139/t CO_2-e ($3.48/kg CH_4).

Table 19 Average in-shed abatement costs using 3NOP

Component	Unit	Value
Cost	$/kg 3NOP	$7
Quantity per cow per year[1]	Kg	0.75
Annual cost	$/cow	$5.25
Emission reduction (if fed continuously)	%	30%[2]
Assumed reduction if fed twice to lactating animals	%	12%[3]
CH_4 emission factor	t CO_2-e/cow/yr (kg CH_4/cow/yr)	2.625 (105)
CH_4 emission reduction	t CO_2-e/cow/yr (kg CH_4/cow/yr)	0.324 (12.95)
Cost of emission reduction	$/t CO_2-e ($/kg CH_4)	$16.22 ($0.41)

[1] Based on 150 mg/kg DM (Melgar *et al* 2020) and 5 t DM/cow/year; [2] Melgar *et al* (2020); [3] Reflecting twice daily feeding only (50% reduction) and 300 days per year only

Source: Graeme Doole and Mark Neal, DairyNZ (pers comm)

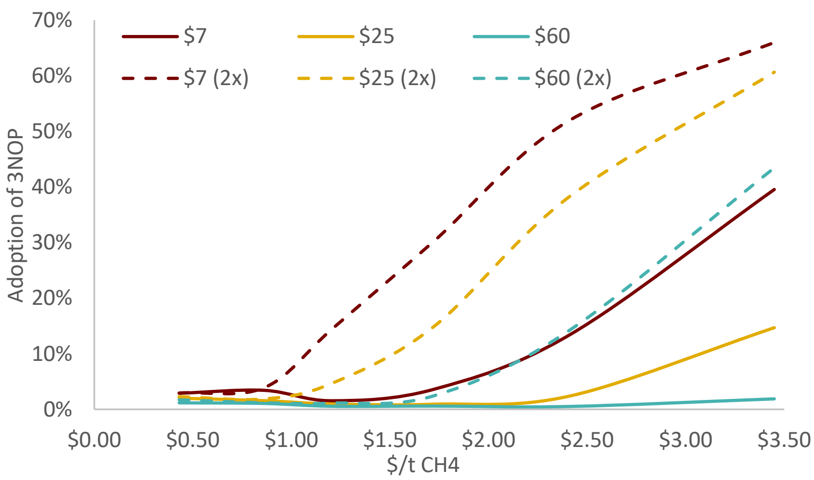
For the analysis we have included a **high technology scenario** in which 3NOP is assumed to double in efficacy from 12% to 24% (see summary of assumptions in Table 20.

Table 20 Mitigation technology assumptions for Dairy Sector (medium and high technology assumptions)

	Medium	High
3 NOP Effectiveness	12%	24%
Cost	$0.41/kg	$0.41/kg
Sensitivity	$1.45-$3.48/kg	$1.45-$3.48/kg

The impacts of these scenarios on 3NOP uptake rates under the processor hybrid option are shown in Figure 20.

Figure 20 Impacts of 3NOP on 2030 uptake rates – Processor Hybrid option with benchmark EMCs



Source: model results from Graeme Doole

At the highest cost, 3NOP use drops to very low levels (under 5%) even at a high emissions price ($3.45/kg CH_4 equivalent to $138/t CO_2-e) in 2030. Doubling the efficacy rate assumption makes a significant difference to the result, with the results equivalent to a 3NOP price of $7/kg, reflecting non-linearities in response. The chart also shows the effects of prices on LLGs. The emission prices on the x-axis are increasing because of the use of the multiplier assumed in the processor hybrid option (see Table 16), but these multipliers are applied to the LLG price also. A high price on N_2O means less fertiliser use and less feed, which in turn means less milk per cow and less methane per cow on which the 3NOP top have an effect.

3.5.4 Efficiency Improvement

The dairy model has assumed some potential for zero or negative cost emission reductions. Doole asserts (see Annex 2) that modelling studies, case studies and farm-system experiments provide examples of mitigation resulting in improved farm profit. Emissions are reduced while increasing productivity through better balancing pasture growth and utilisation. He suggests costs are even lower because decreasing supplement use reduces costs of labour and machinery also, eg he notes empirical work that shows decreasing the use of imported feed by $1,000/ha decreases the burden of other costs by around $500/ha.

Despite the possibility of these outcomes, and that many dairy farms may not currently be using feed efficiently, Doole suggests evidence for improving feed-use efficiency is mixed. Barriers include the high cost of attaining a herd of improved genetic merit, high managerial ability required to reduce replacement rates, diversity in farm resources, and the need for advanced pasture-management skills to maintain pasture quality.

Nevertheless, there is a significant impact on N_2O emissions. The explanation for this response is provided by Graeme Doole (see Box 3).

Box 3 Impacts of pricing on N_2O emissions

The cost of reducing the environmental footprint of a dairy system is reflected in an abatement-cost curve. The shallow parts of such a curve, associated with lower initial levels of abatement, represent the use of cheaper abatement options. These are typically linked to improving the efficiency of nitrogen-use efficiency on a farm; thus, the first steps for a dairy system reducing greenhouse-gas emissions will usually be targeted towards nitrous-oxide levels. Principal examples of such practices are reducing the amount of nitrogen fertiliser applied in autumn (Doole 2014), improving the efficiency of imported supplement feeding (Neal and Roche 2019), and seeking to improve the efficiency of production through improving pasture management (Beukes *et al* 2010).

Many farms within the dairy sector are not efficiently using feed currently (Anderson and Ridler 2010; Macdonald *et al* 2017; Neal and Roche 2019). The optimisation of feed use within these systems will allow a movement towards higher pasture harvest with lower levels of imported feed and a lower cost structure (Neal and Roche 2019). Studies that have showed profitable or low-cost mitigation feature farms where feed was expensive because it was being used inefficiently, to the degree that removing or reducing bought-in feed leads to an increase in pasture harvest with lower costs (Vibart *et al* 2015; van der Weerden *et al* 2018). The economic gains associated with the last point can be so significant that low to moderate decreases in greenhouse-gas emissions can be achieved while increasing farm profit, relative to current practice (Vibart *et al* 2015; de Klein and Dynes 2017).

Accelerated rates of cost are experienced as abatement builds. Once a farmer has attained the efficient use of nitrogen within the agricultural system, the next steps usually involve reducing feed intake (particularly supplement), stocking rate, and lactation length. These cause decreases in the amount of methane emitted, but also sharply impact the cost of abatement because of their direct impact on the amount of milk produced (DairyNZ 2017; de Klein and Dynes 2017). Lower stocking rates are generally associated with higher milk per cow (Macdonald *et al* 2008, 2011), but the standard finding that lower livestock density promotes herbage allowance (Carvalho 2013) is dominated by the concomitant loss in production as stocking rates are reduced (Romera and Doole 2015). Notable exceptions to this general finding exist (eg Anderson and Ridler 2010; Perrin Ag Consultants 2014). However, these do not consider that lower stocking rates increase the need for pasture-management skill on the behalf of farmers, many of whom must increase mowing or silage conservation to maintain pasture quality when pasture utilisation is compromised by a lower livestock density (Kolver *et al* 1999; Macdonald *et al* 2008).

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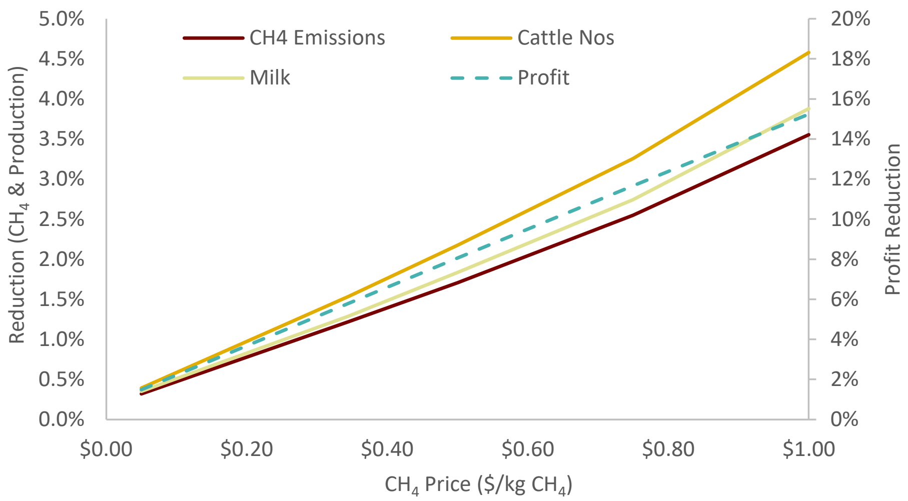
Source: Graeme Doole

3.5.5 Implications of Assumptions for Price Response

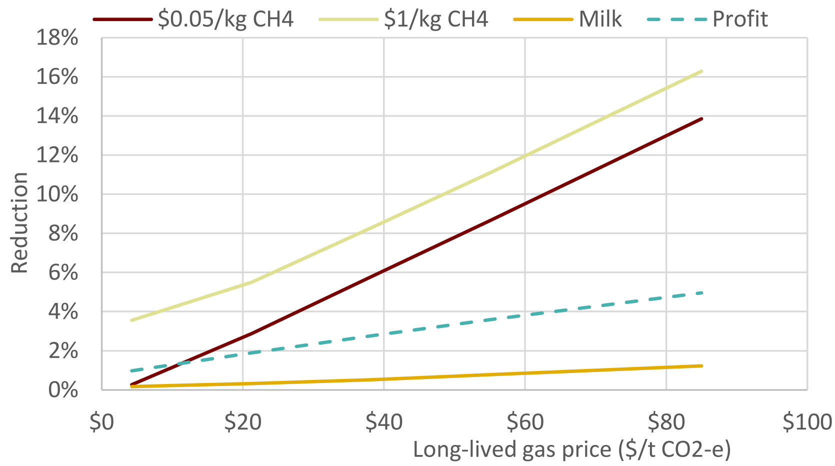
Given the vulnerability of low profit farms, and the limited availability of significant emission reduction technology options, the model predicts a response to a price on methane as shown in Figure 21. At $1/kg CH_4, a 3.6% estimated reduction in methane emissions is achieved via a 4.6% reduction in cattle numbers and a 3.9% reduction in milk production; sectoral profit (from the charge paid on residual emissions and the reduction in output) falls by an estimated 15%.

Figure 21 Impacts of methane prices on emissions, cattle numbers, milk production and profit



The relationship between emission charges and N_2O emissions is different, reflecting the estimated potential for on farm efficiency improvements, including more efficient use of fertiliser. Figure 22 shows the modelled impacts of a price on LLGs, including N_2O. It shows the effect along with different prices of methane also. A rising price on LLGs results in an increasing level of N_2O emission reduction with only a small impact on milk production (and cattle numbers – not shown) and a relatively small impact on profit.

Figure 22 Impacts of emissions price on long-lived gas emissions, production and profit



3.6 Sheep & Beef Model

A spreadsheet model has been developed for *He Waka Eke Noa* to analyse the expected impacts of emissions pricing on sheep and beef farms. It uses historical data on animal numbers, output and profit in different farm categories, and estimates the least cost response to emission prices from: paying the charges and adopting mitigation technologies; it also incorporates limited land use change assumptions. Farm level optimisation or production efficiencies are assumed to have limited emission reduction potential, although the potential effects are analysed (see below).

The model includes the following data and assumptions:

- Base data are taken from the Beef + Lamb New Zealand (B+LNZ) farm survey,[65] grouped into five regions and eight farm classes (Table 21). For each of the 17 categories, the data are further split into profit quintiles,[66] making a total of 85 farm categories.

- The data for each farm category are survey data averages for the five years from 2015-16 to 2019-20.

- Emissions are estimated for each farm category, using emission factors per kg of product and MfE emission factors for fertiliser use.[67]

- Assumptions are included on emission reduction technologies (cost, effectiveness and date of availability) and sequestration (land area, costs and sequestration rates, and the elasticity of response to price changes).

[65] The data were supplied by B+LNZ, but the model has been developed independently.
[66] Farms are ranked by Earnings (Profit) Before Interest, Tax, Rent and manager wage (EBITRm) per hectare. Extensive South Island classes 1 and 2 are ranked nationally by EBITRm per stock unit.
[67] See Annex 1 for details.

Table 21 Regions and farm classes used in the model

Regions: / Farm Class	NNI: Northland-Waikato-BoP	ENI: East Coast	WNI: Taranaki-Manawatu	NSI: Marlborough-Canterbury	SSI: Otago-Southland
1. S.I. High Country				NSI1	SSI1
2. S.I. Hill Country				NSI2	SSI2
3. N.I. Hard Hill Country	NNI3	ENI3	WNI3		
4. N.I. Hill Country	NNI4	ENI4	WNI4		
5. N.I. Finishing	NNI5	ENI5	WNI5		
6. S.I. Finishing Breeding				NSI6	SSI6
7. S.I. Finishing					SSI7
8. S.I. Mixed Finishing				NSI8	

Note: NNI = Northern North Island (Northland, Waikato, Bay of Plenty); ENI = Eastern NI (Gisborne, Hawke's Bay, Wairarapa); WNI = Western NI (Taranaki, Rangitikei, Manawatu); NSI = Northern SI (Marlborough, Canterbury); SSI = Southern SI (Otago, Southland)

Using emission factors per unit of final output introduces some difficulties for the modelling because some farm classes have few final outputs, eg they sell livestock rather than meat, and others such as finishing farms which produce final outputs but will have had low emissions as the animals spent little time on the farm. Modelling this accurately requires a more complicated model than has been employed here (and a different approach to measuring emissions), including estimates of sales of livestock between farm categories and how emission prices faced by one farm are passed on to the other in lower prices. Applying an alternative but simple approach to emissions measurement using average emission factors per animal,[68] would also be inaccurate as these are whole of life factors that do not account for farms where animals spend part of their life only (breeding and finishing farms). The model thus makes simplifying assumptions which mean the results are more valid in aggregate than for individual farm classes. We limit the presentation of results to national averages.

Table 22 summarises sheep & beef farm quintiles data for farm numbers, area and profit. It shows the significant range in profit per ha and the often negative profit numbers for quintile 1 farms.

The Sheep and Beef Farm Survey is a sample survey of the estimated population of commercial sheep and beef farm businesses[69] and is different from the total number of farms with sheep or beef cattle or both. Table 23 shows the national totals for CH_4 emissions, farm and livestock numbers and areas, compared with the data in the model. Although the model represents a small proportion of the total number of farms,[70] it contains data for close to 90% of sheep and beef cattle numbers and 90% of CH_4 emissions. Beef and Lamb NZ estimate there are approximately 9,200 commercial sheep & beef farms in total.

[68] These are available in Ministry for the Environment (2020a), for example
[69] Provided by StatsNZ based on their Ag Census/Survey from defined criteria
[70] B+LNZ's Compendium of New Zealand Farm Facts reports the number of farms by farm type, which includes non-commercial smallholding farms owned by people who have other jobs.

Table 22 Commercial sheep & beef farm numbers, area and profit (average for 2015/16 to 2019/20)

			Farm Profit Before Tax ($/ha)					
Farm Class	No of farms	Effective area (ha)	Q1	Q2	Q3	Q4	Q5	Mean
NNI3	225	666	-$20	$178	$230	$286	$411	$227
NNI4	1,665	354	-$22	$152	$268	$372	$697	$314
NNI5	240	255	$14	$336	$606	$793	$1,608	$641
ENI3	420	867	$14	$126	$203	$300	$420	$206
ENI4	825	543	-$1	$149	$218	$315	$494	$243
ENI5	550	359	-$25	$137	$381	$470	$787	$340
WNI3	275	930	$31	$128	$181	$228	$302	$168
WNI4	565	478	$16	$212	$260	$282	$487	$270
WNI5	255	207	-$92	$253	$403	$470	$764	$369
NSI1	85	9,496	$9	$20	$37	$49	$84	$36
NSI2	395	1,642	-$23	$60	$109	$151	$256	$108
NSI6	1,210	448	-$155	$177	$275	$383	$672	$242
NSI8	465	374	-$299	$127	$276	$393	$989	$286
SSI1	115	7,425	$9	$20	$37	$49	$84	$36
SSI2	225	1,211	-$1	$75	$136	$182	$282	$128
SSI6	610	595	$57	$179	$280	$352	$602	$264
SSI7	1,040	250	$199	$341	$435	$615	$761	$470
NZ9	9,165	688	-$10	$109	$196	$260	$432	$191

Source: Data from Beef + Lamb New Zealand

Table 23 Data in model vs national totals

	Units	Sheep	Cattle	Deer	Total	Included in model	% of total
CH_4 2017	t CO_2-e	8,443	5,404	493	14,340	12,893	90%
Farms (sheep & beef)	number				23,403	9,161	39%
Farms (deer)	Number				783		0%
Total area	'000 ha				8,765	7,382	84%
Sheep	million head				27.4	24.5	89%
Beef cattle	million head				3.8	3.2	84%
Deer	million head				0.9	0.1	11%
Stock units (SUs)	Million SUs	24.3	18.2	1.5	44	37.5	85%

Source: CH_4: Table 2; other data from Beef + Lamb New Zealand (2020)

3.6.1 Exotic Sequestration and Land Use Change

Quantity of New ETS Forestry

The current potential value of sequestration on sheep and beef farms is estimated to be greater than the value of farming. With sequestration rates of 18-26 t CO_2/ha per annum and a current (early 2022) NZU price of approximately $75/t CO_2-e, the value of the emission units alone is $1,350-$1,950/ha, significantly above current profit levels for sheep and beef farms in most classes and quintiles (Table 22). This is a relevant comparison if we assume that any additional revenue from forestry at least covers the land opportunity costs and planting costs. If simply assessing land use change using the highest value land use, a large percentage of the farm area would be modelled as changing land use. Other models, such as those discussed in Section 2 (eg Dorner *et al* 2018) have used price elasticities to estimate land use change.

The sheep & beef model developed for *He Waka Eke Noa* projects the shift to forestry in aggregate using the historical relationship between NZU prices and new planting rates (see Section 1.3.4). A price elasticity is then used to distribute this total amongst the farm categories, from the starting estimated area of exotic forestry in each category (see Land Use Change Assumptions in Annex 1 for more detail). Using the price elasticities, forest expansion is estimated for each farm category. These are ranked by net value of forest land use change and the total new afforestation area is allocated to each in turn until the total is used up. The main shift to ETS forestry occurs under the base case assumptions and in response to the NZU price; there is an additional shift in response to the emissions price, as discussed in Section 1.3.4 above.

Impacts on Production

At the farm-level the relationship between land used for forestry on a farm and reduction in livestock is likely to be less than 1:1, ie trees will be planted on less productive areas of farms so that, if 10% of a farm is planted, reduction in livestock will be less than 10%. However, the model is working with averages for groups of farms and, within a farm category, a 10% switch of farm area to forest might involve several whole farms, rather than each farm switching 10%. In aggregate the effect is likely to be somewhere in-between. To take account of this we have used a power relationship, ie:

% loss of stock = % loss of farm area$^{\wedge r}$

Our default value for r is 1.25. This means a 10% reduction in area results in a 5.6% reduction in stock.

In addition, riparian planting and native regeneration is available in non-farmed areas, and these are added when profitable to do so, taking account of planting or fencing costs and the value of sequestration.

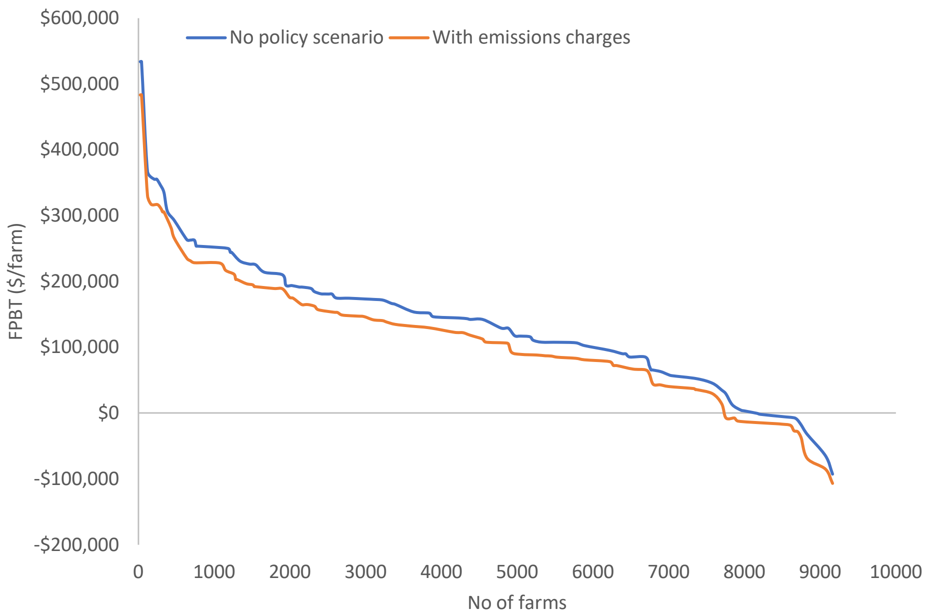
3.6.2 Negative Profit and Land Use Change

Unlike the dairy sector model, current levels of profit (as farm profit before tax, FPBT) in sheep & beef farms are distributed above and below zero per unit of output. The ‘no policy scenario’ in Figure 23 uses the Beef + Lamb NZ historical data (averages of farm survey data from 2015-16 to 2019-20); approximately 17% of farms are estimated to be operating at a loss.[71] This complicates the identification of any profit threshold for farm closure or reduced production.

In a scenario in which an emissions charge on CH_4 and LLGs is introduced, but assuming no compensating revenue from sequestration, an increased number of farms is estimated to have FPBT below zero. Figure 23 illustrates this using a charges of \$0.35/kg CH_4 and \$13.80/t CO_2-e for LLGs for 2030. Table 24 shows the resulting estimates of the number of farms with negative FPBT in the no policy case and with emission prices (using a FLL assumption) but no sequestration revenue (either from the ETS or *He Waka Eke Noa*). It compares this with the modelled additional ETS forestry in these two scenarios also.

[71] Nine out of the total of 85 farm classes in the model are estimated to have average FPBT below zero. These nine classes comprise a total of 1,528 farms.

Figure 23 Distribution of farm profit before tax in sheep and beef farms: No policy scenario and with emissions charges (2030)



Note: emissions charges assumed to be $0.35/kg CH_4 and $13.80/t CO_2-e; no sequestration income assumed
Source: Base case data from Beef + Lamb New Zealand

Table 24 Farm numbers and farm area with negative farm profit before tax (2030) (no additional sequestration revenue)

	2030 no policy	**2030 with emissions price**	**Difference**
Negative FPBT: Farm Nos	1,528 (16.7%)	1,785 (19.5%)	257 (2.8%)
Negative FPBT: Area (ha)	508,512 (8.2%)	778,178 (12.5%)	269,666 (4.3%)
Additional ETS Forestry	529,044 (8.5%)	555,098 (8.9%)	26,054 (0.4%)

Note: emissions price assumed is $0.35/kg CH_4 and 13.80/t CO_2-e for long-lived gases

An additional 3% of farms (and 4% of effective farm area) are estimated to have negative FPBT as a result of the emission prices. Despite these impacts, in modelling we do not assume the farms that are made unprofitable will change land use from sheep and beef farming. This is for two reasons:

1. The risk of double-counting areas converting to ETS forestry
2. The potential for absorption of costs into land prices.

There is a risk of double-counting as some of the areas that may become unprofitable to farm will be those that are modelled to change land use to forestry under the base case (8% of the effective farm area) and in response to emission prices (an additional 26,054 ha) (Table 24). In total (c.555,000 ha) this is approximately double the additional area estimated to be made unprofitable from emissions pricing (c.270,000 ha). The modelling has assumed the additional areas shifting to ETS forestry will be those that already have some exotic forestry, but in practice it may be those farms that are least profitable.[72]

[72] We have modelled areas shifting to ETS forestry as parts of farms, although in practice there may be whole farm conversions. This assumption does not matter if the total area of new forestry is limited, as the modelling assumes.

Even if costs exceed current profit, some of these effects might be absorbed into land prices such that sheep & beef farming may continue under different ownership.[73] We can proxy this effect by undertaking the analysis with FPBT data adjusted to remove interest payments; this then estimates the effect on profit for a farmer with no debt. The results (Table 25) suggest a much smaller base number of farms with negative FPBT but a similar number made unprofitable from the emission charges. However, these are much smaller in area than assumed to convert to ETS forestry (as shown in Table 24).

Table 25 Farm numbers and farm area with negative FPBT excluding interest payments (2030) (no additional sequestration revenue)

	2030 no policy	With emissions price	Difference
Negative FPBT: Farm Nos	208 (2.3%)	416 (4.5%)	208 (2.3%)
Negative FPBT: Area (ha)	47,341 (0.8%)	98,675 (1.6%)	51,334 (0.8%)

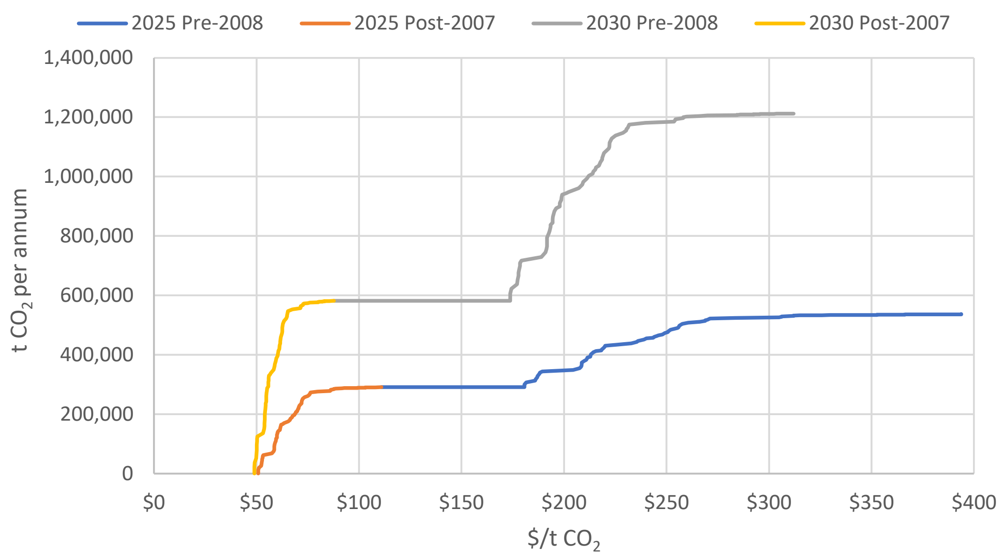
Note: emissions price assumed is \$0.35/kg CH_4 and 13.80/t CO_2-e for long-lived gases

In analysing the impacts on the sheep and beef sector, we have assessed the impacts on profit but have not used the profit impacts to estimate any additional land use change to that identified in the sequestration analysis. However, there are uncertainties in this analysis as we do not know which farms will respond to the increasing NZU price for forestry or how close to zero profit a farm might choose to transition to another land use. Thus there may be some additional land use change and reduction in emissions from reduced livestock numbers beyond that modelled.

3.6.3 He Waka Eke Noa Sequestration

The model includes estimates of areas of native vegetation in the individual farm categories that could be managed to achieve increased sequestration (see Table 66 in Annex 1). Using these areas and assuming equal average areas per farm within a farm category, alongside the costs discussed in Section 3.4 above, we estimate potential additional sequestration at different prices paid for sequestration (Figure 24).

Figure 24 Potential sequestration on sheep & beef farms at different prices



[73] This is a point also raised by Sense Partners (2018)

This assumes sequestration will be entered into the *He Waka Eke Noa* system if the amount paid exceeds the costs for fencing and weed & pest control. Of the total quantity of potential sequestration, a relatively small amount (post-2007 only) is modelled as being available at less than \$100/t CO_2; this is because of the lower assumed value of pre-2008 native vegetation from the lower sequestration rate. Pre-2008 vegetation is modelled to enter the *He Waka Eke Noa* system only above approximately \$170/t CO_2.

3.6.4 Mitigation Technologies

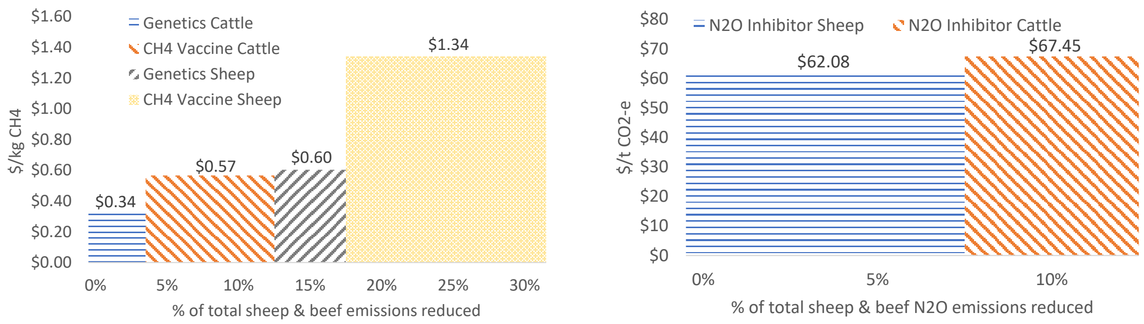
Mitigation technologies, including their availability, effectiveness and costs, are estimated from work undertaken by the NZ Agricultural Greenhouse Gas Research Centre (NZAGRC) (Table 26). This has been used to produce cost curves for mitigation as shown in Figure 25.

Table 26 Mitigation technology assumptions - effectiveness, cost and date of first availability

Option	Animal	Effective-ness	Cost per animal	Available from	Inclusions & exceptions	Year 1 adoption rate	Maximum adoption rate
CH_4 Vaccine	Sheep	30%	\$5.00	2031		8%	90%
	Cattle	30%	\$10.00	2031		8%	90%
CH_4 Inhibitor	Sheep	30%	\$6.00	NA		3%	75%
	Cattle	30%	\$12.00	2031		3%	75%
N_2O Inhibitor	Sheep	50%	\$1.00	2030	FC 5,7,8 only	2%	25%
	Cattle	50%	\$8.00	2030	FC 5,7,8 only	2%	25%
Genetics	Sheep	10%	\$0.75	2025		2%	76%
	Cattle	10%	\$2.00	2031	2026 in FC 5 & 7	2%	76%

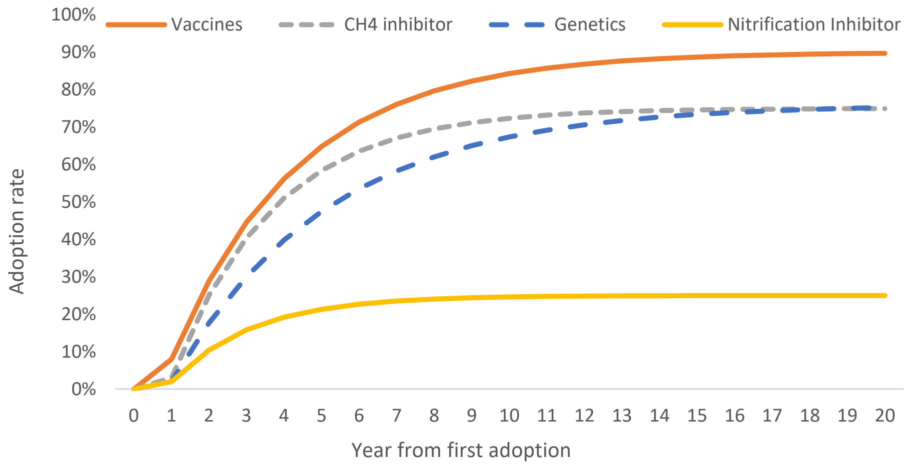
Source: FC = farm class; Phil Journeaux, AgFirst, (pers comm)

Figure 25 Cost curves for mitigations



An adoption rate is assumed for the individual technologies to reflect behavioural responses, such that not all farms adopt technologies from when they are first available. Adoption curves, which were developed in consultation with Phil Journeaux (AgFirst), include the gradual uptake of technologies but at a rate that increases with the emissions price. Examples using high emission prices are shown in Figure 26, with the formulae and assumptions set out in Annex 1; this includes the first year and maximum adoption rates as listed in Table 26. The model uses a biological growth curve under constraints: an initial exponential curve is limited by an assumed maximum level of adoption.

Figure 26 Example assumed technology adoption rates



As with the dairy modelling, a **high technology assumption** is adopted in sensitivity analysis. It assumes a doubling of the starting adoption rate and a halving of cost. This is used to examine the benefits of strategies that invest in faster penetration rates for the individual technologies.

3.6.5 Efficiency Improvement

Because of the lower levels of use of fertiliser compared to dairy, and the less intensive approaches to feeding, there are assumed to be fewer opportunities for emission reductions via efficiency improvement in the sheep & beef sector. Nevertheless, we explore the potential using an assumed 5% reduction in emissions achievable in response to consultant advice and some input of farmer time. We use the assumptions shown in Table 27 to derive an annual farm cost of $2,310 to obtain a 5% reduction in emissions. We further assume that the response will be limited by quintile, so that only the three highest value farm quintiles pay these costs.

Table 27 Potential costs of efficiency improvements

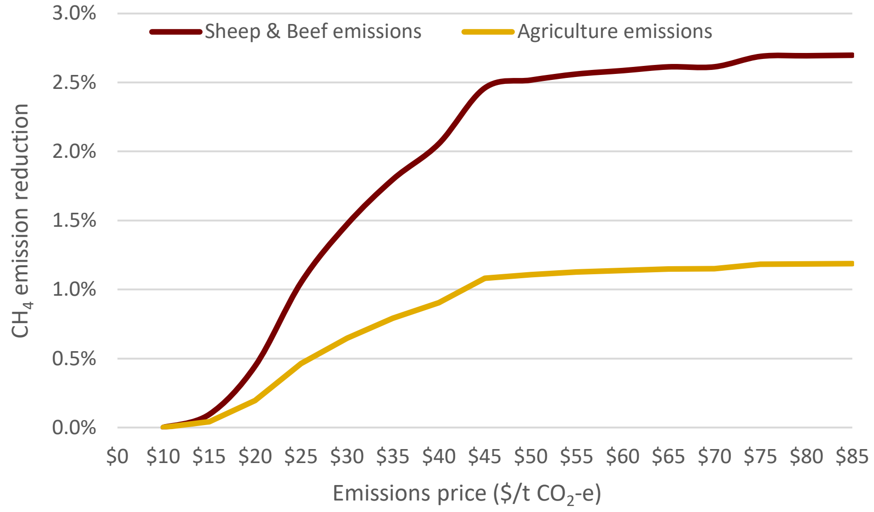
Component	Value
Consultant time	$5,000
Equivalent farmer time	$5,000
Duration of response (years)	5
Annual cost @5%	$2,310

Source: cost assumptions from Erica van Reenan (AgFirst), pers comm

Using these assumptions, the potential response to an emissions price is shown in Figure 27. This suggests a potential 2.5% reduction in sheep & beef methane emissions (and very similar reductions in LLGs) with a charge applied to all gases of approximately $45/t CO_2-e (equivalent to $1.125/kg CH_4). This level of reduction is equivalent to an approximate 1.1% reduction in agriculture sector methane emissions.

We are uncertain about this response, including the levels of adoption, but note this as a potential upside for a pricing regime.

Figure 27 Potential CH_4 emission reductions via sheep & beef farm efficiency improvements



3.6.6 Implications of Assumptions for Price Response

The modelled response of the sheep and beef model to emissions prices is limited to (1) the increased level of exotic afforestation (although most of this is in the base case – see Section 4.1 below) resulting in livestock displacement and (2) the uptake of mitigation technologies. The effects of a methane charge are shown in Figure 28. Emission reductions increase with an initial low charge level because of some additional land use change (% of sheep & beef farm area in area in ETS forestry), leading to some reduction in meat production, but above a certain point there is a sharp increase in emission reductions at a point when mitigation technologies are available and incentivised. These correspond to the steps on the CH_4 mitigation cost curve (see Figure 25).

Figure 28 Impacts of methane charge on sheep & beef farms (2030)

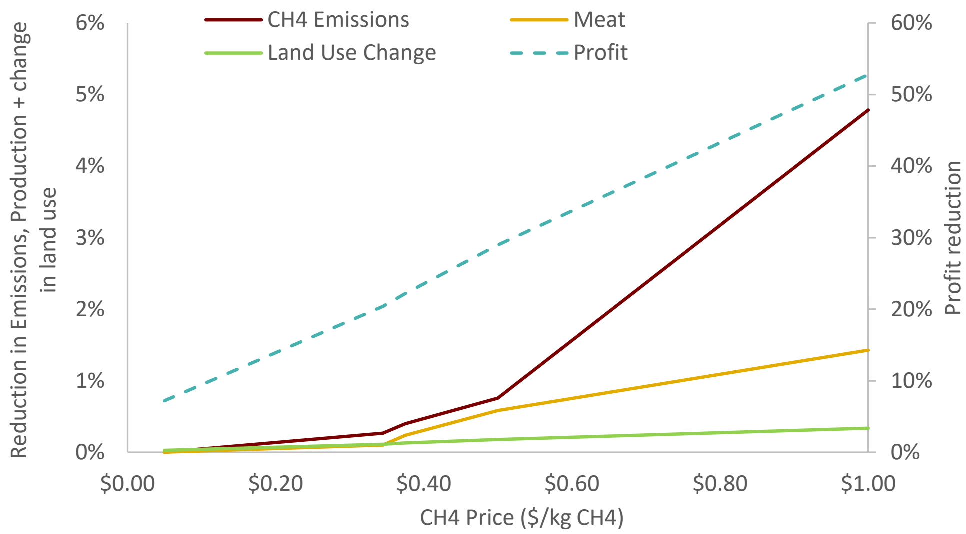
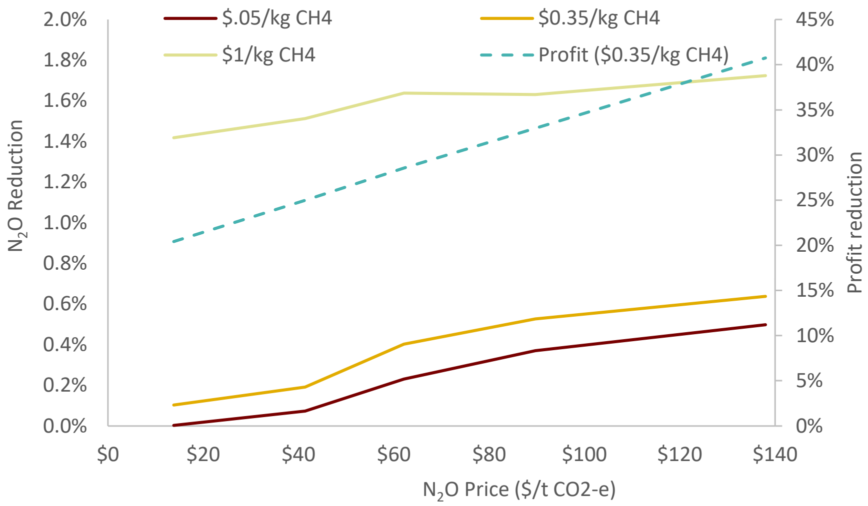


Figure 29 shows the effects of the charge on long-lived gases, including the effects of a methane charge (separate price response curves) on N_2O emissions. The profit impacts are shown for the combined long-lived and $0.35/kg CH_4 charge (ie $13.80/t CO_2-e on methane).[74] There are very small

[74] This is based on a 90% discount on the assumed NZU price

reductions estimated for N_2O because of the very limited availability of mitigation options, with the charge then paid on residual emissions.

Figure 29 Impacts of long-lived gas charge on sheep & beef farms (2030)



3.7 Horticulture Model

The horticulture model is a spreadsheet model which limits the analysis of effects to an increase in fertiliser costs from a price on long-lived gases. There is no assumed response to the prices modelled as the cost increase is a small percentage of estimated profit.
Analysis of the impacts of emissions pricing on horticulture was undertaken by Stuart Ford for Horticulture NZ.[75] We summarise the approach and results below.

A spreadsheet model was used to analyse the impacts on five land uses:

- Pipfruit
- Kiwifruit
- Vegetable Production (Pukekohe)
- Vegetable Production (Canterbury)
- Arable.

The data used to calculate the emissions of each land use was taken from *Overseer*
The assumed area of each farm and average amount of Nitrogen fertilisers applied and the annual emissions are shown in Table 28.

Table 28: Area, amount of N applied (kg / ha) and emissions per ha expressed as tonnes of CO2-e.

Land Use	Area (ha)	Average amount of N applied (kg / ha)	Emissions (tonnes CO_2-e)
Pipfruit	33	43	0.15
Kiwifruit	31	70	0.24
Vegetable Production (Pukekohe)	100	183	0.61
Vegetable Production (Canterbury)	100	125	0.44
Arable	200	110	0.38

Source: Ford (2021)

[75] Ford (2021)

The area of each industry has been taken from the FreshFacts 2020 (Horticulture NZ 2020) and the Foundation for Arable Research (FAR).[76] The areas used are shown in Table 29.

Table 29: Industry areas used in the modelling.

Land Use	Industry Area (ha)
Pipfruit	10,396
Kiwifruit	12,905
Vegetable Production (Pukekohe)	31,000
Vegetable Production (Canterbury)	13,220
Arable	180,000

It is assumed that each of the land uses are already at Good Management Practice,[77] and there are no available sequestration options to offset emissions.

3.8 Scaling Up

The emission reduction results are produced from separate models for dairy and for sheep & beef. These are combined to produce an overall assessment of the impacts on total agricultural emissions. The data included in the individual models are slightly different from the totals in the national inventory, so adjustments are made to aggregate the effects at the sectoral level.

Table 30 shows the emissions included in the models for sheep & beef and for dairy, alongside the numbers calculated in the national inventory for the 2017 base year (as reported in greater detail by agricultural sector by the CCC) and the modelled numbers as a percentage of the inventory numbers. The numbers in the models are different because of slightly different assumptions and exclusion of some farms, eg the sheep & beef model includes commercial farms only. Other agriculture is included here using data from the inventory only.

Table 30 Agriculture Sector emissions 2017

GHG	Sheep & Beef Model*	Sheep & Beef Inventory	Dairy Model*	Dairy Inventory	Other Agri-culture	Total Model*	Total Inventory
CH_4 (t CH_4)	511,536 (93%)	552,872	616,132 (104%)	592,444	28,418	1,156,085 (98%)	1,174,508
CH_4 (t CO_2-e)	12,788,395 (93%)	13,821,793	15,403,289 (104%)	14,811,105	710,453	28,902,136 (98%)	29,362,699
N_2O (t CO_2-e)	1,824,125 (81%)	2,243,349	3,158,703 (72%)	4,379,939	467,103	5,449,931 (77%)	7,094,394
CO_2 (t CO_2-e)	272,458 (88%)	308,848	688,527 (104%)	661,949	77,063	1,038,048 (99%)	1,047,861
Total (t CO_2-e)	14,884,977 (91%)	16,373,990	19,250,519 (97%)	19,852,993	1,254,619	35,390,115 (94%)	37,504,954

* Percentages in brackets are modelled numbers as a % of inventory numbers
Source: Inventory data from Climate Change Commission (2021b)

[76] https://www.far.org.nz/
[77] This means that they are already compliant with the ETS and the Freshwater NES because of NZGAP requirements for the horticulture land uses and the Canterbury Land and Water Regional Plan document and the subsequent district plan changes. These voluntary and legislative documents require that the land uses are already at or above Good Management Practice and have achieved the targets set for discharges to water.

In scaling up to an impact on total sectoral emissions, we apply to a percentage of emissions only using the following assumptions:

- Where the percentage in Table 30 is less than 100%, we assume the reduction applies to that percentage of emissions, eg a modelled 1% reduction in sheep & beef CH_4 emissions is assumed to be an actual 0.93% reduction of total sheep & beef emissions and a 0.44% reduction in total agricultural sector CH_4 emissions.

- Where the percentage in Table 30 is greater than 100%, we assume the reduction is the same as modelled, eg a 1% reduction in modelled dairy CH_4 emissions is assumed to represent an actual 1% reduction in dairy CH_4 emissions.

Taking account of emissions not accounted for in the models and the contribution of the individual land uses to total agriculture emissions, the multipliers in Table 31 are used to convert a 1% reduction in land use specific emissions to sectoral emissions. For example, an estimated 1% reduction in sheep & beef CH_4 emissions is estimated to be a 0.44% reduction in agriculture CH_4 emissions.

Table 31 Multipliers to convert land use specific 1% emission reductions to agriculture sector emission reductions

Sector	CH_4	N_2O	CO_2	LLG
Dairy	0.52	0.45	0.66	47%
Sheep & Beef	0.44	0.26	0.26	26%

4 Results of Analysis

4.1 Base Case – no Emissions Pricing

A base case is modelled to take account of existing policy settings which include the National Policy Statement on Freshwater Management (NPS-FM) and the current ETS settings which incentivise afforestation and land use change from farming to forestry.

The baseline assumptions are those assumed to occur in the absence of further policy. We estimate the impacts relative to a 2017 baseline, which is that used for the legislated biogenic methane target.[78] The aggregate results are shown in Table 32. The estimated baseline reduction in methane emissions in 2030 is calculated to be 4.5% of 2017 agricultural emissions, along with a reduction in LLG emissions of close to 4%. If we reduce the estimated area of new ETS forest planting to 30,000 ha per annum, this reduces to 3.1% reduction in methane and a 2.7% reduction in LLGs.

Table 32 Projected changes under baseline

		2017	2025	% reduction	2030	% reduction
NZU Price	\$/t CO_2-e		\$85		\$138	
Farm area	Dairy	1,755,149	1,755,149	0.0%	1,755,149	0.0%
(hectares)	Sheep & beef	6,261,274	6,060,424	3.2%	5,737,940	8.4%
Animal	Dairy cattle	4,703,550	4,631,110	1.5%	4,631,110	1.5%
numbers	Other cattle	3,228,666	3,121,613	3.3%	2,919,625	9.6%
	Sheep	24,497,698	23,500,160	4.1%	21,880,347	10.7%
	Deer	103,550	101,364	2.1%	95,806	7.5%
Production	Milk (kt MS)	1,767	1,745	1.2%	1,745	1.2%
	Sheep & beef meat (t)	733,966	710,383	3.2%	674,837	8.1%
Adjusted	CH_4 (kt CH_4)	1,172	1,149	2.0%	1,120	4.5%
emissions	N_2O (kt CO_2-e)	7,071	6,939	1.9%	6,804	3.8%
	CO_2 (kt CO_2)	1,048	1,033	1.4%	1,017	3.0%
	LLG (kt CO2)	8,119	7,973	1.8%	7,821	3.7%

There are significant estimated reductions in sheep & beef farm area and in animal numbers. This is a result of the estimated increased land use change from farming to forestry, incentivised by the NZU price. Baseline changes in land use and animal numbers in dairy and sheep & beef farms are included as the starting position for the analysis of emissions pricing options.

As noted above, modelling land use change does not differentiate between part-farm afforestation and full-farm conversion. It only estimates the hectares changing within a farm category. This has implications for the estimate of profit impacts. In the former case, the additional revenues from forestry would be assumed to stay in the sheep & beef sector and to add to average profits, but in the latter, farmers would be assumed to receive a one-off payment and then to exit the industry.

[78] National emission objectives set in the Climate Change Response (Zero Carbon) Amendment Act 2019 require reductions in agricultural emissions. These are:

- Net zero emissions of all greenhouse gases (GHGs) other than biogenic methane (CH_4), but including nitrous oxide (N_2O), by 2050; and
- 24 to 47 per cent reduction of biogenic methane emissions below 2017 levels by 2050, including a 10 per cent reduction below 2017 by 2030.

From the perspective of current farmers and the nation), this may not matter, but from an agriculture industry perspective, the loss of profit is of interest.

Table 33 shows the estimated impact of additional ETS revenue on average sheep & beef farm profits. In 2030, the ETS revenue increases average farm profits by an estimated 127%. If the costs of the pricing options are considered relative to these elevated profit levels the impacts will be a smaller percentage than if considered relative to the baseline (2017) profits. It is uncertain which farms will be forested, and whether the areas will be widely distributed across farms or concentrated in a small number of farms. Given this uncertainty, in the analysis of the impacts of the pricing options we have assessed impacts on profit relative to the 2017 average profit ($130,237/farm).

Table 33 Baseline impacts on average sheep & beef farm profit

	2017	2025	2030
Profit ($/farm)	$130,237	$164,345	$295,164
Profit/ha	$191	$241	$432
Change from 2017		+26%	+127%

4.2 Processor Level ETS

4.2.1 Description

This is the backstop pricing option assumed for analysis, ie what will happen if there is no agreed *He Waka Eke Noa* pricing option.

Processors include manufacturers or importers of fertiliser and the processors of agricultural or horticultural products, eg milk and meat. They would be included in the ETS as obligated parties with requirements to surrender NZUs equal to their emissions, calculated using emission factors per unit of output, eg kg CO_2-e/t of milk solids.[79]

As with EITE industrial participants in the ETS, they will be provided with allocations of NZUs to partially compensate them for their costs. This is assumed to be 95% of average emissions per unit of output from a processor in 2025, falling by one percentage point per year, eg to 90% in 2030.[80] If emissions are calculated using the same emission factors as used for allocation, the net surrender obligation is equal to 5% of their emissions, rising by one percentage point per year.

The inclusion of agricultural emissions in the ETS is assumed to produce some additional Government revenue because additional NZUs will be placed on the market via auction to increase total NZU supply. The Government's intent is for this to be recycled back to the agriculture sector to encourage mitigation, innovation and additional planting of forestry.[81] This could operate in a manner equivalent to the use of the revenue under the processor hybrid option (see below).

[79] Emission factors are currently defined in Climate Change (Agriculture Sector) Regulations 2010. We use updated values based on Journeaux (2019)

[80] The assumption of a falling level of free allocation is the same as used in industrial allocation under the ETS. This reflects an assumption that, increasingly over time, international competitors to emissions intensive industries will be facing emissions pricing or equivalent policy, and that this will be reflected in international commodity prices, such that New Zealand firms are increasingly able to recover the costs of emissions costs in sales revenues.

[81] Office of the Minister for Climate Change (2019)

The revenue raised is uncertain, because of uncertainties over price and the quantity of units released. The quantity might be less than the total additional demand (at current prices) if a shortfall is used to produce price increases (and drive additional emission reductions across the ETS as a whole), or if demand from the agriculture sector is used to reduce the current NZU stockpile.[82]

4.2.2 Modelling

For modelling the impacts, it is assumed that processors pass the costs of purchasing NZUs on to farmers and horticulturalists as a reduction in the amount paid per unit of farm product (milk, meat etc), based on the average emissions intensity of those products. This has been modelled as a full pass through of costs, although in practice it would depend on differences between farmers and processors in price elasticity of demand and market power.[83] Because of the free allocation to offset the surrender obligations, the cost is modelled as 5% (rising annually) of the modelled market price of NZUs.

4.2.3 Results

The processor ETS is modelled using a single set of price assumptions; these are based on the assumed NZU prices in 2025 ($85/t CO_2-e) and 2030 ($138/t CO_2-e), with 95% and 90% allocations in 2025 and 2030 respectively. The aggregate results are shown in Table 34 as the change relative to the baseline in 2025 and 2030. The prices are the effective net prices after the allocation has been provided, both for CH_4 and long-lived gases (LLGs).

Table 34 Aggregate results for Processor ETS

	CH_4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	LLG	Milk	Sheep & Beef Meat	Dairy Profit	Sheep & beef profit	Gross levy revenue ($m)
2025	$0.11	$4.25	-0.2%	-0.2%	-0.5%	-0.21%	-1.7%	-4.1%	$140
2030	$0.35	$13.80	-0.8%	-0.6%	-1.8%	-0.11%	-5.5%	-14.7%	$451

The emission reductions are additive to those in the baseline, ie in relation to the biogenic methane target, the estimated 0.8% reduction in CH_4 emissions in 2030 is additional to the baseline 4.5% reduction (Table 32). The results include the impacts on aggregate sectoral emissions, production of milk and meat and on sectoral profit.

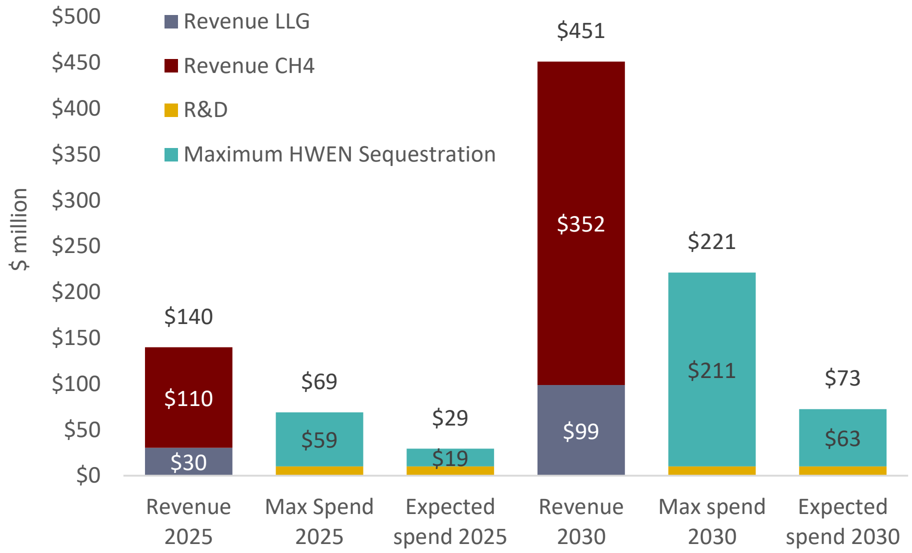
The revenue raised from the charge is reported also. This is assumed to be used to fund R&D and might be used to fund sequestration and emission reduction payments (in which case it becomes a very similar instrument to the PH, apart from the processor ETS using GHG combined emission factors for the charge element).

In Figure 30 we compare the revenue raised with the estimates of potential spend on R&D ($10 million) and maximum HWEN sequestration (Table 18), eg a high estimate of $211 million in 2030, and a total (including R&D spend) of $221 million. Administration costs are assumed to be covered by the Government (Table 17) such that there is an estimated $230 million surplus. We also show the results using expected spend based on a lower amount of sequestration (post-2007 only) and

[82] The NZU stockpile is the excess of units held in private accounts over that required for participants to meet their surrender obligations. It is forecast to total nearly 120 million tonnes in 2025 (https://environment.govt.nz/what-government-is-doing/key-initiatives/ets/nz-ets-market/unit-flow-forecasts/)
[83] The simpler assumption is made partly because pass-through levels might be subject to Government policy intervention, including via requirements for separate identification in prices.

payment at 75% of the expected NZU price, recognising that not all of the *He Waka Eke Noa* eligible sequestration will count towards national targets, in contrast to that in the ETS. There is sufficient revenue in both years, even with the maximum estimated sequestration, but the cost of sequestration payments will exceed the revenue from LLGs alone.[84]

Figure 30 Comparison of revenue raised estimates with potential spend – Processor ETS



The individual results for dairy and sheep & beef are included in Annex 3.

4.2.4 Horticulture

The impacts on horticulture are shown separately because the results are provided for individual land uses, and because the estimated impacts do not include emission reductions. Rather, the emission charge is assumed to be paid and simply result in a reduction in profit. Table 35 shows the estimated impacts on cash operating surplus for the individual land uses. The only significant impacts are for arable farmers at the highest cost options.

These results are assumed to apply to all pricing options.

Table 35 Estimated impacts of long-lived gas emissions prices ($/t CO_2-e) on cash operating surplus

		2025			2030	
Land use	**$4.25**	**$21.25**	**$85.00**	**$13.80**	**$41.40**	**$138.00**
Apple	0.00%	0.01%	0.03%	0.00%	0.01%	0.05%
Kiwifruit	0.00%	0.02%	0.07%	0.01%	0.03%	0.11%
Vegetables, Auckland	0.05%	0.25%	1.00%	0.16%	0.48%	1.62%
Vegetables, Canterbury	0.03%	0.16%	0.62%	0.10%	0.30%	1.01%
Arable	0.16%	0.81%	3.24%	0.53%	1.58%	5.26%

Source: Stuart Ford, The Agribusiness Group

[84] This is a relevant concern if the intent is for revenue from LLGs to be used towards meeting the net GHG target, but with methane revenue used solely to fund reductions in methane.

4.3 Farm Level Levy

4.3.1 Description

The Farm-Level Levy (FLL) is the first of the *He Waka Eke Noa* alternatives and introduces separate prices for CH_4 and LLGs. The calculation of emissions uses a typology involving three elements: A, B and C, where:

A = emissions of methane (kg CH_4) x charge rate (\$/kg CH_4)
B = emissions of long-lived gases (kg CO_2-e) x charge rate (\$/kg CO_2-e)
C = absorption by eligible sequestration (kg CO_2) x payment rate (\$/kg CO_2-e)

The equation for the full exposure charge for any farm is:

Emissions charge = A + B - C

LLG emissions (b) and absorption (C) are both measured using CO_2-equivalents (CO_2-e), based on a GWP of 298 for N_2O.[85] As with other options, there is also the potential for revenue to be earned for sequestration from options that are not recognised currently under the ETS (Table 18).

4.3.2 Modelling

Modelling the FLL is relatively straightforward.[86] Emissions are calculated at the farm level and the emission price applies, with no discounts or rebates.

A variant of the FLL is included below (Section 4.7) that uses some of the revenue collected to purchase emission reductions in a similar way to that included under the processor hybrid (PH) below.

4.3.3 Results

The FLL has been analysed with a wide range of prices. Table 36 shows the results for 2025 with prices ranging from \$0.05/kg of CH_4 to \$1/kg and long-lived gas prices ranging from \$4.25/t to \$85/t CO_2-e. The prices for LLGs are based on 95%, 75% and 0% discounts to the assumed 2025 NZU price. Sequestration is modelled in Table 36 at a reduced price of 75% of the estimated 2025 NZU price (\$64/t CO_2-e).

The highest prices modelled show a 3% reduction in methane and 7% reduction in LLGs, but with large reductions in average profits, most notably a 41% reduction in average sheep & beef farm profits. As discussed above, the sheep & beef profit impacts are without the effects of the ETS forestry, but they include *He Waka Eke Noa* sequestration in the results. Because of the limited area of post-2007 native vegetation, its inclusion has a relatively small impact on profit.

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[85] The Global Warming Potential for a 100-year time horizon (GWP_{100}) of 298 for N_2O is based on the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). We have used this in this report because this is the same assumption as used in the national emissions inventory and currently in the ETS, although we note the recent recommendations to shift to AR5 for the setting of emission budgets (Ministry for the Environment 2021b). This would introduce a GWP_{100} of 265 for N_2O.

[86] The complexities of establishing an emission measurement system at the farm level are taken into account via the separate assessment of administration costs.

Table 36 Farm Level Levy Results, 2025

CH4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	LLG	Milk production	Sheep & beef meat productio n	Dairy profit	Sheep & beef profit	Gross levy revenue
$0.05	$4.25	-0.1%	-0.1%	-0.2%	0.0%	-1.0%	-2.7%	$80
$0.05	$21.25	-0.2%	-1.2%	-0.3%	-0.2%	-1.9%	-4.8%	$174
$0.05	$85.00	-0.7%	-5.6%	-1.2%	-0.8%	-5.0%	-12.1%	$497
$0.11	$4.25	-0.2%	-0.5%	-0.3%	-0.2%	-1.8%	-4.2%	$143
$0.11	$21.25	-0.3%	-1.2%	-0.5%	-0.3%	-2.7%	-6.2%	$236
$0.11	$85.00	-0.9%	-5.7%	-1.5%	-1.0%	-5.8%	-13.4%	$558
$1.00	$4.25	-2.3%	-2.0%	-3.5%	-2.3%	-14.9%	-27.5%	$1,117
$1.00	$21.25	-2.4%	-2.7%	-3.8%	-2.1%	-15.8%	-30.5%	$1,208
$1.00	$85.00	-2.9%	-7.0%	-5.0%	-1.9%	-18.7%	-40.8%	$1,519

Prices at $0.11/kg CH_4 and $4.25/t CO_2-e are the same as the processor ETS with 95% free allocation in 2025. The estimated impacts on emission reductions differ from the processor ETS, partly reflecting differences in emission factors assumed for the dairy sector.

The gross levy revenue is the amount raised from the levy prior to any expenditure, including expenditure on *He Waka Eke Noa* eligible sequestration. We discuss the sufficiency of revenue below.

Table 37 shows the 2030 results, with prices for long-lived gases escalating with the assumed NZU price. The $0.35/kg CH_4 and $13.80/t CO_2-e option is equivalent to the prices under the processor ETS. Sequestration is assumed to be valued at $104/t CO_2 (75% of the assumed NZU price in 2030).

The highest prices again show some significant reductions in emissions, eg a 5% reduction in methane emissions, which added to the 4.5% estimated under the baseline, is close to the targeted 10% reduction in 2030[87] with the gap likely to be well within the error margins of the modelling. But as with the 2025 results, the impacts on profits are high: over a 20% reduction for dairy farms and over 40% for sheep & beef.

Table 37 Farm Level Levy Results, 2030

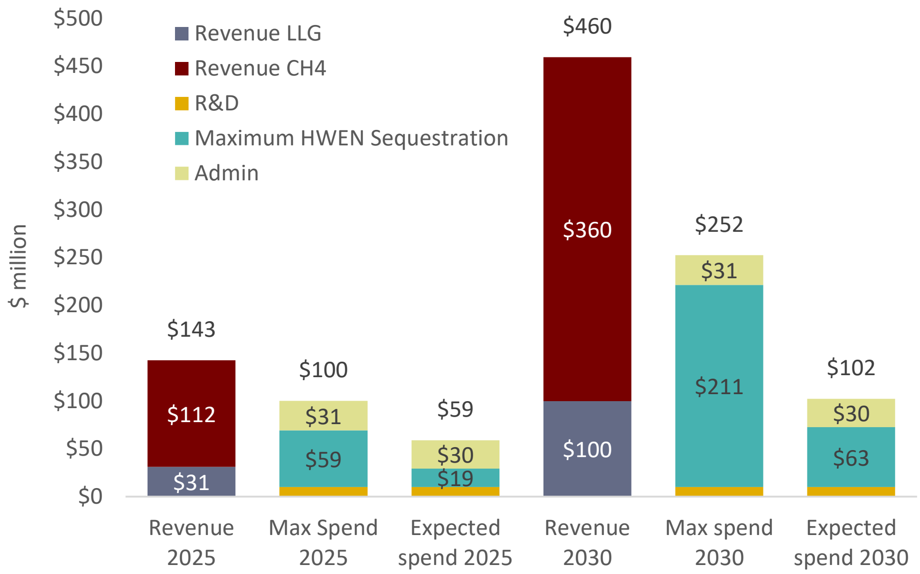
CH4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	LLG	Milk production	Sheep & beef meat production	Dairy profit	Sheep & beef profit	Gross levy revenue
$0.05	$13.80	-0.2%	-0.8%	-0.3%	0.0%	-1.5%	-2.1%	$133
$0.05	$41.40	-0.3%	-2.5%	-0.6%	-0.1%	-2.9%	-6.0%	$281
$0.05	$138.00	-1.2%	-8.4%	-2.1%	-0.3%	-7.0%	-19.2%	$739
$0.11	$41.40	-0.5%	-2.6%	-0.9%	-0.1%	-3.6%	-7.5%	$340
$0.35	$13.80	-0.8%	-1.5%	-1.3%	-0.1%	-5.8%	-12.5%	$460
$0.35	$41.40	-1.0%	-2.9%	-1.6%	-0.2%	-7.2%	-16.2%	$607
$0.35	$138.00	-1.8%	-8.8%	-3.1%	-0.5%	-11.3%	-30.1%	$1,060
$1.00	$13.80	-3.9%	-2.9%	-3.9%	-1.4%	-15.2%	-25.4%	$1,149
$1.00	$41.40	-4.1%	-4.2%	-4.2%	-1.5%	-16.6%	-29.2%	$1,292
$1.00	$138.00	-5.0%	-9.9%	-6.0%	-1.4%	-20.5%	-44.2%	$1,732

[87] Assuming a similar percentage reduction occurs in the waste sector

4.3.4 Revenue Sufficiency

Figure 31 compares the estimates of the revenue raised with estimates of the uses of the revenue. The pricing options used is the same as in the processor ETS; this is 2025 and 2030 prices of \$0.11/kg and \$0.35/kg for CH_4 and \$4.25/t and \$13.80/t CO_2-e for LLGs. As with the PL-ETS, we present the results for maximum and expected expenditure components, including high and average values for administration costs (Table 17) and sequestration payments assuming the full NZU prices and all sequestration available, including pre-2008 natives (see Table 18) or the expected spend with pre-2007 on dairy and sheep & beef farms only. The total revenue raised across all gases is sufficient to cover the estimated uses of the revenue even under the maximum cost assumptions, however the expected payments for sequestration will exceed the revenue raised from LLGs.[88]

Figure 31 Comparison of revenue with call on revenue



4.3.5 High Technology Assumptions

An alternative set of model runs is presented below using high technology assumptions. This assumes lower prices and higher adoption rates. It makes no appreciable difference in 2025 because of the low availability of any technologies. The 2030 results are shown in Table 38.

There are increased reductions in CH_4, eg 2.4% reduction under the highest price setting compared to a 1% reduction for the same prices in Table 37. The impacts are largely from the greater assumed uptake in the sheep & beef sector.

Table 38 Farm Level Levy Results, 2030 with high technology scenario

CH_4 price (\$/kg CH_4)	LLG Price (\$/t CO_2-e)	CH_4	LLG	Milk production	Sheep & beef meat production	Dairy profit	Sheep & Beef profit	Gross levy revenue (\$m)
\$0.05	\$13.80	-0.2%	-0.6%	-0.3%	0.0%	-1.4%	-2.1%	\$130
\$0.35	\$13.80	-2.1%	-0.9%	-1.1%	-0.1%	-5.7%	-12.5%	\$452
\$0.11	\$41.40	-0.5%	-2.5%	-0.8%	-0.1%	-3.6%	-7.5%	\$340
\$0.35	\$41.40	-2.4%	-2.8%	-1.6%	-0.2%	-7.1%	-16.2%	\$598

[88] This is a relevant concern if the intent is for revenue from LLGs to be used towards meeting the net GHG target, but with methane revenue used solely to fund reductions in methane.

4.4 Farm-Level Levy with Output-based Rebate

4.4.1 Description

One of the identified problems with the FLL option is that the charge level set high enough to encourage significant levels of emission reduction, especially using mitigation technologies, may result in high costs for farmers from the charge applied to residual emissions (those not reduced). The costs of charge payment can be a significant percentage of current profit, particularly for sheep and beef farms, eg a 5% reduction in Table 37 was associated with a 44% reduction in profit.

An output-based rebate would use some of the revenue raised from the FLL and redistribute it back to farmers to reduce the impact on profit. To do so, the ideal rebate is one which pays farmers but does not distort the incentive to reduce emissions. A key design element of this approach is therefore that the basis used for calculating the rebate payment is different from that used for calculating emissions, so a farmer that reduces emissions does not receive a lower rebate.

An output-based rebate is paid out on the basis of final output, eg kg of milksolids or meat. If a farmer reduces their emissions, they pay a lower charge but so long as they produce the same quantity of output, they receive the same level of rebate. Thus, in theory, the farmer faces the same marginal incentive to reduce emissions via reduction in emissions intensity of output as under the FLL without facing the same impact on profit. The rebate in this system is effectively like an increase in the price paid for output, and might mimic this even more closely if, say, the levy was paid by the farmer and the rebate was paid to the processor, which is similar to how the ETS functions currently with free allocations given to different parties from those facing surrender obligations.[89]

One of the *He Waka Eke Noa* objectives has been to focus emission reductions on efficiency improvements and the adoption of mitigation technologies (which reduce emissions intensity) rather than via reductions in agricultural output that could result in emissions leakage to other countries rather than a reduction in global emissions.[90] In contrast to a FLL alone, where the impact can be to achieve reductions via reduced output (see Figure 21), especially at high prices, an accompanying output-based rebate introduces an opportunity cost on output reductions.[91]

An output-based rebate is the same approach as used currently for industrial allocation to EITE industries[92] and is similar to the output-based approach suggested by the Interim Climate Change Commission (ICCC) for ETS design.[93]

The emissions charge is calculated using the same approach as for the FLL (A + B – C). The rebate uses the following formula:

$$\text{Rebate} = O_f \times EF_o \times RR \times P_e$$

[89] For example, obligated parties under the ETS include coal suppliers and electricity generators who pass the costs of purchasing NZUs on to consumers of electricity. Because of the high impacts on some exporters, free allocations are provided to protect profit and limit the risks of output reduction and emissions leakage. But these allocations are given to the purchasers of coal and electricity, eg glasshouse owners burning coal and the aluminium smelter using electricity. In agriculture, the farmers are the equivalent of the electricity generators selling their output. A rebate payment paid to processors would enable farmers to increase the price of livestock sales, much as they do currently when the export value of meat or milk increases.

[90] See further discussion in Denne (2022)

[91] Denne (2011)

[92] Ministry for the Environment (2021a)

[93] Interim Climate Change Committee (2019a)

Where: O_f = annual farm output (of milk, meat etc)
EF_o = emission factor per unit of output
RR = % rebate rate
P_e = price (separate for CH_4 and long-lived gases)

The prices for CH_4 and long-lived gas rebates would be the same as those used for the emissions charge.

4.4.2 Modelling

This option has been modelled by assuming the same marginal price effects as for the FLL providing incentives for adoption of mitigation technologies, while the rebate provides revenue to offset the impacts on profit. It is modelled as a low average cost and a high marginal cost of emissions. The rebate limits the impact on profits, and this reduces the incentives for reduced output or land use change.

Because of the very different ways in which the dairy and the sheep & beef models are estimating effects, the results using the FLL plus output-based rebate differ significantly. As noted in Sections 3.5.5 and 3.6.6 above, the dairy model estimates reductions in CH_4 emissions largely via the impacts of prices on farm profit, with low profits resulting in reductions in cattle numbers and in milk production as land is withdrawn from production (or stocking rates are lowered). Because the rebate limits the impacts on profit, there is little emission reduction response in the dairy sector. This outcome would be expected to be somewhat different if there was greater availability or increased effectiveness of technologies, such as the methane inhibitor 3NOP (see Section 3.5.3).

In contrast to the dairy model that is responding to the average costs of emission pricing, the sheep & beef model primarily responds to the marginal price on emissions. Thus the emission reductions are broadly similar to those from the FLL (they are slightly lower because there is less shift of land to forestry from farming being made relatively less profitable to forestry) with a much lower impact on profit.

Potential Perverse effects

For modelling the impacts of this approach, we have not included any potentially distortionary effects. In practice, the system might reward *increases* in output, depending on the emissions intensity of production and the rebate rate. A farm with a low emissions intensity might receive a rebate per unit of output greater than the amount of levy paid averaged over output.

For modelling purposes, we have assumed that this averages out within farm categories, ie there are at least as many farms with net costs (charges > rebates) as with net benefits and that, in aggregate, there is no incentive to produce more because the total rebate paid will be less than the total charge paid (some revenue will be used to pay for sequestration and administration costs). In addition, any incentives to increase output will fall over time as the rebate rate reduces so that, at most, it would be a temporary problem.

4.4.3 Results

The FLL + output-based rebate option was analysed with higher emission prices and an assumed 90% rebate in 2030. The emission reductions estimated were higher from sheep and beef (3.9% reduction in methane compared with 1.3% from dairy, whereas a greater modelled reduction in N_2O

emissions was from dairy farms (12%). The results suggest that sheep & beef farms may have a net positive impact on average, taking account of the value of the rebate and sequestration payments. However, this analysis was undertaken with a larger estimated quantity of available sequestration.

Table 39 Farm Level Levy + Output-based Rebate Results, 2030, including 90% rebate

CH_4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	N_2O	Milk production	Sheep & beef meat production	Dairy profit	Sheep & Beef profit	Gross levy revenue ($m)
$1.75	$70	-2.3%	-6.6%	-0.8%	-3.8%	-3.6%	2.5%	$150

The model results suggest that an emissions price higher than that envisaged as being sustainable under the FLL could be imposed, resulting in emission reductions without the large profit impacts seen in the FLL.

4.4.4 Practical Concerns

The *He Waka Eke Noa* partners chose not to pursue the FLL + output-based rebate further for reasons that include: (1) the perceived potential for perverse incentives to increase production and (2) a perceived requirement for some (complex) market intervention to ensure rebates are passed on in the market to farmers not producing final outputs.[94]

4.5 Farm-Level Levy with Land-based rebate

4.5.1 Description

The FLL with land-based rebate is another levy/rebate system. It stems from a desire to provide a rebate that is fixed so it provides no incentives for changing behaviour.

A simple rebate with the same dollar amount per hectare would provide payments to extensive farms at a level significantly greater than their charge liability. For example, within the sheep & beef industry, South Island high country farms average approximately 15kg CH_4/ha, while intensive finishing farms have emissions close to 200kg CH_4/ha. Providing a rebate at the same $/ha rate has the potential to vastly over-compensate one and/or under-compensate the other. To take account of these issues, the proposed approach provides a rebate using area adjusted for the carrying capacity of the land, ie the land area of a farm times an emission factor that varies with the estimated (or assumed) per hectare carrying capacity.

The emissions charge is calculated using the same approach as for full exposure (A + B – C). The rebate uses the following formula.

Rebate = $L \times EF_{cc} \times RR \times P_e$

Where: L = land area in ha

EF_{cc} = emission factor specific to a given carrying capacity (kg/ha)

4.5.2 Modelling

A practical design of this system was explored but not continued, because of the significant difficulties perceived in developing a mapping system that would produce a widely accepted

[94] Economic theory would suggest a rebate paid on output would flow upwards or downwards in a market, regardless of who the rebate was paid to. Project partners were less convinced.

estimate of carrying capacity. However, on the assumption that it could be developed, the option was modelled using base year stocking rates (by farm class for sheep & beef and by region for dairy) as a proxy for carrying capacity. This captures the important element of the design, ie that:

- the rebate is disconnected from emissions so the incentives exist to reduce emissions via efficiency improvements; and
- the rebate received is close in dollar amount to the charge paid so that costs are minimised.

The results are shown in Table 40.

Table 40 Farm Level Levy + Land-based Rebate Results, 2030, including 90% rebate

CH_4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	N_2O	Milk production	Sheep & beef meat production	Dairy profit	Sheep & Beef profit	Gross levy revenue ($m)
$1.75	$70	-1.8%	-6.7%	-0.1%	-3.7%	-1.8%	3.6%	$61

As with the output-based rebate, the results suggest that sheep & beef farms may have a net positive impact on average, taking account of the value of the rebate and sequestration payments. And as above, the analysis was undertaken with a larger estimated quantity of available sequestration.

4.6 Processor Hybrid

4.6.1 Description

The processor hybrid (PH) option uses a processor level charge to raise revenue, which is then used to fund payments to farmers for emission reductions or sequestration actions taken at the farm level. These emission reductions would be undertaken via a voluntary Emission Management Contract (EMC) which a farmer could choose to agree to but which would then be binding for its duration. Participation would involve additional costs for monitoring and verification of emission reductions.

The charge would be levied on the basis of output at the processor level, using emission factors that reflect average emissions throughout the production of the individual outputs (milk, meat and so on).[95] A discount would be applied initially to reduce the impact, such that the costs would be very similar to those assumed for the Processor ETS option; it is assumed the costs are passed on to farmers via a reduction in the price paid for farm output, and this will in turn be reflected in the value of livestock sales also.

4.6.2 Incentive Effect

In theory the incentive effects of paying for reductions should be the same as charging for emissions for the use of mitigation technologies and for on-farm efficiencies, eg reduced fertiliser use or optimising feed intakes. Economic theory is usually used to suggest charges (at levels equal to the marginal damage costs of emissions) are better (more economically efficient) instruments to address emissions than payments (or subsidies) because charges reduce profit levels in emitting firms, thus achieving some reductions via reduced output and from firms exiting an industry.[96]

[95] As used in the Processor ETS option but here differentiated by gas

[96] See discussion in Baumol and Oates (1988)

For the *He Waka Eke Noa* pricing options one of the considerations has been to achieve emission reductions without reducing output because of the risk of emissions leakage. Thus payments for emission reductions might be favoured if they exclude those from reduced output. Two approaches to EMCs have been explored.

- Benchmark-based. Historical emission benchmarks are set for individual farms and all reductions relative to a benchmark would be counted. This would include those associated with reduced output.

- Action-based. Emissions reductions from a specific action (eg using an identified emission reduction technology such as a vaccine) to be rewarded. Output reduction is excluded.

In analysing this pricing option, the action-based approach has been used for sheep & beef farms, whereas a benchmark approach was used initially for dairy (an action-based approach is included in the updated analysis in Section 4.8). The benchmark has not been used for sheep & beef because it might reward the significant reductions in emissions associated with land use change from farming to forestry which is incentivised by the NZU price. To pay for reductions associated with land use change using *He Waka Eke Noa* funds would be a highly inefficient use of the revenue, achieving no (or very little) additional emission reduction benefits. In dairy, there is little reduced production impact in the base case so the emission reductions are more likely to be additional. They include the use of mitigation technology (3NOP) but the EMC costs are dominated by paying farmers to reduce their livestock numbers and milk output.

One risk of the benchmark EMC is that the incentives are not two-sided. Emission reductions are rewarded but emission increases are not penalised, apart from via the charge on processor output. This may have perverse incentives if, for example, a farm is rewarded in an EMC for reducing livestock numbers while another farm increases livestock while choosing not to sign an EMC. However, theory would suggest this would not happen as all farms face an increase in costs (or a reduction in the value of output) relative to the status quo.

Historical emission benchmarks set for individual farms raise equity issues where some have made historical improvements to emissions intensity. However, there are practical issues of data unavailability in pushing the benchmark year back further to address this.

4.6.3 Modelling

To model the effects of this option, we use the following equation to specify the processor charge for each gas (CH_4 and N_2O):

Processor charge = O_p x (EF_p x P_e) x (1 – DR)

Where: O_p = annual processor output
EF_p = emission factor per unit of output (separately for CH_4 and LLGs)
P_e = emissions charge (separately specified for CH_4 and LLGs)

The emission reduction payment (ERP) is then made on the following basis.

ERP = ER x (P_e x (1 – DR)) x M_E + S x P_s

Where: ER = measured emission reductions (separately for CH_4 and LLGs)
M_E = multiplier applied to the discounted price for emissions
S = measured sequestration
P_s = price paid for sequestration (P_s may be different from P_e)

One complexity to the use of this instrument is the assumed requirement for a fixed cost for farmer participation as there would be a need for greater farm-specific emission monitoring. The benefits to individual farmers would need to exceed that amount before a farmer would sign a contract; the benefits are the amounts paid for emission reductions minus the costs of achieving those reductions. Fixed cost assumptions used are:

- Dairy: $1,000/farm
- Sheep & beef: $2,000/far (for EMC and sequestration management contract)

4.6.4 Results

Results for 2025 are shown in Table 41 using a multiplier of 2.5 and in Table 42 using a multiplier of 5, for a smaller number of price options. Revenue is raised using the prices listed in the table but emission reductions are purchased using that price times the multiplier. In addition to the estimated emission reductions, the results are shown including the gross levy revenue collected from the charge alongside the expenditure on emission reductions under the agreed EMCs and other expected costs that include *He Waka Eke Noa* sequestration (assumed to be paid at $19m – post-2007 dairy and sheep & beef payments in Table 18 paid at 75% of the expected NZU price), administration costs (assuming the average value in Table 17, ie $27 million pa) and an assumed $10 million spent on R&D.

Table 41 Processor Hybrid Results, 2025, 2.5X Multiplier

CH4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	LLG	Milk	S & B meat	Dairy profit	S & B profit	Gross levy revenue ($m)	EMCs ($m)	Other costs ($m)	Net ($m)
$0.05	$4.25	-1.1%	-0.4%	-1.2%	0.0%	-2.6%	-2.2%	$82	$12	$57	$13
$0.05	$21.25	-0.6%	-2.7%	-1.2%	0.2%	-0.6%	-4.3%	$197	$69	$57	$71
$0.05	$85.00	-2.8%	-12.1%	-6.5%	0.8%	10.6%	-11.6%	$604	$443	$57	$104
$0.11	$4.25	-1.2%	0.0%	-1.7%	0.2%	-2.0%	-3.8%	$141	$21	$57	$63
$0.11	$21.25	-1.0%	-2.1%	-2.1%	0.3%	-0.9%	-5.8%	$255	$77	$57	$122
$0.11	$85.00	-3.2%	-11.9%	-7.4%	0.9%	10.3%	-12.9%	$658	$454	$57	$147
$1.00	$4.25	-7.8%	-6.1%	-15.4%	2.2%	1.9%	-26.9%	$997	$383	$57	$558
$1.00	$21.25	-8.8%	-9.1%	-17.3%	2.1%	5.3%	-29.9%	$1,088	$492	$57	$539
$1.00	$85.00	-12.0%	-14.9%	-23.7%	1.8%	20.5%	-40.2%	$1,407	$978	$57	$373

Table 42 Processor Hybrid Results, 2025, 5X Multiplier

CH4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	LLG	Milk	S & B meat	Dairy profit	S & B profit	Gross levy revenue ($m)	EMCs ($m)	Other costs ($m)	Net ($m)
$0.05	$4.25	-0.8%	0.0%	-1.3%	0.0%	-0.8%	-2.2%	$82	$31	$57	-$6
$0.11	$4.25	-1.3%	-0.3%	-2.5%	-0.2%	-0.2%	-3.8%	$141	$52	$57	$32
$0.11	$21.25	-2.1%	-5.9%	-4.1%	-0.3%	4.3%	-5.8%	$252	$194	$57	$2

There are some curious results, eg methane emissions rising as the LLG price rises (see the 4th and 5th pricing options in Table 41 for example where methane reduction falls from 1.2% to 1.0% as the LLG price rises from $4.25/t to $21.25/t). This reflects feedbacks between the LLG price and methane in the dairy model. A price on LLG increases the costs of fertiliser and feed, resulting in reduced starting feed intake and reduced methane emissions per cow. This in turn affects the economics of 3NOP, such that much less is adopted.

Revenue Sufficiency

Under the 2.5x multiplier, there is surplus revenue at all prices examined. At a 5X multiplier there is some revenue shortfall for the lowest charge rate (insufficient revenue to pay for the assumed fixed costs required). The highest charge rate comes close to not breaking even because there is a higher spend on EMCs with the higher multiplier

The 2030 results are shown in Table 43 (2.5x) and Table 44 (5x). There is some revenue shortfall under both multipliers.

Table 43 Processor Hybrid Results, 2030, 2.5X Multiplier

CH4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	LLG	Milk	S & B meat	Dairy profit	S & B profit	Gross levy revenue ($m)	EMCs ($m)	Other costs ($m)	Net ($m)
$0.05	$13.80	-0.5%	-1.4%	-0.7%	0.0%	-1.4%	-0.5%	$147	$41	$100	$6
$0.05	$41.40	-1.4%	-7.1%	-2.8%	-0.1%	2.1%	-4.4%	$330	$167	$100	$63
$0.05	$138	-5.2%	-19.0%	-11.1%	-0.3%	24.1%	-17.5%	$919	$856	$100	-$37
$0.11	$41.40	-3.6%	-6.4%	-7.6%	-0.1%	-1.6%	-5.9%	$497	$234	$100	$163
$0.35	$13.80	-3.8%	-5.2%	-5.9%	-0.1%	-3.5%	-7.5%	$452	$119	$100	$233
$0.35	$41.40	-4.2%	-6.4%	-7.6%	-0.2%	1.4%	-14.4%	$622	$240	$100	$282
$0.35	$138	-8.5%	-19.0%	-16.5%	-0.5%	24.7%	-28.3%	$1,169	$967	$100	$103
$1.00	$13.80	-10.3%	-9.6%	-16.6%	-1.4%	3.7%	-23.1%	$1,053	$464	$100	$489
$1.00	$41.40	-12.0%	-14.8%	-19.8%	-1.5%	10.2%	-26.7%	$1,194	$672	$100	$423
$1.00	$138	-16.7%	-22.8%	-29.1%	-1.4%	38.3%	-42.2%	$1,648	$1,524	$100	$24

Table 44 Processor Hybrid Results, 2030, 5X Multiplier

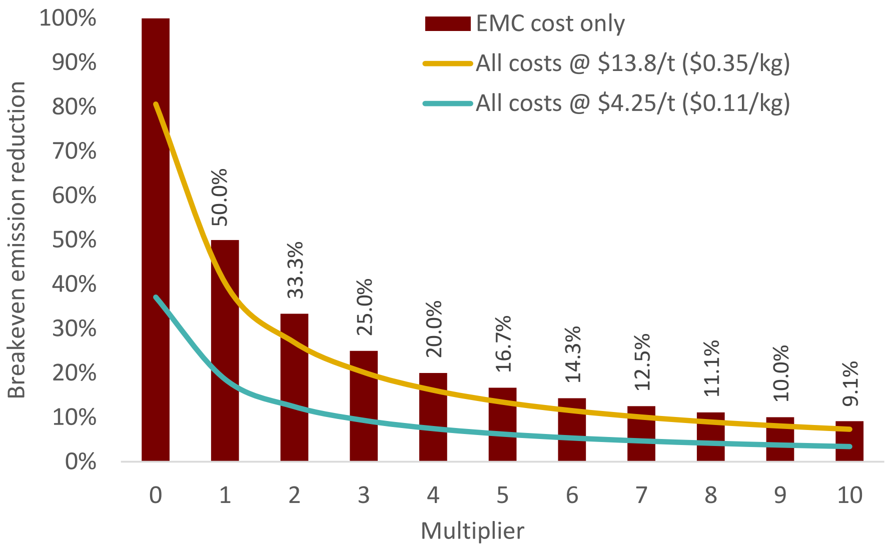
CH4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	LLG	Milk	S & B meat	Dairy profit	S & B profit	Gross levy revenue ($m)	EMCs ($m)	Other costs ($m)	Net ($m)
$0.05	$13.80	-0.9%	-3.5%	-1.7%	0.0%	1.6%	-0.5%	$143	$101	$100	-$59
$0.35	$13.80	-6.3%	-9.2%	-10.1%	-0.1%	-0.1%	-6.8%	$441	$317	$100	$24
$0.11	$41.40	-3.2%	-11.8%	-6.6%	-0.1%	10.1%	-6.0%	$377	$442	$100	-$166
$0.35	$41.40	-7.8%	-12.8%	-13.6%	-0.2%	15.2%	-13.7%	$596	$655	$100	-$159

The relationship between the multiplier (M) and the emission reduction that would result in zero revenue can be estimated (assuming no other use of the revenue) at any emissions price using a simple formula of 1/(1 + M).[97] This is illustrated by the columns in Figure 32. Any additional spend (on administration costs, sequestration and so on), reduce the breakeven emission reduction

[97] For example, if a charge of $1/kg raises $100 million from 100 million kg of emissions with no multiplier, but with a multiplier of 7 emissions reduce by 12.5% (to 87.5 million kg) then revenue raised falls to $87.5 million. This is the same as would be paid out to those reducing emissions ($7/kg x 12.5 million kg reduced).

further, as shown by the two lines in Figure 32 which are the breakeven reductions if $100m is spent on these other costs. In Table 44 there is insufficient revenue from a low charge (on CH_4) or where the emission reductions are high.

Figure 32 Relationship between multiplier and breakeven emission reduction

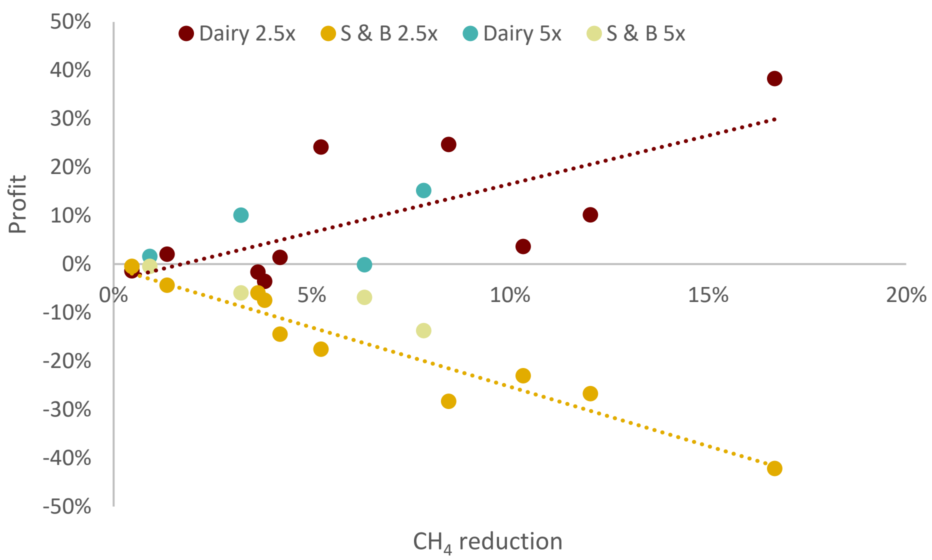


This suggests a careful balance needs to be struck with the use of the multiplier; it needs to be sufficiently high to achieve emission reductions when the emission reduction potential is relatively low, but as potential emission reductions rise (eg with mitigation technologies with 30% effectiveness), the multiplier might need to be scaled back.

Emission Reductions

Very different relationships between emission reductions and profit were seen in the individual models (Figure 33).

Figure 33 Relationship between CH_4 reductions and profit for different farming sectors – processor hybrid 2030 (2.5 and 5x multipliers)



Higher CH_4 emission reductions resulted in high profit loss in sheep & beef because they were associated with higher charge rates, but with relatively few opportunities to reduce emissions and receive an EMC payment. In contrast, for the dairy sector increased CH_4 emission reductions were associated (broadly) with an increase in profit because the EMC payments were larger than the costs associated with reducing livestock numbers (loss of marginal profit).

Some price combinations showed promise for significant emission reductions (a 5% reduction in CH_4 was seen by the partners as something to aim for because, added to the 4.5% estimated reduction in the base case (Table 7), this would approach the 2030 domestic target of a 10% reduction in biogenic methane) with relatively small reductions in profit and in production. Additional analysis focussed on sensitivity analysis with high technology assumptions and pricing options that included low emissions prices combined with higher multipliers.

4.6.5 Alternative Assumptions

Table 45 shows results for 2030 for low charges (no higher than expected in the processor-level ETS) with different multipliers, and with benchmark-based and actions-based EMCs.

Table 45 Processor Hybrid Results, 2030, Benchmark and Action-Based, Medium Technology Assumptions

CH4 price ($/kg CH4)	LLG price ($/t CO2-e)	Multi-plier	CH_4	LLG	Milk	Meat	Dairy profit	S&B profit	Revenue ($m)	EMCs ($m)	Net ($m)
Benchmark											
$0.35	$13.80	2.5	-3.8%	-5.2%	-5.9%	-0.1%	-3.5%	-7.5%	$452	$119	$242
$0.35	$13.80	5	-6.3%	-9.2%	-10.1%	-0.1%	-0.1%	-6.8%	$441	$317	$34
$0.35	$13.80	7	-9.4%	-12.5%	-14.0%	-0.1%	3.2%	-6.2%	$431	$556	-$216
$0.17	$13.80	7	-4.7%	-9.7%	-7.7%	0.0%	1.9%	-1.0%	$270	$286	-$106
Actions-based											
$0.35	$13.80	2.5	-1.7%	-1.2%	-1.8%	-0.1%	-5.8%	-7.5%	$460	$4	$365
$0.35	$13.80	5	-2.2%	-1.3%	-1.8%	-0.1%	-5.7%	-6.8%	$460	$17	$353
$0.35	$13.80	7	-3.0%	-1.5%	-1.8%	-0.1%	-5.7%	-6.2%	$460	$48	$322
$0.35	$13.80	10	-5.1%	-2.0%	-5.1%	-5.2%	-1.7%	-0.1%	$460	$150	$219
$0.17	$13.80	7	-1.5%	-0.6%	-1.0%	0.0%	-3.5%	-1.0%	$278	$7	$181

The results suggest the actions-based emissions reductions are two to four percentage points lower than with benchmark EMCs. Under the actions-based EMC, a maximum 5% reduction in CH_4 is possible with a 10x multiplier and prices of \$0.35/kg CH_4 and \$13.80/t CO_2-e (the same as assumed under the ETS). A 10x multiplier is equivalent to paying the full NZU price for emission reductions. This would not be possible under the benchmark approach as payments using a multiplier above approximately 5x are estimated to exceed the amount of revenue available. The 10x multiplier with an actions-based EMC has low estimated impacts on profit, less than 2% for both dairy and sheep & beef.

Table 46 shows the results using the same assumptions but with high technology assumptions, as noted in the model sections above.[98] There is a significant increase in the emission reductions, particularly under the actions-based EMCs. This also means more is paid out under the EMCs so a 10x multiplier, as used above, would exhaust the available revenue.

[98] The two models take different approaches to technology uptake. Reflecting this, the high technology assumptions are a doubling of the technology efficacy in dairy and a doubling of the starting uptake rate for sheep & beef plus a halving of price.

Table 46 Processor Hybrid Results, 2030, Benchmark and Action-Based, High Technology Assumptions

CH4 price ($/kg CH4)	LLG Price ($/t CO2-e)	Multi-plier	CH_4	LLG	Milk	Meat	Dairy profit	S&B profit	Revenue ($m)	EMCs ($m)	Net ($m)
Benchmark											
$0.35	$13.80	2.5	-4.3%	-2.8%	-5.5%	-0.1%	-3.9%	-7.3%	$450	$118	$242
$0.35	$13.80	5	-11.3%	-7.9%	-9.6%	-0.1%	0.0%	-6.4%	$439	$410	-$61
$0.35	$13.80	7	-15.2%	-11.5%	-13.1%	-0.1%	4.5%	-5.8%	$430	$715	-$375
$0.17	$13.80	7	-7.5%	-7.5%	-7.0%	0.0%	1.2%	-0.8%	$269	$307	-$129
Actions-based											
$0.35	$13.80	2.5	-2.2%	-1.4%	-1.8%	-0.1%	-5.7%	-7.3%	$460	$9	$360
$0.35	$13.80	5	-7.9%	-2.8%	-1.7%	-0.1%	-5.0%	-6.4%	$460	$131	$239
$0.35	$13.80	7	-11.5%	-3.3%	-3.4%	-5.8%	-1.3%	-0.1%	$461	$289	$82
$0.35	$13.80	10	-13.2%	-4.2%	-0.2%	-4.7%	-1.0%	-0.1%	$462	$487	-$115
$0.17	$13.80	7	-3.6%	-1.5%	-1.1%	0.0%	-3.3%	-0.8%	$278	$37	$151

4.7 Farm Level Levy with Technology Support

4.7.1 Description

This option is a FLL with some of the revenue used to purchase emission reductions in addition to those incentivised by the charge. As with the PH, the payments would be based on a multiplier, but unlike the PH the payments would be limited to emission reductions associated with use of technologies only. There would be no reward for emission reductions associated with reductions in production. It is unlikely that on-farm efficiencies would be rewarded, because they require the use of an historical benchmark.

Payments might be made via an EMC in a similar way to the PH, although a simpler approach might be to subsidise the companies producing the technologies so they could be supplied at a reduced price, while the incentive to use the technologies is based on the farm-level levy. There are risks with this approach, depending on the relative market power of the technology supplier (and price elasticity of demand) and thus their potential to retain the subsidy rather than passing it on in lower prices.

The FLL + technology support option relies for its effectiveness on the rapid introduction of mitigation technologies. This is uncertain, but for modelling we assume the availability based on the assumptions discussed in Sections 3.5.3 and 3.6.4.

4.7.2 Modelling

To model this option it is assumed that the price of technologies is reduced (subsidised) and that there is an incentive to use the technologies based on the emissions prices.

The FLL + technology support option was identified later in the programme and a full set of prices have not been analysed. Specifically, the analysis focussed on lower prices and did not include runs with $1/kg CH_4.

4.7.3 Results

The results are shown in Table 47 for 2025 and in Table 48 for 2030. The results include medium and high technology assumptions. The 2025 results are shown for a 2.5x multiplier, although there is no measurable uptake at this or higher multipliers because of the assumed low availability of technologies by this date. The 2030 results use a range of multipliers.

Table 47 FLL + Technology Payments Results 2025 (2.5x multiplier), medium technology

CH4 price ($/kg CH4)	LLG Price ($/t CO2-e)	CH_4	LLG	Milk	Meat	Dairy profit	S&B profit	Revenue ($m)	Net ($m)
Medium Technology									
0.05	$4.25	-0.1%	-0.5%	-0.2%	0.0%	-0.9%	-2.2%	$77	$4
$0.11	$4.25	-0.2%	-0.5%	-0.3%	-0.2%	-1.8%	-3.7%	$140	$66
$0.11	$21.25	-0.2%	-1.4%	-0.4%	-0.3%	-2.7%	-5.7%	$235	$161
High Technology									
$0.05	$4.25	-0.1%	-0.4%	-0.2%	0.0%	-0.9%	-2.2%	$77	$3
$0.11	$4.25	-0.3%	-0.5%	-0.3%	-0.2%	-1.7%	-3.8%	$139	$65
$0.11	$21.25	-0.4%	-1.4%	-0.4%	-0.3%	-2.6%	-5.8%	$233	$159

The 2025 results have very low emission reductions because of the relatively low prices and technology availability. The net costs include payment for R&D ($10m), sequestration (assuming the price paid is 75% of the NZU price and a total of $19 million), admin costs based on the averages of the costs in Table 17 ($45 million pa).

Table 48 FLL + Technology Payments Results 2030

CH4 price ($/kg CH4)	LLG Price ($/t CO2-e)	Multi-plier	CH_4	LLG	Milk	Meat	Dairy profit	S&B profit	Rev-enue ($m)	Tech pay-ments ($m)	Net ($m)
Medium Technology											
$0.05	$13.80	5	-0.2%	-1.4%	-0.3%	0.0%	-1.4%	-0.5%	$129	$0	$12
$0.35	$13.80	5	-2.3%	-1.8%	-1.2%	-0.1%	-5.6%	-10.6%	$439	$7	$314
$0.11	$41.40	5	-0.5%	-3.0%	-0.9%	-0.1%	-3.6%	-5.8%	$340	$0	$223
$0.35	$41.40	5	-2.6%	-3.5%	-1.6%	-0.2%	-7.0%	-14.2%	$585	$7	$460
$0.17	$13.80	7	-1.8%	-1.8%	-0.7%	0.0%	-3.3%	-1.2%	$269	$6	$170
$0.17	$13.80	10	-2.0%	-1.9%	-0.7%	0.0%	-3.3%	-1.2%	$268	$10	$165
$0.35	$13.80	7	-4.0%	-2.9%	-1.4%	-0.1%	-5.6%	-7.2%	$449	$53	$304
$0.35	$13.80	10	-6.0%	-3.3%	-1.2%	-0.1%	-4.7%	-7.2%	$441	$150	$198
High Technology											
$0.05	$13.80	5	-0.2%	-1.4%	-0.3%	0.0%	-1.4%	-0.5%	$128	$0	$11
$0.35	$13.80	5	-10.4%	-4.1%	-1.0%	-0.1%	-4.1%	-10.7%	$244	$9	$118
$0.11	$41.40	5	-0.7%	-3.1%	-0.9%	-0.1%	-3.6%	-5.9%	$338	$0	$221
$0.35	$41.40	5	-10.9%	-5.9%	-1.4%	-0.2%	-5.4%	-14.3%	$383	$9	$257
$0.17	$13.80	7	-5.5%	-3.2%	-0.7%	0.0%	-3.0%	-1.2%	$260	$54	$113
$0.17	$13.80	10	-9.1%	-4.2%	-0.6%	0.0%	-2.2%	-1.2%	$252	$147	$13
$0.35	$13.80	7	-12.8%	-4.9%	-0.8%	-0.1%	-2.4%	-7.3%	$412	$299	$20
$0.35	$13.80	10	-13.8%	-5.5%	-0.5%	-0.1%	0.9%	-7.2%	$408	$469	-$154

The 2030 results show technology payments at higher prices and multipliers. The results suggest, even with the medium technology assumptions, using high multipliers (7 or 10) that CH_4 emission reductions of 4-6% coupled with LLG emission reductions of approximately 3%, are possible with emission prices at expected levels under the ETS backstop. These prices have impacts on profit of less than 10% and have estimated positive net revenue after paying for administration costs (assumed at $29.5 million – the average cost for FLL + tech payments in Table 17), sequestration (assumed at $63 million based on payment of $104/t CO_2, ie 75% of $138/t CO_2) and an R&D contribution.

The high technology option shows greater emission reductions, similar impacts on profits and a larger draw on revenue for technology payments. At the highest multiplier and high emission reductions there is a net negative result (costs exceed revenue). The same principles apply as illustrated in Figure 32 above. For the FLL + technology payment option, over time as more emission reduction opportunities arise with technology development, the emphasis may need to shift from the incentive of the emission reduction payment to the charge itself.

4.8 Summary of Quantified Impacts

4.8.1 2025 Results

Table 49 shows the impacts estimated for 2025. The results are for relatively low prices, based on those expected under the PL-ETS in 2025. This assumes an NZU price of $85/t and a 95% allocation, equivalent to a net cost of $4.25/t CO_2-e or $0.11/kg of CH_4.

Table 49 Summary of Pricing Option Impacts, 2025

	CH_4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	LLG	Milk	Meat	Dairy Profit	Sheep & beef profit	Gross levy revenue ($m)
Baseline			-2.0%	-1.8%	-1.2%	-3.2%	-2.8%	26.2%	$0
PL–ETS	$0.11	$4.25	-0.2%	-0.2%	-0.5%	-0.2%	-1.7%	-4.1%	$140
FLL	$0.05	$4.25	-0.1%	-0.1%	-0.2%	0.0%	-1.0%	-2.2%	$80
	$0.11	$4.25	-0.2%	-0.5%	-0.3%	-0.2%	-1.8%	-3.7%	$143
	$0.11	$21.25	-0.3%	-1.2%	-0.5%	-0.3%	-2.7%	-5.7%	$236
PH - B	$0.05	$4.25	-1.1%	-0.4%	-1.2%	0.0%	-2.6%	-2.2%	$82
(2.5x)	$0.11	$4.25	-1.2%	0.0%	-1.7%	0.2%	-2.0%	-3.8%	$141
	$0.11	$21.25	-1.0%	-2.1%	-2.1%	0.3%	-0.9%	-5.8%	$255
FLL+Tech	$0.05	$4.25	-0.1%	-0.5%	-0.2%	0.0%	-0.9%	-2.2%	$77
(5x)	$0.11	$4.25	-0.2%	-0.5%	-0.3%	-0.2%	-1.8%	-3.7%	$140
	$0.11	$21.25	-0.2%	-1.3%	-0.4%	-0.3%	-2.7%	-5.7%	$235

Note: PH – B = PH with benchmark-based EMCs

The baseline effects are the impacts of the freshwater regulations and the existing ETS (for forestry only) relative to the 2017 base. The impacts of the other options are all relative to this baseline. This means the effects are additional, ie the impacts of the PH + benchmark EMCs with prices of $0.11 and $21.25 are an estimated 1% reduction in methane; this adds to the 2% from the baseline, resulting in a total estimate of a 3% reduction in 2025.

The emission impacts of all options are relatively low initially. The PL-ETS has a slightly higher estimated impact on emissions than does the FLL using the same prices. This is likely to be the result of slightly different emission factors used rather than a greater effectiveness in practice. We would expect the FLL to have a larger effect because it provides incentives for emission reduction options that are not incentivised by the PL-ETS.

The PH has a greater impact on emissions than the FLL at the lowest prices because of the impacts of the multiplier on marginal incentives for emission reductions. For sheep and beef farms this results in additional use of technologies. For dairy, this is largely via reductions in cattle numbers and in milk production.

The FLL with technology payments option results in greater emission reductions than the FLL alone, but lower reductions than the PH. We have not included the impacts on horticulture and arable land because they are very small at these low emission prices.

4.8.2 2030 Results

Table 49 shows the impacts in 2030. The pricing basis includes an assumed NZU price in 2030 of \$138/t and 90% free allocation in the PL-ETS backstop, resulting in a net cost of \$13.80/t CO_2-e and \$0.35/kg CH_4. Pricing options are highlighted that result in methane reductions of 4% or more, profit impacts of under 10% and with positive net revenue. This includes examples from PH and FLL + technology payment options.

Table 50 Summary of Pricing Option Impacts, 2030

	CH_4 price (\$/kg CH_4)	LLG Price (\$/t CO_2-e)	Multi-plier	CH_4	LLG	Milk	Meat	Dairy Profit	Sheep & beef profit	Gross levy revenue (\$m)	Net (\$m)
Base Case				-4.5%	-3.8%	-1.2%	-8.1%	-1.6%	127%	\$0	\$0
PL–ETS	\$0.35	\$13.80		-0.8%	-1.5%	-1.3%	-0.1%	-5.8%	-10.9%	\$451	?
FLL	\$0.05	\$13.80		-0.5%	-2.6%	-0.9%	-0.1%	-3.6%	-5.8%	\$133	\$39
	\$0.35	\$13.80		-1.0%	-2.9%	-1.6%	-0.2%	-7.2%	-14.5%	\$460	\$366
	\$0.11	\$41.40		-0.9%	-3.5%	-1.7%	0.0%	1.6%	-0.5%	\$340	\$247
	\$0.35	\$41.40		-3.6%	-6.4%	-7.6%	-0.1%	-1.6%	-5.9%	\$607	\$513
PH–B	\$0.05	\$13.80	2.5	-0.9%	-3.5%	-1.7%	0.0%	1.6%	-0.5%	\$143	-\$59
	\$0.11	\$41.40	2.5	-3.6%	-6.4%	-7.6%	-0.1%	-1.6%	-5.9%	\$497	\$163
	\$0.35	\$41.40	2.5	-4.2%	-6.4%	-7.6%	-0.2%	1.4%	-14.4%	\$622	\$282
	\$0.17	\$13.80	7	-4.7%	-9.7%	-7.7%	0.0%	1.9%	-1.0%	\$270	-\$115
	\$0.35	\$13.80	2.5	-3.8%	-5.2%	-5.9%	-0.1%	-3.5%	-7.5%	\$452	\$233
	\$0.35	\$13.80	5	-6.3%	-9.2%	-10.1%	-0.1%	-0.1%	-6.8%	\$441	\$24
	\$0.35	\$13.80	7	-9.4%	-12.5%	-14.0%	-0.1%	3.2%	-6.2%	\$431	-\$225
PH–AB	\$0.17	\$13.80	7	-1.5%	-0.6%	-1.0%	0.0%	-3.5%	-1.0%	\$278	\$171
	\$0.35	\$13.80	2.5	-1.7%	-1.2%	-1.8%	-0.1%	-5.8%	-7.5%	\$460	\$356
	\$0.35	\$13.80	5	-2.2%	-1.3%	-1.8%	-0.1%	-5.7%	-6.8%	\$460	\$343
	\$0.35	\$13.80	7	-3.0%	-1.5%	-5.7%	-6.2%	-1.8%	-0.1%	\$460	\$312
	\$0.35	\$13.80	10	-5.1%	-2.0%	-5.1%	-5.2%	-1.7%	-0.1%	\$460	\$210
FLL+ tech	\$0.05	\$13.80	5	-0.2%	-1.4%	-0.3%	0.0%	-1.4%	-0.5%	\$129	\$27
	\$0.11	\$41.40	5	-0.5%	-3.0%	-0.9%	-0.1%	-3.6%	-5.8%	\$340	\$238
	\$0.35	\$41.40	5	-2.6%	-3.5%	-1.6%	-0.2%	-7.0%	-14.2%	\$585	\$477
	\$0.35	\$13.80	2.5	-2.5%	-2.4%	-1.4%	-0.1%	-5.8%	-7.4%	\$456	\$339
	\$0.35	\$13.80	5	-2.8%	-2.2%	-1.4%	-0.1%	-5.8%	-7.3%	\$455	\$343
	\$0.35	\$13.80	7	-4.0%	-2.9%	-1.4%	-0.1%	-5.6%	-7.2%	\$449	\$295
	\$0.35	\$13.80	10	-6.0%	-3.3%	-1.2%	-0.1%	-4.7%	-7.2%	\$441	\$189

Note: PH–B = PH with benchmark-based EMCs; Note: PH–AB = PH with action-based EMCs

4.8.3 High Technology Scenario

Table 51 provides the 2030 results using high technology options, ie assuming greater availability and/or lower costs. If these improvements are obtainable, it suggests value in efforts to rapidly advance the technologies and in pricing options that incentivise them.

The high technology results show greater emission reductions and more pricing options that are forecast to achieve significant reductions with low profit impacts and positive net revenue.

Table 51 Summary of Pricing Option Impacts, 2030 with high technology assumptions

	CH_4 price (\$/kg CH_4)	LLG Price (\$/t CO_2-e)	Multi-plier	CH_4	LLG	Milk	Meat	Dairy Profit	Sheep & beef profit	Gross levy revenue (\$m)	Net (\$m)
Base Case				-4.5%	-3.8%	-1.2%	-8.1%	-1.6%	127%	\$0	\$0
PL–ETS	\$0.35	\$13.80		-0.8%	-0.6%	-1.8%	-0.1%	-5.5%	-14.7%	\$451	?
FLL	\$0.05	\$13.80		-0.2%	-0.6%	-0.3%	0.0%	-1.4%	-0.5%	\$130	\$36
	\$0.35	\$13.80		-2.1%	-0.9%	-1.1%	-0.1%	-5.7%	-10.9%	\$452	\$358
	\$0.11	\$41.40		-0.5%	-2.5%	-0.8%	-0.1%	-3.6%	-5.9%	\$340	\$247
	\$0.35	\$41.40		-2.4%	-2.8%	-1.6%	-0.2%	-7.1%	-14.5%	\$598	\$504
PH–B	\$0.05	\$13.80	2.5	-1.1%	-3.4%	-1.6%	0.0%	1.6%	-0.5%	\$143	-\$58
	\$0.11	\$41.40	2.5	-4.7%	-6.9%	-7.4%	-0.1%	-1.2%	-6.0%	\$498	\$149
	\$0.35	\$41.40	2.5	-14.0%	-16.3%	-13.3%	-0.2%	21.2%	-13.4%	\$597	-\$336
	\$0.17	\$13.80	7	-7.5%	-7.5%	-7.0%	0.0%	1.2%	-0.8%	\$269	-\$139
	\$0.35	\$13.80	2.5	-4.3%	-2.8%	-5.5%	-0.1%	-3.9%	-7.3%	\$450	\$232
	\$0.35	\$13.80	5	-11.3%	-7.9%	-9.6%	-0.1%	0.0%	-6.4%	\$439	-\$71
	\$0.35	\$13.80	7	-15.2%	-11.5%	-13.1%	-0.1%	4.5%	-5.8%	\$430	-\$385
PH–AB	\$0.17	\$13.80	7	-3.6%	-1.5%	-1.1%	0.0%	-3.3%	-0.8%	\$278	\$142
	\$0.35	\$13.80	2.5	-2.2%	-1.4%	-1.8%	-0.1%	-5.7%	-7.3%	\$460	\$351
	\$0.35	\$13.80	5	-7.9%	-2.8%	-1.7%	-0.1%	-5.0%	-6.4%	\$460	\$229
	\$0.35	\$13.80	7	-11.5%	-3.3%	-3.4%	-5.8%	-1.3%	-0.1%	\$461	\$72
	\$0.35	\$13.80	10	-13.2%	-4.2%	-0.2%	-4.7%	-1.0%	-0.1%	\$462	-\$125
FLL+	\$0.05	\$13.80	5	-0.2%	-1.4%	-0.3%	0.0%	-1.4%	-0.5%	\$128	\$26
tech	\$0.11	\$41.40	5	-0.7%	-3.1%	-0.9%	-0.1%	-3.6%	-5.9%	\$338	\$236
	\$0.35	\$41.40	5	-10.9%	-5.9%	-1.4%	-0.2%	-5.4%	-14.3%	\$383	\$254
	\$0.35	\$13.80	2.5	-4.8%	-3.0%	-1.4%	-0.1%	-5.7%	-7.5%	\$446	\$177
	\$0.35	\$13.80	5	-10.6%	-4.6%	-1.2%	-0.1%	-4.3%	-7.3%	\$421	\$173
	\$0.35	\$13.80	7	-12.8%	-4.9%	-0.8%	-0.1%	-2.4%	-7.3%	\$412	\$11
	\$0.35	\$13.80	10	-13.8%	-5.5%	-0.5%	-0.1%	0.9%	-7.2%	\$408	-\$163

Note: PH–B = PH with benchmark-based EMCs; Note: PH–AB = PH with action-based EMCs

4.8.4 Impacts on Emissions Intensity

Table 52 shows the estimated impacts of pricing options on emissions intensity in 2030 with medium and high technology assumptions. There is no estimated impact in 2025.

Table 52 Pricing Option Impacts on2030 Emissions Intensity – Medium & High Technology Assumptions

Option	CH_4 price ($/kg)	LLG Price ($/t CO_2-e)	Multi-plier	Dairy intensity[1] (Medium)	S&B intensity[2] (Medium)	Dairy intensity[1] (High)	S&B intensity[2] (High)
Base Case				10.9	20.3	10.9	20.3
PL-ETS	$0.35	$13.80		10.9	20.3	10.9	20.3
FLL	$0.35	$13.80		10.9	20.3	10.9	19.7
PH-BM	$0.35	$13.80	5	10.9	20.0	9.9	19.9
PH-AB	$0.35	$13.80	7	10.8	20.0	9.2	20.0
FLL + Tech	$0.35	$13.80	7	10.6	19.8	9.0	19.7

[1] kg CO_2-e/kg MS; [2] kg CO2-e/kg meat

4.9 Uncertainties

There are some uncertainties surrounding these results. These include the following.

- The assumptions under the base case around future afforestation rates. NZU prices are rising which would suggest higher additional rates of planting, but our ability to predict the response is limited by the historical record being based on lower prices. Set against this, the Government has recently produced a discussion paper suggesting that some limits might be placed on new exotic afforestation.

- The potential for efficiency improvements. These are included in the modelling of the dairy farming response, but not for sheep & beef farming. This is likely to be consistent with the actual response but we may be underestimating the potential.

- The rate of technology development. The effectiveness of some of the pricing options depends on the relatively rapid development and commercialisation of mitigation technologies. A slower rate of development is a risk of these options. Set against this, reasonably conservative assumptions have been used on rates of uptake.

- The effects of land use change in the dairy sector. The models used is focussed on the dairy sector and does not simulate what would happen to land if dairy production is made unprofitable. There may be some additional land use activity that produces emissions.

5 Cost Benefit Analysis

5.1 Approach

5.1.1 Differences from Sectoral Analysis

In this section we compile the results to estimate the impacts at a national level using social cost benefit analysis (CBA) rather than the sectoral analysis discussed above.

The key differences are:

- The payments of emission charges or the payments for emission reductions (under EMCs etc) are treated as transfer payments only. They move money between the Government and farmers and growers but they do not change the total amount of money in New Zealand.

- Costs (and reductions in costs) arise when something is done that otherwise would not. This includes reduced expenditure on inputs (eg feed), lower revenues when livestock numbers are reduced, costs of tree planting and fencing, plus administration costs.

- Benefits of emission reductions are included in the analysis in monetary terms. This is the estimated benefit to New Zealand of reducing emissions in agriculture which means less emission reduction is required in other sectors (or less purchase of emission reduction credits from abroad).

- Costs and benefits in future time periods are discounted relative to 2022 and summed to estimate a net present value (NPV).

These elements are explained in some more detail below.

5.1.2 Partial Equilibrium Analysis

CBAs differ from economic impact assessments (EIAs) which measure impacts using effects on indicators such as GDP or value added. These may use computable general equilibrium models (CGE) or more simple models using multipliers that estimate impacts upstream or downstream from the initial impact. A separate analysis is considering these wider effects in the economy. CBAs limit the consideration of effects to the sectors being examined, while usually assuming any wider effects are subsumed in market prices operating in competitive markets. So for example, if the emissions pricing regime leads to a reduction in output of milk, the effects of this are assumed to be limited to the impacts on profit in the dairy sector (or the profit of any land use that displaces current dairy farms). There is assumed to be no additional impact on upstream suppliers to dairy farms or downstream processors of milk because all prices are assumed to be based on opportunity costs, ie they reflect the value the resources used could obtain if used in some other activity. If less milk is produced, the firms operating upstream and downstream of dairy farms adjust and redeploy their labour and other resources elsewhere.[99]

[99] Consistent with this, NZ Treasury suggests that, apart from unique circumstances of specialised employment, "multiplier effects do not exist", recommending that they are ignored unless there is high unemployment (NZ Treasury 2015) *Guide to Social Cost Benefit Analysis*.

CBA is measuring the effects after there has been adjustments in the economy. In practice there will be short run costs during this time of adjustment. This is likely to include some mix of people moving location to find new employment, firms ceasing to operate and others starting. CBAs are therefore described as partial equilibrium analyses; they are partial in that they limit the consideration of effects to part of the economy and they are equilibrium analyses in that they measure effects as they would be after a period of adjustment. The CBA described here uses these standard CBA assumptions.

5.2 Components of Analysis

5.2.1 Opportunity Costs

All costs are measured as opportunity costs. The cost of using a resource for one thing is the missed opportunity to use it for something else that has a value. So, for example, if there is a labour cost associated with the administration of the pricing scheme, the labour cost is the value of that labour if it had been used for some other activity. The market wage rate is assumed to represent this cost, apart from when there is high unemployment (which there is not currently) or when wage rates are artificially raised above market rates. Similar approaches are taken for other costs, eg the opportunity cost of reducing animal numbers is the lost profit that results, and the opportunity cost of building a fence includes the labour cost and the cost of the materials that could have been used elsewhere.

Administration costs

The administration costs use the same input data as used in the Administration Costs report.[100] The present value of costs is estimated for 2021/22, based on costs for all years from 2021/22 to 2029/30. The Administration Costs report estimated the PV of costs in the 2020/21 year.

For the farm level levy IT costs are significant and up-front and will result in high costs when the timeframe for analysis is only to 2030. The IT systems are assumed to have value beyond 2030, and if the pricing approach continues, these IT systems will continue to be used with some regular updates. In the administration costs analysis a depreciation rate has been used which assumes straight-line depreciation over seven years. However, this is different from economic depreciation, which measures the change in the value of the system; effectively, how much would the system operator be willing to pay for the existing IT system in 2030. It is likely to be less than a new system but substantially more than zero (as the seven-year depreciation schedule would assume). We note that *Overseer* is still being used 30 years after its first development.[101] We take a simple assumption that the value of these IT systems in 2030 is 50% of its initial value in 2030.

Because of the high costs of establishing a farm-level system, alternative approaches have been considered which start with a simple emissions calculator and transition to a more complex system in a few years. Two transition options are included in the analysis:

- Pricing starts in 2025 with a simple calculator and simple sequestration from 2025-2027, then detailed calculation and sequestration from 2027 onward;

[100] He Waka Eke Noa (2022b)
[101] https://www.mpi.govt.nz/agriculture/farm-management-the-environment-and-land-use/overseer-a-nutrient-management-tool-for-farmers-and-growers/

- Pricing starts in 2026 with a simple calculator and sequestration from 2026-2028, and detailed calculator and sequestration from 2028 onward.

Costs of Sequestration

The sequestration included in the models includes that responding to NZU prices under the ETS. The majority of ETS forestry-based sequestration is included in the base case as well as the price option results and this quantity is ignored in the options analysis. There is some additional ETS forestry when *He Waka Eke Noa* pricing options decrease farm profits and this is included. The ETS sequestration benefits are counted at full value (see *Benefits* below) and the planting and fencing costs are included in the costs analysis.

There are separate estimates of the costs of the sequestration eligible under *He Waka Eke Noa*. These include the costs of fencing or fence repair to exclude stock and the costs of planting for riparian areas. These costs use assumptions are set out in Section 3.4.

R&D Costs

It is assumed that some of the revenue raised by the levy (or the sale of additional NZUs under the ETS option) is used to pay for additional R&D. Rather than estimate the returns to marginal R&D spend, we assume that this funding is justified by the benefits and ignore it (ie we assume the discounted future benefits are equal to the costs).

5.2.2 Benefits

Emission Reductions

Benefit estimation takes a similar approach to opportunity costs. The benefit of reducing emissions in agriculture is the avoided cost of reducing them elsewhere.[102] NZ Treasury has developed a set of Shadow Emission Values using this concept (Table 53), based on modelling of the expected marginal costs of emission reductions.[103] These shadow prices do not treat methane differently from LLGs and we might, for example, examine the marginal benefits of agricultural emission reductions as avoided costs of reduction from the waste sector. However, for simplicity we use an all GHG approach here.

Table 53 Shadow values of emission reductions ($/t CO_2-e)

Year	Low	Central	High
2021	$42	$63	$84
2022	$48	$72	$96
2023	$55	$81	$108
2024	$61	$90	$120
2025	$67	$99	$132
2030	$97	$145	$192
2035	$116	$173	$230

Source: NZ Treasury (2021)

[102] Some CBAs have measured benefits using estimates of marginal global damage costs but these are highly uncertain and involves taking a different definition of society from that which is normally used in a social (CBA). In addition, in the context of New Zealand's international commitments damage costs bear no real relationship to the socially desirable level of emission reductions (which is the purpose of defining a social cost), eg if New Zealand priced all its emissions at the global damage cost this would not necessarily be the level of emission reductions that we have committed to or that the global community expects. Our assumption for analysis is that New Zealand has set a national target for emission reductions and intends to meet this target. Reducing agricultural emissions means less needs to be done elsewhere.

[103] NZ Treasury (2021)

The benefits are estimated for the individual years (2025 and 2030) using the emission reduction estimates for those years times the shadow values for those years. These values and a formula to take account of benefits in other years are then discounted to estimate the present value (PV) of benefits using the same formula as used for costs.

Sequestration

The benefits of sequestration need to take account of how much is additional and how much will be counted in the national inventory and contribute towards targets, because this determines whether the Shadow Values are relevant.

Sequestration counted for payment in the *He Waka Eke Noa* pricing system includes pre-2008 and post-2007 areas, both with existing vegetation. The pre-2008 areas are assumed to need fencing and pest control, but the benefits to the farmer at a low assumed sequestration rate (1.83 t CO_2/ha), even if paying the full NZU price, are insufficient to cover costs. In contrast, post-2007 natives are likely to be entered. These are assumed to include a mix of areas that will require additional fencing to obtain benefits and areas that otherwise (with no *He Waka Eke Noa* pricing) would be cleared. For pricing, the full sequestration rate (6.5t CO_2/ha) is used, and this is clearly relevant to areas that would otherwise be cleared. It might not apply to areas that are fenced to obtain additional sequestration (some proportion of this rate only might apply).

Set against this, we apply a percentage to the sequestration to account for only some being measured as counting towards targets. We use an assumption that only 25% of the sequestration eligible for *He Waka Eke Noa* payments will contribute to meeting national targets (see Annex 4 for details).

5.2.3 Discounting

CBAs use discount rates to adjust the effects of impacts that occur in different time periods. This is used as a measure of the extent to which people prefer costs delayed and benefits brought forward. This might be either because if costs are delayed, money could be used to obtain a return in some other activity in the meantime (an opportunity cost of capital concept), or simple preference or myopia (a social rate of time preference).

CBAs typically produce results using a NPV as the sum of discounted benefits minus the sum of discounted costs. Sometimes this is expressed as a benefit: cost ratio (BCR) but this is an inferior indicator because the result is sensitive to the definition of costs and benefits, for example a reduction in farm profit might be treated as a cost or a lower benefit.

A real discount rate of 5% has been applied as the base assumption. This is the default value recommended by the Treasury.[104] Sensitivity analysis has used 2% (an alternative discount rate used by the Treasury in its CBAx model which has been developed to assist government agencies undertake CBAs).[105]

5.3 Producing a Net Present Value

The CBA of the *He Waka Eke Noa* pricing options compares the options on the basis of the NPV of costs and benefits between 2022 and 2030, discounted to 2022. Some of the investments will have

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[104] https://www.treasury.govt.nz/information-and-services/state-sector-leadership/guidance/financial-reporting-policies-and-guidance/discount-rates

[105] NZ Treasury (2021)

effects or value beyond 2030 but the analysis of effects has not extended past this time. This partly reflects the uncertainty over the policy application beyond this time, which includes the option of transitioning from one option to another (eg processor hybrid to the farm level levy). In addition, there is considerable uncertainty over the development of mitigation technologies such that their effectiveness is expected to be much better understood by 2030. To take account of this, where there are significant capital costs, eg investments in monitoring systems as part of the administration costs, we have included a positive residual value in 2030 which reduces the present value of the costs to 2030. Other impacts, such as reduced stock numbers that limit emissions are assumed to be reversible.

For the administration costs, which include the costs of monitoring systems, we have values for every year. In contrast, the modelling undertaken for the analysis of pricing options has produced costs and benefits for two individual years (2025 and 2030) but not the years in-between. To approximate the net benefits over the whole 2025-2030 period,[106] we have assumed a straight-line change in costs and benefits between the two years. All costs and benefits are estimated using 2022-dollar values.

5.4 Pricing and Multiplier Assumptions

To compare the different options, the same emissions price is used. This is based on the assumed prices under the processor-level ETS as shown in Table 54.

Table 54 Price Scenario assumptions

	2025	2030
NZU price ($/t CO_2-e)	$85	$138
Discount	95%	90%
Effective price ($/t CO_2-e)	$4.25	$13.80
CH_4 equivalent ($/kg CH_4)	$0.11	$0.35

The other main assumption used is for the multiplier applying under the options using emission reduction payments. The individual options have different demands for revenue. And specifically, the benchmark EMC involves significantly more revenue because payments are made to farmers for reductions in livestock, whereas the FLL with technology payments and the actions-based EMC option pays revenue out for a more limited set of activities. Taking account of available revenue, we assume a multiplier of 5 for the benchmark EMC and 10 for the FLL + technology payments and actions-based EMC options.

5.5 Results

5.5.1 To 2030

The overall results for the different options are shown in Table 55, using a 5% discount rate and emission prices assumed to the same as with the PL-ETS, ie $0.11/kg CH_4 and $4.25/t CO_2-e in 2025 rising in a straight line to $0.35/kg CH_4 and $13.80/t CO_2-e in 2030. More details are provided in Annex 5. The initial analysis is to 2030, with estimates of results beyond this discussed below. The emission reductions shown in Table 55 are for 2030 only, but the estimates of costs and benefits are for every year (2025 to 2030), discounted to 2022.

[106] We assume the pricing systems begin on 1st January 2025, with the final costs in 2030 applying to the full year, ie to 31st December 2030.

Table 55 Summary of Impacts: PV (to 2030) in 2022 $ values ($ million) – 5% discount rate

Base Option:	**Processor ETS**	**FLL + Tech payments (2025 start)**	**FLL + Tech payments (2026 start)**	**Processor Hybrid + Benchmark EMCs**	**Processor Hybrid + Action-based EMCs**
Multiplier assumed	na	10	10	5	10
Costs					
Admin costs	-$56	-$280	-$263	-$319	-$197
Emission reduction costs	$32	-$232	-$233	-$246	-$184
Sequestration costs	-$33	-$149	-$154	-$145	-$145
Total costs	**-$58**	**-$661**	**-$649**	**-$710**	**-$526**
Emission reductions (2030) (kt)					
CH_4 (kt CH_4)	9	63	63	67	53
CH_4 (kt CO_2-e)	234	1576	1576	1686	1316
N_2O (kt CO_2-e)	35	140	140	559	47
CO_2 (kt CO_2-e)	10	55	55	66	47
Total (kt CO_2-e)	279	1,771	1,771	2,311	1,410
Sequestration (2030) (kt)					
HWEN Sequestration	0	600	600	600	600
Extra ETS Sequestration	488	467	467	436	435
Total	488	1067	1067	1036	1036
Costs per tonne					
$/t CO_2-e (excl admin costs)	-$37	$52	$52	$35	$52
$/t CO_2-e (incl admin costs)	$29	$114	$110	$80	$108
Benefits					
Emission Benefits	$109	$584	$575	$896	$458
Sequestration Benefits	$217	$252	$232	$236	$235
Total Benefits	**$326**	**$836**	**$806**	**$1,132**	**$693**
Net Costs/Benefits	**$268**	**$175**	**$157**	**$422**	**$167**

All the options have positive NPVs; the level is determined largely by the balance between the extent (and benefit) of emission reductions and the administration costs in measuring and achieving those emission reductions.

Cost Differences

The results differ in the extent of costs:

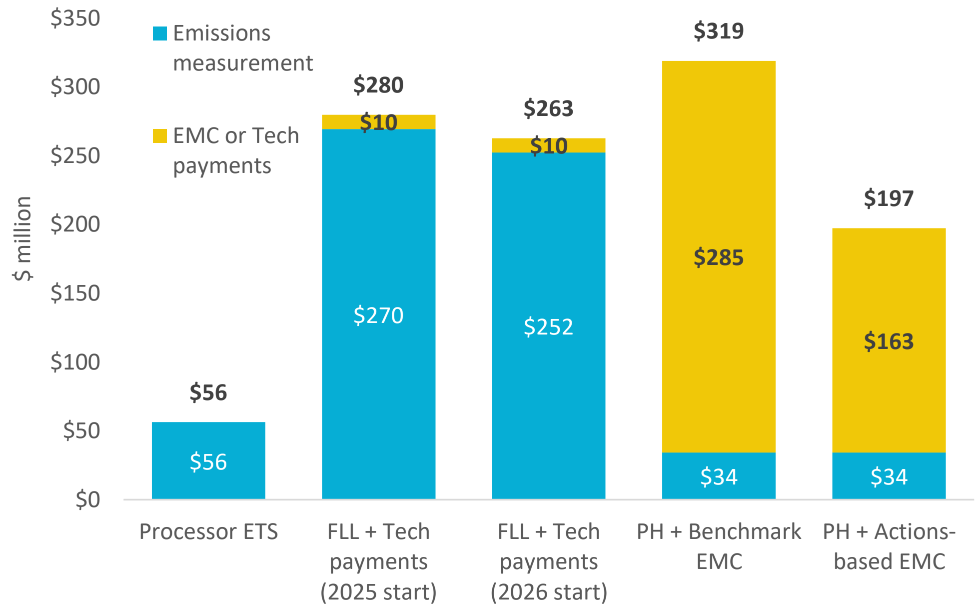
- The PL-ETS option has low costs because it has a simple measurement and revenue collection system at the processor level and has no additional element used to measure and incentivise emission reductions at the farm level. The PL-ETS options also has low costs per t CO_2-e reduced because it only incentivises emission reductions from reduced livestock and production, which are lower cost than the use of technologies. Excluding administration costs, costs per tonne are estimated to be negative (positive value) reflecting efficiency gains measured in the dairy sector modelling;

- The other options have a combination of high-cost measurement of emissions at the farm level (FLL options) and/or administration and measurement of emission reductions (EMC options and to a lesser extent technology payments) (see Figure 34);[107]

- The PM + benchmark approach has lower unit costs of emission reductions because the costs are dominated by reductions in production rather than use of technologies.

[107] The administration cost estimates use the average of low and high costs (He Waka Eke Noa 2022b) for the FLL system (the on-farm emission calculations) and for the FLL + Tech (the funding of technologies).

Figure 34 Administration cost components for the pricing systems



Benefit Differences

They differ with the extent (and benefit value) of emission reductions:

- For all options the benefits of emission reductions exceed the emission reduction costs themselves, eg for the first FLL + Technology payments option, the costs are estimated at $232 million and the benefits at $584 million. The equivalent costs per tonne reduced vary between negative (positive value) and $52/t CO_2-e,[108] which is less than the benefits (which rise from $99/t in 2025 to $145/t in 2030);

- The PL-ETS has little impact on emission reductions and thus has low benefits to accompany the low costs;

- The PH + benchmark EMCs option has the highest emission reductions because it includes those from production losses;

- The actions-based EMC option has lower emission reductions than the FLL + technology payment options because the EMC is assumed to involve a participation payment for farmers that provides an entry barrier.

Contribution of Sequestration

Sequestration costs are the planting costs for additional areas shifting to ETS forestry (in addition to those estimated under the base case) and the costs of fencing and pest & weed control for natives eligible under the *He Waka Eke Noa* proposals. *He Waka Eke Noa* sequestration is valued using the same benefit values as for emission reductions (Table 53), but it is assumed that not all counts towards meeting national emission targets; for analysis we assumed only 25% of the measured sequestration provides a national benefit based on these valuations (assumptions are in Annex 4). On average, *He Waka Eke Noa* sequestration is modelled as being rewarded with a payment rate

[108] These are measured as the PV of costs divided by the PV of tonnes reduced. The value is equivalent to an amount that, when multiplied by the emissions reduced in each year, would produce the same estimated PV of costs.

that exceeds the national benefits, although there will be additional benefits that have not been monetised from the additional biodiversity benefits.

The total sequestration benefits rely on the additional value of ETS forestry incentivised by the emission price. This is estimated for sheep & beef farms (see Table 24) on page 40 above. The additional ETS forestry is assumed to be exotic planting with low planting and other costs and a much higher sequestration rate (up to 26t CO_2/ha/year – see A1.7 in Annex 1) than for the native vegetation assumed for *He Waka Eke Noa* sequestration. The benefits exceed the costs for these new areas.

FLL Options and Delayed Start

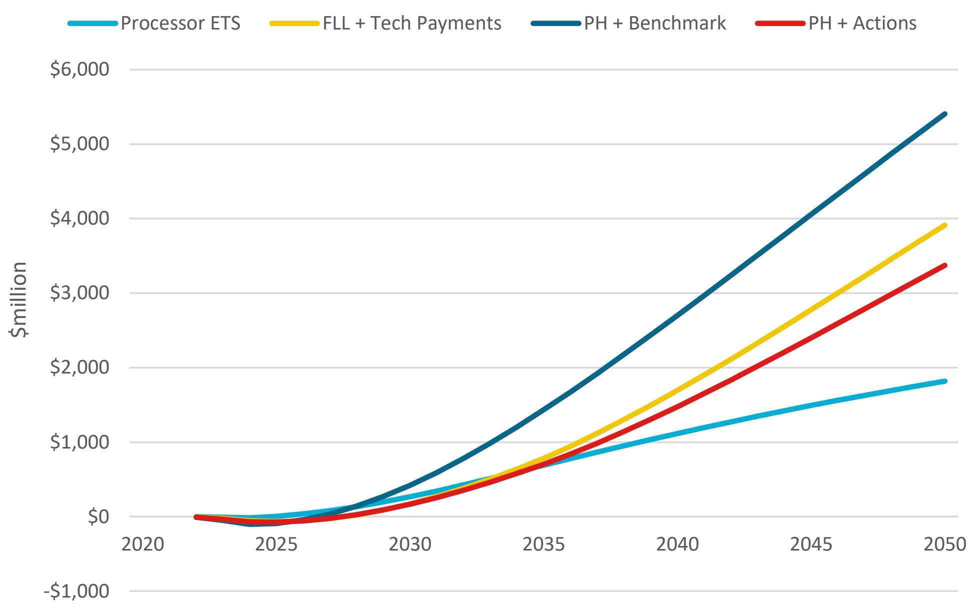
The FLL + Technology payments options show greater net benefits for the early start. This is because the reduction in benefits of delaying by one year is greater than the benefit of pushing the costs into the future. The delay in benefits is greater for sequestration than it is for emission reductions.

5.5.2 Extending the Analysis Beyond 2030

The initial analysis has been to 2030 only because this was the focus of the sectoral analysis. Extending the analysis beyond 2030 is expected to raise the benefits more than costs for all options.

Figure 35 demonstrates this using some simple assumptions of annual emission reductions continuing to increase at the same level as the annual average between 2025 and 2030. It shows the NPV from 2022 to the year in the x-axis, eg the NPV for the FLL + Technology Payments is approximately $800 million if the analysis is to 2035 but increases to approximately $4 billion if extended to 2050. NPVs become more net positive because the administrative costs are assumed to have high up-front costs but to have reasonably static costs thereafter in real terms, whereas emission reductions (for which benefits exceed costs) are expected to increase over time. The benefits continue to exceed costs for emission reductions because the pricing options examined set emission prices (even using multipliers) that are no higher than the estimated national benefits of emission reductions per tonne reduced. Figure 35 extends the analysis to 2050, although the certainty of this analysis becomes steadily less reliable as we go out in time.

Figure 35 Potential NPV for pricing options if analysis is extended to different end years



5.5.3 Lower Discount rate

Table 56 summarises the impacts using a 2% discount rate. The emission reductions are the same but there are changes in the valuation of costs and benefits falling in different time periods.

NPVs improve at the lower discount rate for all options. This is because there are higher net benefits in future years (towards 2030) and these are weighted more heavily under a lower discount rate. The FLL option has a small and less negative NPV.

Table 56 Summary of Impacts: PV (to 2030) in 2022 $ values ($ million) – 2% discount rate

Base Option:	**Processor ETS**	**FLL + Tech payments (2025 start)**	**FLL + Tech payments (2026 start)**	**Processor Hybrid + Benchmark EMCs**	**Processor Hybrid + Action-based EMCs**
Multiplier assumed	na	10	10	5	10
Costs					
Admin costs	-$64	-$322	-$305	-$360	-$222
Emission reduction costs	$38	-$282	-$282	-$294	-$223
Sequestration costs	-$39	-$179	-$184	-$175	-$175
Total costs	-$65	-$782	-$771	-$828	-$619
Costs per tonne					
$/t CO_2-e (excl admin costs)	-$37	$52	$52	$35	$53
$/t CO_2-e (incl admin costs)	$26	$112	$109	$77	$105
Benefits					
Emission Benefits	$130	$705	$695	$1,072	$554
Sequestration Benefits	$258	$301	$279	$281	$280
Total Benefits	$388	$1,007	$974	$1,354	$834
Net Costs/Benefits	$323	$224	$203	$526	$215

6 Summary and Conclusions

6.1 Overview of Issues

The analysis in this report has been developed in step with the *He Waka Eke Noa* partners, as they reflected on the relative merits of the pricing options and as they gained an increased understanding of the potential contribution of the pricing options to the *He Waka Eke Noa* objectives.

Analysis of the base case with no additional pricing, suggests responses to freshwater regulation (the NPS-FM) and the extent of land use change expected from the high and rising NZU price encouraging more afforestation, are forecast to produce reductions in methane emissions of over 4%. Based on this, the partners were looking for pricing options that would deliver an additional 5% or greater reduction in methane emissions, without having a significant impact on agricultural production. There is no specific target for LLG emission reductions, so there has been greater focus on the methane results, but the partners are aware of the expectation of a significant contribution either in gross (emission reductions) or net terms (taking account of sequestration).

6.1.1 Emission Reduction Options

There are three broad approaches to reducing emissions from agriculture and horticulture:

1. Increasing efficiency, ie reducing the inputs of feed or fertiliser per unit of output;

2. Adoption of emission reduction technologies to reduce emissions intensity of production; or

3. Reducing agricultural production in New Zealand.

Increasing efficiency (beyond any underlying trends) is a desirable option and there are opportunities that have been included in the modelled response in the dairy sector. The limitations include the potential rebound effect where more efficient producers increase output so that the absolute emission reductions may be limited. The opportunities for efficiency improvements in the sheep & beef sector are regarded as less available (partly because of less intensive production systems) or requiring relatively high costs to identify at the farm level.

Emission reduction technologies offer greater potential but they are still largely experimental rather than being available commercially. There is high expectation that technologies will become available in the near future, although this is an uncertainty. The analysis assumes they will be available soon and will contribute increasingly to emission reductions from 2025, but decision makers using these results will need to bear in mind the risks associated with any policy options which rely on these technology expectations.

Reducing agricultural production provides more emissions reduction certainty, but only from a New Zealand-centric position. There is a significant risk of emissions leakage because New Zealand's agricultural production is meeting global demand that is not expected to reduce in response to policy measures taken here.[109]

[109] Production elsewhere may be at higher cost, so there might be a demand response to an increase in commodity prices.

6.1.2 Pricing Emissions

Emissions pricing is an ideal policy tool when there is uncertainty over how best to reduce emissions at the farm level. Emissions pricing rewards all reductions, however they are achieved, and the overall response will be revealed as farmers respond creatively to the new incentives and technologies emerge, some of which are not currently anticipated.

Emission pricing is usually treated as a simple mechanism that can produce an optimal response. The ideal design to achieve this ensures every kg change in emissions results in the same change in the costs of emitting and increases in emissions face an equal and opposite change in costs to emission reductions. However, levying a price on all emissions to achieve a relatively small percentage reduction (given the initial constraints on potential efficiency gains and mitigation technologies) means a significant proportion of the charge is unavoidable, as illustrated in Figure 1 on page 4. This means a large effect of a price instrument is to raise revenue. This has been significant in the partners' consideration of pricing mechanisms that use the revenue to obtain emission reductions and not just the emission price.

Theory would suggest the response to paying for an emission reduction will be the same as that to a charge on emissions, although other factors will be at play, including the voluntary nature of the payment compared with the charge, in addition to the fixed costs associated with payment options using a contract mechanism. However, the use of a payment mechanism has introduced the potential for a multiplier to be used, which means the emission reduction incentive can be several times greater than the level of the charge. This is an important element when some farm types are vulnerable to high prices.

The alternative approach of a high price and a rebate (output or land-based) has been considered and has significant theoretical attraction. The *He Waka Eke Noa* partners have not been convinced of the workability of these approaches.

The multiplier-based payment mechanisms can be more widely or narrowly focussed. As noted above the options considered include those that focus on technologies and those that simply measure changes in emissions over time relative to an historical benchmark. The actions-based EMC or FLL + technology payment options limit the potential response (and they rely on the development of technologies); the benchmark approach introduces the potential to pay for reduced production, in addition to equity issues from farms with different starting levels of emissions intensity in the benchmark year.

6.2 The Pricing Options Examined

The options examined are summarised in Table 57 and discussed below.

Table 57 Pricing Options and impacts

	Processor-Level ETS (PL-ETS)	Farm-level levy (FLL)	FLL + Rebate	Processor hybrid (PH)	FLL + technology payment
Who pays?	Processor	Farmer/ Landowner	Farmer/ Landowner	Processor	Farmer/ Landowner
Pricing basis	Output	Farm-level calculations	Farm-level calculations	Output	Farm-level calculations
Aggregation	GHGs combined	Split-gas	Split-gas	Split-gas	Split-gas
Efficient incentives for emission reduction	No. Charges output only	Yes	For emissions intensity improvement only	Depending on inclusions in EMC	Rewards intensity improvement more than it penalises gross emissions
Rewards output reduction	Yes	Yes	Limited[1]	Benchmark-based EMC only	Yes via charge but not via multiplier
Sequestration included	Current ETS only[2]	ETS + HWEN options	ETS + HWEN options	ETS + HWEN options	ETS + HWEN options
Impact on profits[3]	Limited impact because of free allocation.	Potentially high but varies with emissions price.	Limited impact because of rebate	Limited impact because of low charge.	Limited impact because of low charge.
Revenue sufficiency	Yes: no required use of the revenue	Varies with level of charge.	As for FLL. Revenue for rebates limited by spend on sequestration, admin etc	Potential size of multiplier limited by cost of sequestration	As for PH and with higher admin costs.
Admin costs	Low	High (farm level measurement)	High (as for FLL)	Medium (but EMCs can be high cost)	High (as for FLL)

[1] There may be an incentive for some farms to increase output, depending on rebate percentage, but this will be balanced by others with incentives to reduce output.
[2] HWEN sequestration could potentially be paid for from revenue raised via ETS auction
[3] Some farms may have significant revenue from ETS forestry, either through earning and selling NZUs or selling land to foresters.

6.3 Incentives and Costs

6.3.1 Processor-Level ETS

The backstop PL-ETS does not provide incentives for the full range of emission reductions because the obligation to surrender New Zealand Units (NZUs) (and the associated cost of their purchase) varies with the level of output rather than with the emissions associated with that output. There is no incentive for farm-level actions, including on-farm efficiency measures or the use of mitigation technologies to reduce the emissions intensity of production. Incentives from the surrender obligation are limited to reducing output.

The positive arguments for the PL-ETS are that it is relatively simple to implement because of the existing system, with low administration costs. Some of the incentives for a wider range of emission reductions might be targeted by paying for emission reductions separately (the PL-ETS could operate similarly to the PH).

6.3.2 Farm-Level Levy

In contrast to the PL-ETS, the FLL provides incentives for the full range of emission reduction options and disincentivises all emission increases. Achieving this comes at a cost, including higher costs for emissions measurement. Emission reductions increase with emissions price, with a relatively high price needed to incentivise the full range of mitigation technologies (the level of charge must exceed the marginal cost of the technologies – see the costs discussed in Sections 3.5.3 and 3.6.3). But high prices are also associated with high impacts on farm profit and in reductions in output.

This means additional options considered include:

- using a low price FLL (which limits the emission reductions incentivised);
- using rebates to compensate for costs; and
- addressing the marginal incentives to reduce emissions by paying for emission reductions.

6.3.3 FLL plus Rebates

Rebates can be used alongside the FLL to redistribute some of the revenue raised from the charge to reduce the overall impacts on farmer or landowner profit. Ideally this is achieved by paying rebates in a way that is proportional to the costs faced but where the payment of the rebate does not incentivise emission increases or changes in activity or output. If a workable option can be identified, rebate payments enable a high level of charge to be applied, providing incentives for a full range of emission reduction responses, while reducing the downside risks of output loss and emissions leakage. Rebates have been used elsewhere with these objectives, including in the ETS in the form of free allocation of NZUs on the basis of output from emissions-intensive, trade-exposed industrial activities.

Two options have been explored by *He Waka Eke Noa* with rebates on the basis of output or land area (adjusted for productive capacity of the land).

The FLL with rebate options were analysed on the assumption that the implementation difficulties could be overcome. The results were mixed, however. For sheep & beef farms, the results were as expected, with this option producing levels of emission reduction similar to that obtained from the FLL using the same price,[110] while the impacts on profit were very significantly reduced. For dairy, the lower impacts on profit were also seen but this limited the extent of methane emission reductions. Most of the modelled dairy emission reductions came from reduced output when the total costs of the charge made some dairy production unprofitable. Sheep & beef production may also be made unprofitable; however the response is unclear when many farms are operating now with low or even negative profitability.

The impacts of the FLL plus rebate options have not been included in the final results because of the implementation challenges perceived by the *He Waka Eke Noa* partners.

6.3.4 Processor Hybrid

The PH enables revenue to be raised at low cost (at the processor level). The incentives to reduce emissions then come via payments for emission reductions under EMCs between farmers and the Government or via a simpler mechanism that subsidises the sale and application of mitigation technologies. EMC options considered have included those based on payments for specific actions (use of technologies or identifiable efficiency improvements) or changes in emissions relative to an historical emissions benchmark for a farm.

The results suggest that the PH can produce significant levels of emission reduction when a multiplier is applied to EMC payments sufficient to raise the incentive price above the marginal costs

[110] The reductions were slightly lower because there was a lower impact on profit and this on the incentives for land use change from farming to forestry

of emission technologies, with significant reductions also associated with payments for livestock reductions under the benchmark approach.

The EMC approach requires a voluntary response to the payment opportunity and thus requires the benefits to the farmer (the excess of payments over the costs of emission reductions) to exceed the costs, including their contribution to administration costs (an EMC payment), inconvenience costs and the opportunity costs of time involved. This may limit the response compared with the FLL, even at the same price.

6.3.5 FLL and Technology Payments

A FLL with payments for reductions using technologies incorporates the benefits and costs of the FLL. This includes the incentives for more emission reductions via the farm-level price coupled with the higher costs of measurement at that level. Payments for actions to reduce emissions excludes reductions in output. This reduces the potential emission reductions but is consistent with the full set of *He Waka Eke Noa* objectives.

The results suggest that, using a high multiplier, significant reductions can be achieved, although this depends on the technology development and adoption assumptions.

6.3.6 Sequestration and Revenue Sufficiency

Currently, sequestration is incentivised under the ETS in the form of the potential to earn NZUs for absorption from new forestry on land areas greater than one hectare. With rising NZU prices, significant levels of new afforestation are forecast under the base case, resulting in emission reductions from a reduced sheep and beef farm area and reduced animal numbers.

The *He Waka Eke Noa* options have introduced the potential for additional forms of sequestration to be rewarded. This includes rewards for sequestration from current native forests that are managed to achieve additional growth, eg from stock exclusion. This additional sequestration can provide some compensatory revenue for some farmers, contribute to reducing atmospheric CO_2 and may provide some environmental co-benefits, eg from greater biodiversity. However, it does not necessarily provide a contribution to meeting national emission targets as emission reductions or ETS-eligible forestry do.

The payments for sequestration under *He Waka Eke Noa* compete with other potential uses of the revenue, eg payments for emission reductions. Thus, the modelling has raised the question over how much should be paid per tonne reduced. The answer to this question is beyond the analysis in this report and requires a balancing of the various costs and uncertain benefits of this additional sequestration.

6.3.7 Faster Technology Uptake Assumptions

The modelling has included the effects of high technology scenarios in which mitigation technologies are lower cost or have greater or earlier availability. As expected, these assumptions result in greater reductions and lower costs. This effect is behind the assumption that some of the revenue raised from an emissions charge would be used to fund additional research, particularly into these mitigation technologies and their implementation.

6.4 Cost Benefit Analysis Results

The CBA of the options suggest all have positive net benefits using prices that are the same as expected under the PL-ETS. This is because these prices provide incentives for emission reductions that are lower cost than the national benefits of emission reductions. In addition, there is an overall surplus from the benefits of sequestration above the costs of that sequestration, reflecting the extent of assumed additional ETS forestry in response to an emissions price. The surpluses from emission reductions and sequestration are greater than the estimated administrative costs for the options.

The greatest net benefits are estimated for the PH + benchmark EMC option but this is associated with emission reductions from reductions in production (with leakage risk). The NPVs for the other options are quite similar, with the FLL + technology payments having higher administration costs but higher emission reductions estimated also.

6.5 Concluding Thoughts

The results of analysis suggest the following.

- Regardless of the design of a *He Waka Eke Noa* pricing system, the high and expected rising price of NZUs in the ETS is expected to provide a strong incentive for land use change from farming to forestry. Exotic planting to gain NZUs will be largely on sheep & beef farms.

- *He Waka Eke Noa* pricing introduces a value for additional sequestration to that included in the ETS. Only a small percentage (estimated at 25%) of this sequestration will contribute to achievement of national emission targets; at the time of writing this report, work is continuing within *He Waka Eke Noa* considering what price to pay for it.

- The analysis has identified options that can reduce emissions to a level consistent with domestic targets, taking account of expected change under the base case. These include options using prices at levels anticipated under the PL-ETS, or even slightly lower. These options include the PH and FLL + technology payment options, both using multipliers to amplify the signal to reduce emissions. The analysis has raised several issues that need to be weighed in making a choice of preferred option.

    - **Where to place the charge**, weighing the costs of the measurement system versus the incentive effects. Processor level charges are lower cost but provide incentives themselves for very few emission reductions. In contrast, farm-level charges require higher cost farm-level measurement but provide incentives for the full range of emission reductions.

      A FLL on its own would need to be set at a high price to provide incentives for emission reductions, with significant impacts on farm profit, particularly for sheep & beef farms. It has greater advantages when there are more farm-level mitigation options and when greater use can be made of the charge than payments to reduce emissions.

    - Providing the **main incentives for emission reduction via charges or payments**. Charges are simplest but payments combined with a multiplier enable an amplified incentive at a lower emissions price. This is particularly attractive when there are few potential emission reductions and the charge is largely unavoidable (Figure 1). As the emission reduction potential rises, multipliers will need to fall as there is greater risk of exhausting the available revenue and the relative role of the charge in achieving emission reductions will rise.

- Limiting incentives for emission reductions to **mitigation technologies and efficiencies or including reductions in production**. This weighs up risks of emissions leakage (from production loss which is also somewhat at odds with the *He Waka Eke Noa* objectives) with those of potential slow development of technology, which risks falling short of targeted reductions. Providing incentives for reductions in production provides greater emissions reduction certainty but also requires the use of a benchmark against which emission reductions can be measured, and this raises equity issues from differences in starting levels of emissions intensity.

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Annex 1: Sheep & Beef Model Assumptions

Table 58 summarises the main assumptions and data used.

Table 58 Main Assumptions

Factor	Component	Assumption
Charges	CH_4 N_2O	Separate charges modelled, including as marginal and average prices (for pricing involving rebates). Emission charges are expressed as marginal prices and these affect emission reduction behaviour. Rebates are used to change average costs and these affect decisions to change land use. Average costs are used to express impact relative to profit
Mitigations	Technologies	See Table 62
	Stock reduction	Occurs only when effective farm area (EFA) is planted and in modified proportion to area planted as % of EFA. Stock reduction % = %Δ in area planted$^{\wedge 1.25}$
	Fertiliser reduction	As for stock reduction
Riparian planting	Area	Assumed as those set aside under Resource Management (Stock Exclusion) Regulations 2020
	Sequestration	3.4 t CO_2-e/ha
	Costs	Planting costs (assume already fenced), pest & weed control
Native regeneration	Area	Estimated from farm survey
	Sequestration	1.83 t CO_2-e/ha (pre-2008); 6.5t/ha (post-2007)
	Costs	Fencing and pest control
Exotic planting	Area	ETS only. Total EFA possible, but responds to change in farm profit and NZU price.
	Sequestration	Variable by region based on *Pinus radiata* absorption to year 17 in MPI look-up tables
	Costs	Planting costs. Loss of farm production (measured as gross margin).
Productivity improvements		Assumes no productivity improvements or optimisation gains, although this is examined in sensitivity analysis

A1.1 Farm Data

Farm data are taken from B+LNZ and split into regions and farm classes (see Table 21 above), each split into five quintiles.[111] Base data are from B+LNZ quintiles data for the five years from 2015-16 to 2019-20 using Sheep and Beef Farm Survey data.[112]

A1.2 Farm Financials

The costs of charge payments, mitigations and net costs (or revenues) from sequestration are compared with profit. The main indicator used is farm profit before tax (FPBT).

If stock numbers are reduced to reduce emissions, the costs are estimated using gross margins per stock unit, taken from the quintile data.

[111] Farms are ranked by Earnings (Profit) Before Interest, Tax, Rent and manager wage (EBITRm) per hectare. South Island classes 1 and 2 are ranked nationally by EBITRm per stock unit (EBITRm/SU) due to their scale and extensive management systems.
[112] 2018-19 data available here: https://beeflambnz.com/data-tools/benchmark-your-farm

A1.3 Emissions

Emissions are estimated for stock and for fertiliser. There are two main approaches possible for estimating emissions from stock: emission factors (EFs) per animal or per unit of product output. Applying these to the data results in very similar totals but distributes the emissions differently between farms, depending on whether or not they produce final outputs.

The model uses emissions per kg of product, noting that this means the results are more meaningful in aggregate than in detail for individual farm classes. The emission factors used are shown in Table 59; they include base factors in kg CO_2-e/kg of product which are distributed between CH_4 and N_2O using MfE's per animal emission factors (Table 60).

Table 59 Emission factors per product

	t CO_2-e/kg product	% CH_4	CH_4 (kg/kg)	N_2O (kg/kg)
Sheep	23.57	91%	21.35	2.22
Beef	14.2	86%	12.23	1.97
Venison	30.7	88%	27.06	3.64

Source: Journeaux (2019); Ministry for the Environment (2020a)

Table 60 Emission factors for livestock (kg CO_2-e/head/year)

	Enteric Fermentation	Manure management	Manure management	Manure management	Agriculture soils (live stock)	Total	Total	Total
	CH_4	CH_4	N_2O	GHG	N_2O	CH_4	N_2O	GHG
Dairy cattle	2132	198	15	213	489	2329	504	2833
Non-dairy cattle	1452	19	0	19	237	1471	237	1708
Sheep	307	3	0	3	32	311	32	343
Deer	573	7	0	7	78	580	78	658

Source: Ministry for the Environment (2020a)

Emission factors used for fertiliser are shown in Table 61. We use:

- Pasture N (kg/ha) data from B+LNZ quintiles data times ha of effective area, and apply the EF for non-urea nitrogen fertiliser. This may overstate the quantity of N applied and of N_2O emissions from fertiliser, but it is small compared to total emissions, so we have not corrected for this.

- Lime (kg/ha) data from B+LNZ quintiles data, times ha of effective area, and apply the EF for limestone.

Table 61 Emission factors for fertiliser (kg CO_2-e/kg fertiliser)

	N_2O	CO_2	GHG
Non-urea nitrogen fertiliser	5.40		5.40
Urea nitrogen fertiliser not coated with urease inhibitor	3.48	1.59	5.07
Urea nitrogen fertiliser coated with urease inhibitor	3.27	1.59	4.86
Limestone		0.44	0.44
Dolomite		0.48	0.48

Source: Ministry for the Environment (2020a)

A1.4 Mitigations

Technologies

Mitigations available, including emission reduction potential, cost per animal and the year assumed to be first available are shown in Table 62; the values are tested in sensitivity analysis. It is assumed that only one of a CH_4 vaccine or inhibitor is used. In practice, because it is lower cost and is assumed to be available at the same time, the vaccine is always chosen in the model.

Table 62 Mitigation assumptions

Mitigation		Emission reduction	Cost per animal	1. S.I. High Country	2. S.I. Hill Country	3. N.I. Hard Hill Country	4. N.I. Hill Country	5. N.I. Finishing	6. S.I. Finishing Breeding	7. S.I. Finishing	8. S.I. Mixed Finishing
CH4 Vaccine	Sheep	30%	$5.00	2031	2031	2031	2031	2031	2031	2031	2031
CH4 Vaccine	Cattle	30%	$10.00	2031	2031	2031	2031	2031	2031	2031	2031
CH4 Inhibitor	Sheep	30%	$6.00	NA	NA	NA	NA	NA	NA	NA	NA
CH4 Inhibitor	Cattle	30%	$12.00	2031	2031	2031	2031	2031	2031	2031	2031
N2O Inhibitor	Sheep	50%	$1.00	NA	NA	NA	NA	2030	NA	2030	2030
N2O Inhibitor	Cattle	50%	$8.00	NA	NA	NA	NA	2030	NA	2030	2030
Genetics	Sheep	10%	$0.75	2025	2025	2025	2025	2025	2025	2025	2025
Genetics	Cattle	10%	$2.00	2031	2031	2031	2031	2026	2031	2026	2031

NA = assumed to be not available in the time period modelled
Source: Phil Journeaux, pers comm

An adoption rate is assumed for the individual technologies, such that not all farms adopt technologies from when they are first available. The adoption rates assumed are calculated using the following formulae.

$$AR_{t+1} = AR_t + r.\frac{(K - AR_t)}{K}$$

Where: AR_t = Adoption rate in year t (and AR_{t+1} = adoption rate the next year)
r = the change in adoption rate from year t to t+1
K = maximum assumed adoption rate

The first-year (AR_1) adoption rate is set but the annual change is assumed to vary with the emissions price using the following formula.

$$r = \alpha\,.\frac{\log_e(P)}{P_{max}}$$

Where: α = a coefficient set for each technology
$\log_e(P)$ = the natural log of the emissions price (for CH_4 or N_2O in \$/t CO_2-e)
P_{max} = a maximum emissions price; set at \$100/t CO_2-e

The assumptions used for the individual factors are shown in Table 63.

Table 63 Assumptions used in calculating adoption rates (sheep & beef)

	AR1	K	α
Genetics	2%	76%	3.5
Vaccine	8%	90%	5.0
CH4 Inhibitors	3%	75%	5.0
Nitrification Inhibitors	2%	25%	2.0

Source: T Denne and P Journeaux

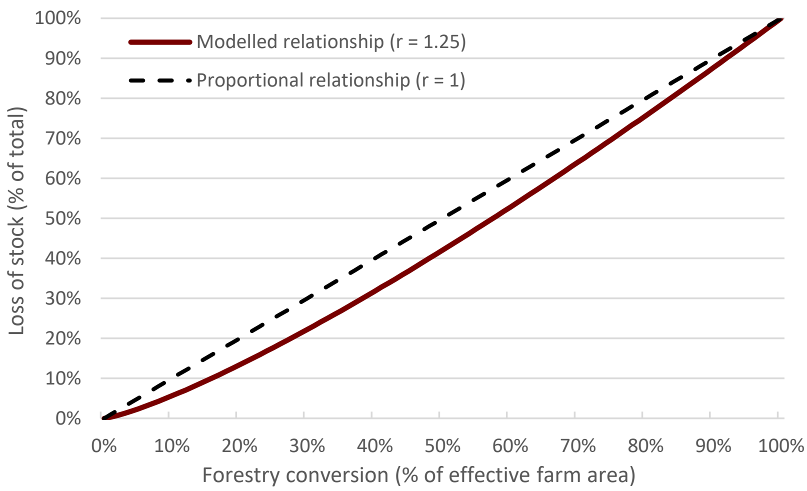
Stock Reduction

Stock reduction occurs when livestock are displaced by exotics planting (see below). It results in reduced emissions (assuming farm production falls with stock numbers) and costs based on gross margins per stock unit.

At a farm level, the reduction in production will not be in proportion to the change in land area as individual farms would be expected to plant trees on areas within a farm that are less profitable for animal production. However, the model is working with averages for groups of farms and, within a farm category, a 10% switch of farm area to forest might involve several whole farms, rather than each farm switching 10%. In aggregate the effect is likely to be somewhere in-between. To take account of this we have used a power relationship, ie: % loss of stock = % loss of farm area^r

Our default value for r is 1.25. This means a 10% reduction in area results in a 5.6% reduction in stock.

Figure 36 Assumed relationship between forestry conversion and loss of stock



A1.5 Riparian Planting

Area

Riparian areas are assumed to be set aside and fenced to meet the requirements of the Resource Management (Stock Exclusion) Regulations 2020 in low slope areas (total of 81,000 km); MfE subtracted areas already fenced because of regional rules or farmer decisions. They estimated a total of 31,721 km (Table 64), although the regional totals only add to 28,024km. We use the lower figure (28,024km) and distribute these across different land use types using data from MPI (see Table 65); the total river length (14,529 km excludes that for other land uses: dairy, deer and other). The total area is approximately 0.1% of farm land, with a maximum of 0.75% in Farm Class 5 Northland/Waikato/BoP.

Table 64 River length requiring exclusion per region and setback area

Region	River length requiring exclusion (km)	Total Area for 3m setback (ha)	Region	River length requiring exclusion (km)	Total Area for 3m setback (ha)
Northland	1,284	771	Tasman	499	299
Auckland	618	371	Nelson	37	22
Waikato	2,198	1,319	Marlborough	619	371
Bay of Plenty	397	238	Canterbury	7,399	4,439
Gisborne	490	294	West Coast	974	584
Hawke's Bay	1,551	931	Otago	5,122	3,073
Taranaki	893	536	Southland	2,542	1,525
Manawatu-Wanganui	2,378	1,427			
Wellington	1,023	614	Total	31,721	19,033

Source: MfE (2020b), p336

Table 65 Assumed riparian areas for planting (3m setback)

		River length requiring exclusion (km)	Area for setback (ha)	Total area (ha)	Area for setback as share of Total (%)
N-W-BoP	3. N.I. Hard Hill Country	286	171	195,568	0.09%
	4. N.I. Hill Country	276	165	716,486	0.02%
	5. N.I. Finishing	891	535	71,343	0.75%
EC	3. N.I. Hard Hill Country	566	340	503,176	0.07%
	4. N.I. Hill Country	546	328	546,706	0.06%
	5. N.I. Finishing	637	382	224,290	0.17%
T-M	3. N.I. Hard Hill Country	711	426	340,114	0.13%
	4. N.I. Hill Country	677	406	297,568	0.14%
	5. N.I. Finishing	692	415	66,433	0.63%
M-C	1. S.I. High Country	445	267	763,047	0.04%
	2. S.I. Hill Country	1,507	904	749,945	0.12%
	6. S.I. Finishing Breeding	1,494	896	643,074	0.14%
	8. S.I. Mixed Finishing	1,494	896	187,172	0.48%
O-S	1. S.I. High Country	296	178	1,132,945	0.02%
	2. S.I. Hill Country	1,938	1,163	414,427	0.28%
	6. S.I. Finishing Breeding	1,037	622	436,725	0.14%
	7. S.I. Finishing	1,037	622	295,626	0.21%
NZ	9. All Classes N.Z.	14,529	8,717	7,584,646	0.11%

Source: MPI
N-W-BoP = Northland, Waikato, Bay of Plenty; EC = East Coast; T-M = Taranaki-Manawatu; M-C = Marlborough-Canterbury; O-S = Otago-Southland

Sequestration Rates

Sequestration rates are taken from Burrows *et al* (2018), which is the source used by BERG (2018) and the Interim Climate Change Committee (2019). Burrows *et al* (2018) suggest a range of 0 – 5.28 t CO_2-e/ha with a median value of 3.4 t CO_2-e/ha.

Costs

Because the area is set aside already, there are no fencing costs or land opportunity costs; they are limited to planting costs. We assume \$10,000/ha. This is assumed to be a one-off cost; we spread it over 15 years[113] at a 5% interest rate to estimate \$963/ha.

A1.6 Native Regeneration

Area

Areas available for native regrowth are assumed to include all areas currently defined as indigenous vegetation in B+LNZ survey data (Table 66). These are distributed across the individual farm region/class quintiles by assuming the same percentage as for the mean within a farm class. So, if the average size of a NI Hard Hill Country farm is 1,074 ha, then the area of potential native sequestration per farm is assumed to be 128/1,074 = 11.9%.

Table 66 Average sequestration area available (ha per farm)

	Native Regrowth	Exotic	Native	Manuka	Scrub	Total Indigenous	% of farm area
1 S.I. High Country	0.0	7.9	136.8	158.9	271.6	567.3	6.0%
2 S.I. Hill Country	15.0	23.6	29.5	10.8	45.4	100.7	5.8%
3 N.I. Hard Hill Country	17.7	24.1	84.9	9.7	15.8	128.0	11.9%
4 N.I. Hill Country	6.1	10.4	34.2	0.3	2.4	42.9	8.3%
5 N.I. Finishing	1.2	8.3	6.5	0.4	0.7	8.8	2.7%
6 S.I. Finishing Breeding	4.5	18.3	21.0	5.0	4.9	35.4	6.0%
7 S.I. Finishing	4.5	4.0	8.0	1.9	1.2	15.6	5.6%
8 S.I. Mixed Finishing	0.0	3.0	0.0	0.0	0.0	0.0	0.0%

Source: B+LNZ Sheep and Beef Farm Survey 2019-20

Sequestration Rates

Sequestration rates for native regrowth are the marginal additional rates from management. These are estimated to be 0.5 t C/ha/yr (or 1.833 t CO_2/ha/yr)[114] for pre-2008 natives. For Post-2007 total stock growth is assumed to be counted, in the same way as for post-89 forests in the ETS. The sequestration rate of 6.5t/ha is the average absorption over 50 years for indigenous vegetation.[115]

Costs

Costs are estimated using the approach described in Section 3.4.

A1.7 Exotics

Area

The area under exotics can be of different sizes, depending on constraints. The model includes

- Maximum planting rate per annum for all planting based on historical precedents;

[113] Assumed to be the timeframe for a farmer decision maker
[114] Source: SCION
[115] Ministry for Primary Industries (2017)

- Maximum area eligible for payment under *He Waka Eke Noa* pricing, eg 1ha only, but with unconstrained eligibility for ETS inclusion;

Revenue Limits

In some early analyses, the total area was limited by a rule under which the revenue from sequestration (under HWEN) cannot exceed:

- the amount paid out as charges (C <= A+B); at most a farmer can be revenue neutral; or
- the amount paid out as charges on N_2O (C <= B)

The equation to estimate the quantity under which C <= A+B is not straightforward as every additional hectare of forestry is also assumed to reduce the land available for farming and thus to reduce the charges paid under an A+B formula. The estimated area is calculated as follows.

$$A_e \times V_{es} + R_{os} = (A_{total} - A_e) \times C_e$$

Where: A_e = Area in exotics

A_{total} = Total area available (the effective area of a farm)

V_{es} = Value of exotics sequestration ($/ha = the sequestration rate times the price)

R_{os} = Revenue from other sequestration, ie riparian planting and regenerating natives

C_e = Cost of emissions per ha, ie t CH_4/ha x price on CH_4 + t N_2O/ha x price on N_2O

From this we estimate:

$$A_e = \frac{(A_{total} - A_e) \times C_e - R_{os}}{V_{es}}$$

and

$$A_e = \frac{A_{total} \times C_e - R_{os}}{(V_{es} + C_e)}$$

Sequestration Rates

We assume planting with *Pinus radiata* and use average annual absorption rates to year 17, consistent with calculations for an assumed averaging approach to counting emissions.

Table 67 Assumed sequestration rates

Region	17 years absorption (t CO_2)	Sequestration rate (t CO_2/ha/year)
Northland-Waikato-BoP	398	23.4
East Coast	439	25.8
Taranaki-Manawatu	436	25.6
Marlborough-Canterbury	258	15.2
Otago-Southland	301	17.7

Source: Estimated from MPI (2017)

Costs

Costs are assumed on the basis of planting and fencing costs. Farm Forestry NZ estimate costs for planting trees on farms as averaging approximately \$1,200/ha[116] and PFOlsen estimates planting costs of \$1,650/ha for forest establishment.[117] We use a cost of \$1,500/ha.

Fencing costs are calculated using the same formula as for native regeneration (see Figure 18). Costs are annualised over ten years using a 5% interest rate.

A1.8 Land Use Change Assumptions

Land use change is assumed to occur between farming and forestry. It is assumed to occur from a mix of push and pull reasons: the falling profitability of farming when emissions are priced and the increasing profitability of forestry when absorption is valued more with rising emission prices.

The problem for assessment of sheep & beef farms is that forestry already looks more profitable than farming. Table 68 summarises the estimated average current profitability (average over five years) as farm profit before tax (FPBT) in comparison with just the sequestration value of forestry at an assumed base value of \$75/t CO_2, the approximate current NZU price, using the sequestration rates in Table 67; this ignores any additional timber revenue from forestry. In all regions and farm classes, forestry is estimated to be more valuable. It will be even more so with higher values of sequestration (as NZU prices rise) and farm emissions are charged.

Table 68 Comparison of farm profitability with forestry value

Region	Class Name	Farm profit before tax (\$/ha)	Value of forestry at \$75/t CO_2
Northland-Waikato-BoP	3. N.I. Hard Hill Country	\$227	\$1,755
	4. N.I. Hill Country	\$314	\$1,755
	5. N.I. Finishing	\$641	\$1,755
East Coast	3. N.I. Hard Hill Country	\$206	\$1,935
	4. N.I. Hill Country	\$243	\$1,935
	5. N.I. Finishing	\$340	\$1,935
Taranaki-Manawatu	3. N.I. Hard Hill Country	\$168	\$1,924
	4. N.I. Hill Country	\$270	\$1,924
	5. N.I. Finishing	\$369	\$1,924
Marlborough-Canterbury	1. S.I. High Country	\$36	\$1,138
	2. S.I. Hill Country	\$108	\$1,138
	6. S.I. Finishing Breeding	\$242	\$1,138
	8. S.I. Mixed Finishing	\$286	\$1,138
Otago-Southland	1. S.I. High Country	\$36	\$1,329
	2. S.I. Hill Country	\$128	\$1,329
	6. S.I. Finishing Breeding	\$264	\$1,329
	7. S.I. Finishing	\$470	\$1,329
New Zealand	9. All Classes N.Z.	\$192	\$1,468

To account for this, we use a combination of approaches.

[116] https://www.nzffa.org.nz/farm-forestry-model/people-and-places/case-studies/mcintoshes/mcintoshes-estimated-costs-of-planting/
[117] https://nz.pfolsen.com/market-info-news/wood-matters/2012/march/good-forest-establishment-has-a-good-economic-return/

- We estimate the total shift in land use from farming to forestry using an econometric relationship as discussed in Section 1.3.4.

- We then distribute this total to individual farm categories using price elasticities.

The total area of exotic forestry under the ETS is determined using an equation of the form:

Planted area = $\alpha + \beta \cdot P_{NZU}$

Where: α = a coefficient for the planting rate (in '000 ha) at a zero price ($\alpha = 1.328$)
β = a coefficient used as a multiplier on the NZU price ($\beta = 0.725$)
P_{NZU} = the NZU price (\$/t CO_2-e)

To distribute the total, separate elasticity values are used for the change in farm profit and the value of forestry. Because the price response is uncertain (we are modelling changes in price outside of any historical record), we use the elasticities to distribute land use change within the farm categories, with greater weight applied to less profitable (low quintile) farms. The elasticities are applied as follows:

- Pull elasticity: to the % change in the \$/t CO_2 value of sequestration $\varepsilon = 4.0$

- Push elasticity: to the % change in the value of farming (measured as EBITRm[118] minus the cost of emission charges) $\varepsilon = -0.08$

[118] Profit for this purpose is estimated using earnings before interest, tax, rent and any wages paid to a manager (actual or family) (EBITRm). The farm profit before tax (FPBT) used elsewhere in the analysis is not used here because it is often negative, leading to difficulties in the application of the elasticity calculation.

Annex 2 Dairy Model

A methodology for estimating the impacts of emissions pricing schemes on the New Zealand dairy sector

Dr Graeme Doole (DairyNZ)

1. Introduction

An economic model has been developed to predict the broad, potential impacts of various emissions prices and/or targets for the NZ dairy sector. It will be used to determine how dairy farm management, financial performance, and emissions evolve over time under different emissions-pricing scenarios. This document describes the model, methods, and assumptions used as a foundation for the assessment.

2. Model

The tool to be used for assessment is a large-scale optimisation model that identifies profit-maximising solutions using GAMS software (Consiglio *et al* 2009; Doole 2015). It is similar to the framework of Doole (2021a).

It represents realistic diversity across individual farms in terms of production, profit, adoption of mitigations, asset structure, debt, greenhouse gas emissions, and nitrogen leaching (Doole, 2019a). The model differs from the ENZ model applied in CCC (2021a) through incorporating a more comprehensive description of dairy-system dynamics associated with the abatement of GHG-e (Doole 2014; Chikazhe and Davidson 2017; Reisinger *et al*, 2017; van der Weerden *et al* 2018).

The model employs an assumption that farmers evolve towards a point of profit maximisation across time, starting from their current position. The profitable configuration of each business changes over time given changes in the external environment (eg milk price, NZU price, policy settings).

3. Data

The method is based on (1) generating a baseline population of individual farms, and (2) projecting it forward across time under various policy scenarios. The model incorporates 11,590 individual farms calibrated to 2017/18 data for a wide range of metrics. The base year is chosen to align with the baseline specified in the Climate Change Response (Zero Carbon) Amendment Act 2019. Plus, the milk price in that year ($6.62/kg MS) is indicative of the historical mean observed in the last decade, helping to ensure that the baseline is not biased either upward or downward by an abnormal milk price (DairyNZ, 2020).

The model studies the period, 2017-2035. The endpoint of this series (2035) aligns with the terminal year studied in the near-term planning scenarios of CCC (2021a), is close enough that we can make informed decisions with regards to the direction and speed of technical innovation, and allows for sufficient time to pass for farm price exposure to be usefully represented in the modelling.

The incorporation of time allows the analysis of important elements of the issue at hand, such as:

- Changes in the level of free allocation and NZU price over time.
- Implementation of other policies across time, such as the National Policy Statement for Freshwater Management 2020 (NPS-FM) and the Resource Management (National Environmental Standards for Freshwater) Regulations 2020 (NES-FW).

- The cost-price squeeze typical of agricultural production, in which input prices rise faster than output prices (Moss, 1992).
- improvements in efficiency and adaptation allow operating costs to decrease over the period, all else held constant (Doole, 2019b).
- Changes in a farming system and/or the adoption of new innovations is a dynamic process.
- The effectiveness of some mitigations grows over time; for example, the breeding of cows who emit lower levels of enteric methane (CCC, 2021a).
- Feedbacks between environmental policy and asset-price appreciation are captured using the method of Muller and Neal (2019).
- Debt will grow if farms are unable to reliably cover their annual operating and loan costs.

3.1 Generating a baseline dairy farm population

The baseline is generated using R software (R Core Team, 2020), following a method applied by Doole (2019a, 2020, 2021a). The aim of the exercise is to use statistically-consistent methods to generate representative data sets for discrete farms across each dairy-farming region in New Zealand. The number of farms in each region is taken from the New Zealand Dairy Statistics publication (LIC/DairyNZ, 2018).

The data sample used to generate the baseline population is from the DairyBase system. DairyBase records, standardises, and reports physical and financial information from New Zealand dairy farms using an online platform (DairyBase, 2016). The DairyBase data is filtered to include only owner-operator farms. A focus on owner-operators simplifies the analysis and introduces little bias, while sharpening insight on the most common farm type.

Farms that record outliers for farm size, milk production per hectare, and/or stocking rate are removed using the standard statistical rule that an extreme observation is one that sits 1.5 times the interquartile range below the first quartile or above the third quartile (Verbeek, 2017). The inclusion/exclusion of farms within the sample is then adjusted until the average farm size, milksolids per cow, and stocking rate for the sample closely matches the regional averages for these variables published in LIC/DairyNZ (2018). This matching is automated using a binary-optimisation procedure to solve a multiple-objective minimisation problem (Doole and Kingwell, 2010).

The main variables generated for each farm for the base year are farm size (ha); stocking rate (cows/ha); milk per cow (kg MS/cow); gross farm revenue ($/kg MS); operating expenses ($/kg MS); nitrogen fertiliser application (kg N/ha); asset level ($/ha); liabilities ($/ha); annual debt payment ($/ha); rent ($/ha); nitrogen leaching (kg N/ha); and methane, nitrous oxide, carbon dioxide, and total emissions (kg CO_2-eq/ha). Individual values for each of these elements is generated for each farm present in a region.

Each random variable for each individual farm is generated in an integrated manner across the set of variables to be estimated using an augmented Fleishman (1978) method. (Augmentation of this method draws on methods developed recently by DairyNZ to overcome abnormal kurtosis levels and/or singular data matrices.) This procedure accounts for the respective means, variances, covariances, skewness, kurtosis, minima, and maxima identified in the earlier estimation stage. The consideration of covariances among each variable is noteworthy, given the various associations between financial and physical variables found within a dairy farm system (Macdonald *et al* 2008, 2017).

Non-parametric Kolmogorov-Smirnov tests (Dickhaus 2018) are applied to confirm that the distributions generated for each variable are consistent with the base data.

Empirical distributions generated for the national dairy sector are reported for several key variables in Figures 1-3 below.

Figure 1. National distribution of (a) number of cows within each herd, and (b) milk production (kg MS) per hectare. Theblack dashed vertical line in each figure is the median of the distribution.

(a) (b)

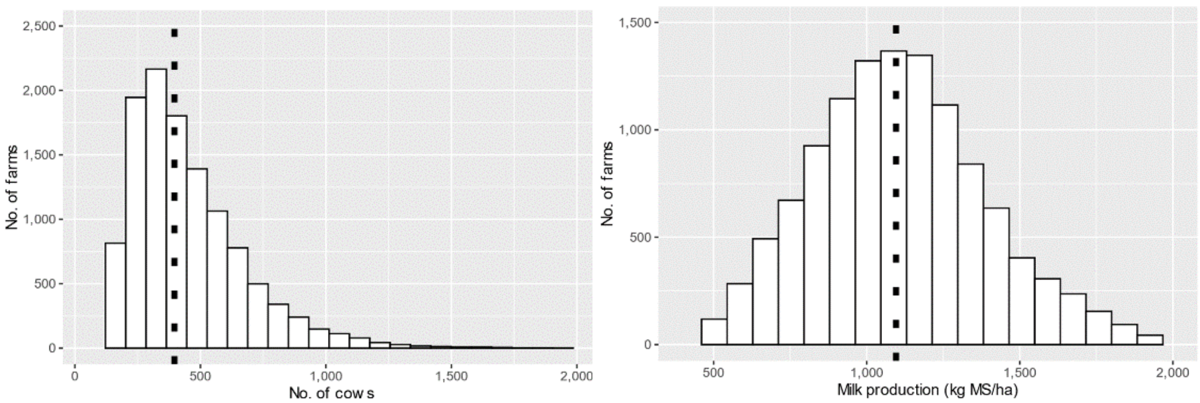


Figure 2. National distribution of (a) operating profit ($m/farm), and (b) debt to asset ratio (%). The black dashed verticalline in each figure is the median of the distribution. The green, orange, and red vertical lines are reported in the right-hand figure for the 25th, 50th, and 90th percentiles, which are consistent with low, medium, and high risk of insolvency.

(a) (b)

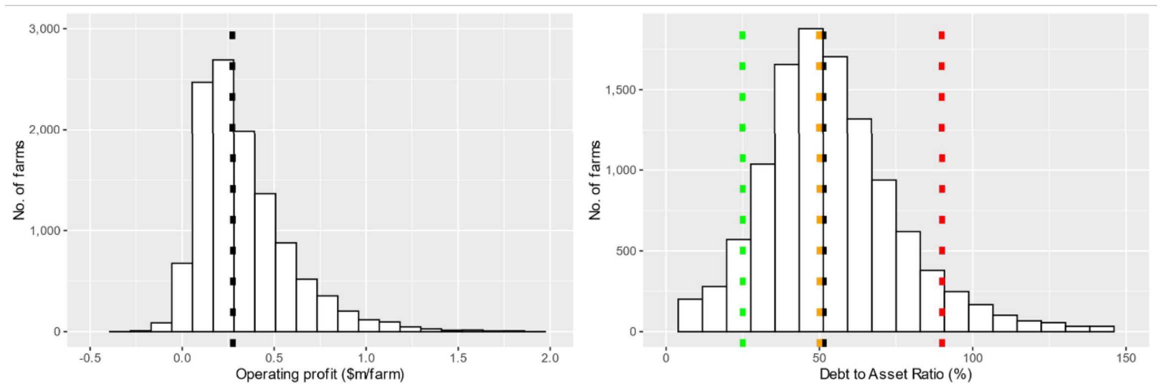
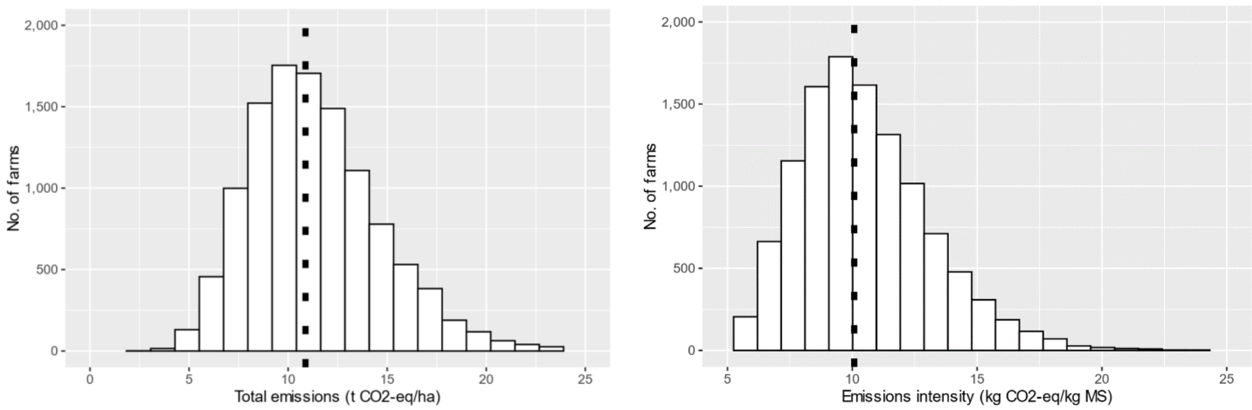


Figure 3. National distribution of (a) total emissions (t CO2-eq/ha), and (b) emissions intensity (kg CO2-eq/kg MS). Theblack dashed vertical line in each figure is the median of the distribution.

(a) (b)



The proportion of carbon dioxide emissions coming from nitrogen fertiliser are computed using dairy system information in Ledgard and Falconer (2015).

3.2 Mitigation Costs

A literature review is conducted to identify and summarise data sets describing the impacts of greenhouse-gas abatement on New Zealand dairy farms. Examples of important studies that are included are: Anderson and Ridler (2010), Doole (2014), DairyNZ (2014), Chikazhe and Davidson (2017), Reisinger *et al* (2017), and van der Weerden *et al* (2018).

The key relationships of interest are how mitigation of different gases impact stocking rate (cows/ha), milk per cow (kg MS/cow), nitrogen fertiliser application (kg N/ha), gross farm revenue ($/kg MS), operating profit margin (%) and nitrogen leaching (kg N/ha). Regression methods are used to estimate relationships between these variables in a robust way that is consistent with interactions within a dairy farm system (Macdonald *et al* 2008; Romera and Doole 2015). The goal is to estimate data-driven non-linear regression equations that vary by farm, in terms of both intercept and slope coefficients. Each of the variables are related; thus, it is necessary to proactively address endogeneity in the estimation procedure. A non-linear, simultaneous equations, mixed error-components model, incorporating random effects for both intercept and slope coefficients, is applied to achieve this goal (Davidian and Giltinan, 1995). This is performed using R software.

Theory from environmental economics stipulates that abatement effort usually imposes an explicit cost on individual enterprises (Hanley *et al* 2007). However, the conclusion that all mitigation is costly contrasts with evidence from a range of modelling studies (Anderson and Ridler 2010; Smeaton *et al* 2011; Doole 2014), case studies (Vibart *et al* 2015), and farm-system experiments (van der Weerden *et al* 2018) that highlight that mitigation of greenhouse-gases can result in improved farm profit. These studies attest to the potential to reduce emissions while increasing productivity through better balancing pasture growth and utilisation (Vibart *et al* 2015). This effect is enhanced when the impact of decreasing supplement use on other costs, such as those for labour and machinery, are also considered. This is based on empirical work that shows that decreasing the use of imported feed by $1,000/ha decreases the burden of other costs by around $500 (Macdonald *et al* 2017; Neal *et al* 2019).

Many farms within the dairy sector are currently not efficiently using feed (Anderson and Ridler, 2010; Macdonald *et al* 2017; Neal *et al* 2019). Yet, evidence pertaining to the potential to reduce emissions at low cost through improving feed-use efficiency is mixed. Most of the available strategies require increasing the genetic potential for production in a herd, reducing replacement rates, and decreasing stocking rates (Beukes *et al* 2010, 2011; Smeaton *et al* 2011; Vibart *et al* 2015). De Klein and Dynes (2017) reviewed the empirical evidence available for this option. They identified an average decrease of 0.95% in milk production per 1% decline in GHG-e across nine studies, close to the 1:1 response that emerged endogenously in the work of Doole (2021a). Further, they note the complexity and cost of maintaining such a system. Barriers to adoption include the high cost of attaining a herd of improved genetic merit, high managerial ability required to reduce replacement rates, diversity in farm resources, and the need for advanced pasture-management skills to maintain pasture quality (Doole, 2014, 2019b; Romera and Doole, 2015; de Klein and Dynes, 2017).

The use of a range of studies, including those that contain the potential to increase profit while decreasing emissions, ensures that such relationships are incorporated in the model applied in this analysis. The estimation of farm-specific abatement relationships ensures that this diversity is not omitted through only considering mean responses, as done in standard analysis (Doole, 2012). Reducing greenhouse gases, particularly methane, will on average come at a cost to the dairy sector (Doole, 2019a, b, 2021a). Yet, the presence of some farms that can improve feed-use efficiency suggests that these costs are lower than what they would be if existing farms were already optimised.

3.3 Limits, prices, and technology

Emissions pathways for each greenhouse gas are proposed for several scenarios in CCC (2021a). These limits are not considered in the analysis, following consultation with MFE and MPI. This pragmatic response is due to the uncertainty around which pathway(s) are assumed to be most relevant and to sharpen focus in this application on the emissions reductions accruing to various emissions prices.

Inflation in farm input prices has been higher than the rate of inflation observed for output prices for the last decade in the New Zealand dairy sector (DairyNZ, 2020), consistent with the cost-price squeeze characteristic of agricultural production (Moss, 1992). Thus, in the model, net inflation erodes farm profit at the rate of 1% per year, based on data from DairyNZ (2020). This assumption is implemented in the model through annual changes in the operating profit margin.

Farm efficiency improvements over the last 30 years have been sufficient to offset, but not supersede, losses arising due to the cost-price squeeze (Romera *et al* 2020). The introduction of limits and/or prices for emissions from dairy farms, in addition to increasing competitiveness of USA growth milk and appearance of substitutes, will likely provide motivation for more-efficient use of inputs (Harris and Doole, 2015; Doole, 2021b).

It is assumed that the NES-FW applies from 2020 and the NPS-FM applies from 2025. The primary additional costs represented under the NES-FW are those associated with a 190 kg N/ha limit for nitrogen fertiliser application and regulations around intensive winter grazing. In comparison, the primary additional costs represented under the NPS-FM are farm- and region-specific limits for nitrogen toxicity set at 2.4 mg/l plus costs associated with establishing, following, and auditing farm environment plans.

The impacts of climate change on management, production, and profit are not incorporated. This is based on the focus of this work on the near term and the flexibility of NZ dairy systems that help to moderate the negative impacts of climate change, at least prior to 2050 (Kalaugher *et al* 2017).

A measure used in the reporting of model output is Economic Value Added (EVA) (Chen and Dodd, 1997; Doole and Shadbolt, 2021). EVA captures the full cost of a business, consisting of operating profit plus capital gain/loss minus rent, tax, interest, and an equity charge. It is a holistic measure of the economic health and competitiveness of a farm and/or sector. A business with an EVA below zero is going backward financially, while an EVA above zero is growing wealth. The assumed tax rate in the EVA computation is the company tax rate of 28%. The assumed opportunity cost of equity is 3.65%.

Around 25,172 km of dairy Accord streams have been fenced to exclude dairy cattle on dairy farms (DELG, 2019). A much larger number of 86,379 km is present in Grinter and White (2016, p.6), where that includes milking platforms, dairy support land, and third-party graziers. The DELG (2019) estimate is used given that the economic model applied here focuses on the milking platform. The total size of the NZ dairy sector is 1,730,374 ha. This yields an average length of stream bank fencing of 15 metres per hectare on the average New Zealand dairy farm. The median buffer length on these farms is 3 m, with a third containing woody vegetation potentially suitable for sequestration (Quinn, 2003; Renouf and Harding, 2015). Assuming that both sides contain such a buffer, then these assumptions infer that 30 m2 of riparian vegetation per ha can potentially be available for sequestration. This is 0.3% of a hectare.

4. Conclusions

The focus of this analysis is to determine how dairy farm management, financial performance, and emissions evolve over time under different emissions-pricing scenarios. This document presents and justifies the model, methods, and assumptions used as a foundation for the assessment. Any outputs of the modelling are conditional on the structure and assumptions contained therein. This emphasises the need to consider the impacts of different assumptions on key results through the application of structured sensitivity analysis (Pannell, 1997).

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Annex 3: Additional Sectoral Analysis Results

A3.1 Processor ETS

Dairy

Table 69 Processor ETS Results - Dairy

	CH_4 price ($/kg CH_4)	N_2O Price ($/t CO_2-e)	CH_4	LLG	Milk production	Profit	Gross revenue ($m)
2025	$0.11	$4.25	-0.41%	-0.36%	-0.51%	-1.73%	$76
2030	$0.35	$13.80	-1.44%	-1.14%	-1.77%	-5.50%	$242

Sheep & Beef

Table 70 Processor ETS Results - Sheep & Beef

	CH_4 price ($/kg CH_4)	N_2O Price ($/t CO_2-e)	CH_4	LLG	Sheep & Beef Meat	Sheep & beef profit	Gross revenue ($m)
2025	$0.11	$4.25	-0.07%	-0.07%	-0.21%	-4.14%	$63
2030	$0.35	$13.80	-0.11%	-0.12%	-0.11%	-14.72%	$205

A3.2 Farm Level Levy

Dairy

Table 71 Impacts of farm level levy on dairy farms - 2025

CH4 price ($/kg CH_4)	N_2O Price ($/t CO_2-e)	CH_4	LLG	Milk	Profit	Gross revenue
$0.05	$4.25	-0.15%	-0.25%	-0.17%	-0.98%	$45
$0.05	$21.25	-0.28%	-2.41%	-0.32%	-1.89%	$104
$0.05	$85.00	-1.12%	-11.57%	-1.21%	-4.96%	$294
$0.11	$4.25	-0.32%	-1.08%	-0.33%	-1.82%	$79
$0.11	$21.25	-0.41%	-2.55%	-0.45%	-2.73%	$138
$0.11	$85.00	-1.36%	-11.77%	-1.46%	-5.79%	$327
$1.00	$4.25	-3.18%	-3.50%	-3.49%	-14.93%	$604
$1.00	$21.25	-3.51%	-5.15%	-3.85%	-15.80%	$659
$1.00	$85.00	-4.59%	-14.20%	-4.99%	-18.72%	$837

Table 72 Impacts of farm level levy on dairy farms - 2030

CH4 price ($/kg CH_4)	N_2O Price ($/t CO_2-e)	CH_4	LLG	Milk	Profit	Gross revenue
$0.05	$13.80	-0.32%	-1.68%	-0.35%	-1.48%	$78
$0.05	$41.40	-0.57%	-5.23%	-0.61%	-2.88%	$168
$0.05	$138.00	-1.97%	-17.59%	-2.12%	-7.05%	$426
$0.11	$41.40	-0.81%	-5.49%	-0.87%	-3.64%	$199
$0.35	$13.80	-1.22%	-3.20%	-1.29%	-5.80%	$255
$0.35	$41.40	-1.52%	-6.00%	-1.62%	-7.19%	$344
$0.35	$138.00	-2.92%	-18.30%	-3.13%	-11.29%	$597
$1.00	$13.80	-3.55%	-5.22%	-3.88%	-15.24%	$634
$1.00	$41.40	-3.85%	-7.89%	-4.24%	-16.58%	$720
$1.00	$138.00	-5.52%	-20.10%	-5.97%	-20.53%	$960

The results with high technology assumptions are shown in Table 73 for the more limited set of prices and 2030 only. There are small additional reductions in CH_4 emissions, although N_2O emissions rise slightly.

Table 73 Impacts of farm level levy on dairy farms – 2030 with high technology

CH4 price ($/kg CH_4)	N_2O Price ($/t CO_2-e)	CH_4	LLG	Milk	Profit	Gross revenue
$0.05	$13.80	-0.3%	-1.4%	-0.3%	-1.4%	$75
$0.35	$13.80	-1.1%	-2.0%	-1.2%	-5.7%	$252
$0.11	$41.40	-0.8%	-5.5%	-0.9%	-3.6%	$199
$0.35	$41.40	-1.5%	-6.0%	-1.6%	-7.1%	$341

Sheep & Beef

Table 74 Impacts of farm level levy on sheep and beef farms – 2025

CH_4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	LLG	Meat production	Profit	Gross Revenue ($m)
$0.05	$4.25	0.0%	0.0%	0.0%	-2.7%	$34
$0.05	$21.25	-0.1%	-0.1%	-0.2%	-4.8%	$70
$0.05	$85.00	-0.3%	-0.3%	-0.8%	-12.1%	$203
$0.11	$4.25	-0.1%	-0.1%	-0.2%	-4.2%	$63
$0.11	$21.25	-0.1%	-0.1%	-0.3%	-6.2%	$99
$0.11	$85.00	-0.4%	-0.4%	-1.0%	-13.4%	$232
$1.00	$4.25	-1.4%	-1.2%	-2.3%	-27.5%	$513
$1.00	$21.25	-1.3%	-1.2%	-2.1%	-30.5%	$549
$1.00	$85.00	-1.1%	-1.0%	-1.9%	-40.8%	$682

Table 75 Impacts of farm level levy on sheep and beef farms – 2030

CH_4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	N_2O	Meat production	Profit	Gross Revenue ($m)
$0.05	$13.80	0.0%	0.0%	0.0%	-2.1%	$55
$0.05	$41.40	-0.1%	-0.1%	-0.1%	-6.0%	$112
$0.05	$138.00	-0.3%	-0.5%	-0.3%	-19.2%	$313
$0.11	$41.40	-0.1%	-0.1%	-0.1%	-7.5%	$141
$0.35	$13.80	-0.3%	-0.1%	-0.1%	-12.5%	$205
$0.35	$41.40	-0.4%	-0.2%	-0.2%	-16.2%	$262
$0.35	$138.00	-0.6%	-0.7%	-0.5%	-30.1%	$463
$1.00	$13.80	-4.8%	-1.6%	-1.4%	-25.4%	$516
$1.00	$41.40	-4.9%	-1.7%	-1.5%	-29.2%	$572
$1.00	$138.00	-4.8%	-1.7%	-1.4%	-44.2%	$772

The effects of the high technology assumptions are shown for 2030 only in Table 76.

Table 76 Impacts of farm level levy on sheep and beef farms – 2030

CH_4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	N_2O	Meat production	Profit	Gross Revenue ($m)
$0.05	$13.80	0.0%	0.0%	0.0%	-2.1%	$55
$0.35	$13.80	-0.3%	-0.1%	-0.1%	-12.5%	$205
$0.11	$41.40	-0.1%	-0.1%	-0.1%	-7.5%	$141

A3.3 Processor Hybrid

Dairy

Table 77 Processor hybrid, dairy farms, 2.5x multiplier, 2025

CH4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	LLG	Milk	Dairy profit	Gross levy revenue ($m)	EMCs ($m)
$0.05	$4.25	-2.1%	-0.9%	-1.2%	-2.6%	$47	$12
$0.05	$21.25	-1.2%	-5.7%	-1.2%	-0.6%	$127	$69
$0.05	$85.00	-5.7%	-25.8%	-6.5%	10.6%	$402	$443
$0.11	$4.25	-2.3%	0.0%	-1.7%	-2.0%	$78	$21
$0.11	$21.25	-2.0%	-4.6%	-2.1%	-0.9%	$157	$77
$0.11	$85.00	-6.5%	-25.4%	-7.4%	10.3%	$427	$454
$1.00	$4.25	-15.9%	-13.5%	-15.4%	1.9%	$488	$383
$1.00	$21.25	-17.7%	-20.0%	-17.3%	5.3%	$543	$492
$1.00	$85.00	-23.6%	-32.0%	-23.7%	20.5%	$730	$978

Table 78 Processor hybrid, dairy farms, 2.5x multiplier, 2030

CH4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	LLG	Milk	Dairy profit	Gross levy revenue ($m)	EMCs ($m)
$0.05	$13.80	-0.87%	-2.62%	-0.71%	-1.40%	$93	$41
$0.05	$41.40	-2.51%	-13.47%	-2.81%	2.06%	$218	$167
$0.05	$138	-9.71%	-36.01%	-11.11%	24.14%	$605	$856
$0.11	$41.40	-6.84%	-12.11%	-7.65%	-1.62%	$356	$234
$0.35	$13.80	-5.01%	-3.83%	-5.60%	-1.59%	$244	$107
$0.35	$41.40	-6.84%	-12.03%	-7.65%	1.42%	$359	$234
$0.35	$138	-14.70%	-35.70%	-16.52%	24.72%	$706	$961
$1.00	$13.80	-17.00%	-17.08%	-16.65%	3.65%	$520	$440
$1.00	$41.40	-20.13%	-26.81%	-19.77%	10.20%	$605	$648
$1.00	$138	-29.10%	-42.26%	-29.13%	38.31%	$858	$1,499

Sheep & Beef

Table 79 Processor hybrid, sheep & beef farms, 2.5x multiplier, 2025

CH4 price ($/kg CH4)	LLG Price ($/t CO2-e)	CH4	N2O	Meat production	Profit	Gross Revenue ($m)	EMCs ($m)
$0.05	$4.25	0.0%	0.0%	0.0%	-2.2%	$34	$0
$0.05	$21.25	0.1%	0.1%	0.2%	-4.3%	$70	$0
$0.05	$85.00	0.3%	0.3%	0.8%	-11.6%	$202	$0
$0.11	$4.25	0.1%	0.1%	0.2%	-3.8%	$63	$0
$0.11	$21.25	0.1%	0.1%	0.3%	-5.8%	$99	$0
$0.11	$85.00	0.4%	0.4%	0.9%	-12.9%	$231	$0
$1.00	$4.25	1.2%	1.2%	2.2%	-26.9%	$509	$0
$1.00	$21.25	1.2%	1.2%	2.1%	-29.9%	$545	$0
$1.00	$85.00	1.0%	1.0%	1.8%	-40.2%	$678	$0

Table 80 Processor hybrid, sheep & beef farms, 2.5x multiplier, 2030

CH4 price ($/kg CH_4)	LLG Price ($/t CO_2-e)	CH_4	LLG	Meat	Profit	Gross levy revenue ($m)	EMCs ($m)
$0.05	$13.80	0.0%	0.0%	0.0%	-0.5%	$55	$0
$0.05	$41.40	-0.1%	-0.1%	-0.1%	-4.4%	$112	$0
$0.05	$138	-0.3%	-0.4%	-0.3%	-17.5%	$314	$0
$0.11	$41.40	-0.1%	-0.1%	-0.1%	-5.9%	$141	$0
$0.35	$13.80	-1.3%	-0.1%	-0.1%	-10.8%	$205	$5
$0.35	$41.40	-1.4%	-0.2%	-0.2%	-14.4%	$263	$5
$0.35	$138	-1.7%	-0.5%	-0.5%	-28.3%	$464	$6
$1.00	$13.80	-3.2%	-1.5%	-1.4%	-23.1%	$533	$24
$1.00	$41.40	-3.4%	-1.7%	-1.5%	-26.7%	$589	$24
$1.00	$138	-3.3%	-1.6%	-1.4%	-42.2%	$790	$25

A3.4 FLL + Technology Payments

Dairy

Table 81 FLL + Technology Payments, 2025 - Dairy

CH4 price ($/kg CH4)	LLG Price ($/t CO2-e)	Multiplier	CH4	LLG	Milk	Dairy profit	Revenue ($m)	EMC or Tech pmt ($m)
$0.05	$4.25	5	-0.2%	-0.9%	-0.2%	-0.9%	$43	$0.0
$0.11	$4.25	5	-0.3%	-1.0%	-0.3%	-1.8%	$77	$0.0
$0.11	$21.25	5	-0.4%	-2.5%	-0.4%	-2.7%	$136	$0.0

Table 82 FLL + Technology Payments, 2030 - Dairy

CH4 price ($/kg CH4)	LLG Price ($/t CO2-e)	Multiplier	CH4	LLG	Milk	Dairy profit	Revenue ($m)	EMC or Tech pmt ($m)
$0.05	$13.80	5	-0.3%	-2.6%	-0.3%	-1.4%	$74	$0
$0.35	$13.80	5	-2.1%	-3.3%	-1.2%	-5.6%	$238	$0
$0.11	$41.40	5	-0.8%	-5.5%	-0.9%	-3.6%	$199	$0

Sheep & Beef

Table 83 FLL + Technology Payments, 2025 – Sheep & Beef

CH4 price ($/kg CH4)	LLG Price ($/t CO2-e)	Multiplier	CH4	LLG	Meat	Profit	Revenue ($m)	EMC or Tech pmt ($m)
$0.05	$4.25	5	0.0%	0.0%	0.0%	-2.2%	$34	$0
$0.11	$4.25	5	-0.1%	-0.1%	-0.2%	-3.7%	$63	$0
$0.11	$21.25	5	-0.1%	-0.1%	-0.3%	-5.7%	$99	$0

Table 84 FLL + Technology Payments, 2030 - Sheep & Beef

CH4 price ($/kg CH4)	LLG Price ($/t CO2-e)	Multiplier	CH4	LLG	Meat	Profit	Revenue ($m)	EMC or Tech pmt ($m)
$0.05	$13.80	5	0.0%	-0.2%	0.0%	-0.5%	$54	$0
$0.35	$13.80	5	-2.8%	-0.3%	-0.1%	-10.6%	$200	$7
$0.11	$41.40	5	-0.1%	-0.3%	-0.1%	-5.8%	$141	$0

Annex 4: Sequestration Modelling Assumptions

Erica van Reenen, Consultant, Principal Author

Estimating percentage of He Waka Eke Noa vegetation that contributes to NZ Target Accounts

There are no datasets available which enable a distinction to be made between vegetation eligible for *He Waka Eke Noa* and vegetation which meets the definitions to be able to account for it in our Target Accounts.

The following approach has been used which provides a very rough estimate. The approach uses estimates provided by MfE.

The approach was to estimate the total area of woody biomass that would meet *He Waka Eke Noa* definitions based on the 2020 inventory categories. This required making assumptions on the proportion of this land which was indigenous, and the proportion that was pre-1990. It was not possible to determine pre-2008 from the data.

The area that contributes to target accounts was based on the total area of post-1989 indigenous forest, less the amount of this registered in the ETS (approximation), less the approximate area on conservation estate as per the table below.

Category	Area total (ha)	Notes
Post-89 indigenous forest	90,506	
Post-89 indigenous forest in ETS	34,908	
Post-89 indigenous forest not in the NZ ETS	55,598	
Post-89 indigenous forest not in the NZ ETS and on private land	42,492	~14% on public conservation estate

The table below summarises the assumptions made on the 'land classified as grassland with woody biomass' (GWB) and the 'pasture (low/high producing grassland) with woody vegetation/shrubs that is not classified as grassland with woody biomass' (PWV).

The equation used to ascertain the percentage of area meeting targets is outlined below:

$$\frac{(Post89\ indigenous \times 0.86)\ - ETS\ registered\ post89\ indigenous}{\big((Post89\ indigenous \times 0.86)\ - ETS\ registered\ post89\ indigenous\big) + (HWEN\ eligible\ GWB) + (HWEN\ eligible\ PWV)} \times 100$$

The total estimated He Waka Eke Noa eligible less what is already in the ETS was: 172,078ha.
The percentage of this that meets targets as per equation above was 25%.

Category	Area total	Area of Indigenous	Area of exotic	Area of pre-1990 (ha)	Area of post-89 (ha)	Area that meets HWEN post-07 (total less exotic, less p90) (ha)	Notes/caveats
Land classified as grassland with woody biomass	510,000 ha	Assume 80 %	Assume 20%	459,000	51,000	40800	Approximately 500,000 ha of GWB occurs on sheep and beef land. Assume only another 10,000ha occurs on other farmland. 90% of this is assumed to be pre-90. It is unclear what proportion of this is indigenous. **Assumed 80% but this could be highly inaccurate and might be lower**.
Pasture (low/high producing grassland) with woody vegetation/shrubs that is not classified as GWB	110,982.4 ha	Assume 80 %	Assume 20%	998,842	110,982	88,786	Assume 28% of all high and low producing grasslands have areas of shrubs and of this the average coverage per hectare is 30%.* Of this assume 90% of these are pre-90. Unclear what proportion is indigenous. **Assumed 80% but this could be highly inaccurate and might be lower**.

Annex 5: CBA Results and Assumptions

Results

2025						
Processor ETS						
	Sheep & Beef	Dairy	Arable & hort	Private total	Taxpayers	NZ Total
Levy payments	-$63.2	-$75.6	-$1.1	-$139.9	$139.9	$0.0
Sequestration payments				$0.0	$0.0	$0.0
EMC Payments				$0.0	$0.0	$0.0
Emission reduction costs	-$2.3	$5.2	$0.0	$2.9		$2.9
Sequestration costs	-$6.2	-$0.2	$0.0	-$6.4		-$6.4
Total	-$71.7	-$70.6	-$1.1	-$143.4	$139.9	-$3.5
Emission reductions (t)						
CH4	8,636	62,918	0	71,554		71,554
N2O	1,229	10,818	0	12,047		12,047
CO2	184	2,812	0	2,996		2,996
Total	10,049	76,549	0	86,598	0	86,598
HWEN Sequestration	0	0	0	0		0
Extra ETS Sequestration	264,507	0	0	264,507		264,507
Value						
$/t	$233	-$68				-$33
Emission Benefits	$1.0	$7.6	$0.0	$8.6	$0.0	$8.6
Sequestration Benefits	$26.2	$0.0	$0.0	$26.2	$0.0	$26.2
Total Benefits	$27.2	$7.6	$0.0	$34.8	$0.0	$34.8

2030						
Processor ETS						
	Sheep & Beef	Dairy	Arable & hort	Private total	Taxpayers	NZ Total
Costs						
Levy payments	-$205.2	-$242.4	-$3.5	-$451.1	$451.1	$0.0
Sequestration payments				$0.0	$0.0	$0.0
EMC Payments				$0.0	$0.0	$0.0
Emission reduction costs	-$3.9	$15.3	$0.0	$11.4		$11.4
Sequestration costs	-$7.8	-$0.2	$0.0	-$8.0		-$8.0
Total	-$216.8	-$227.4	-$3.5	-$447.7	$451.1	$3.4
Emission reductions (t)						
CH4	14,383	219,147	0	233,530		233,530
N2O	2,031	33,460	0	35,491		35,491
CO2	523	9,796	0	10,319		10,319
Total	16,937	262,403	0	279,340	0	279,340
HWEN Sequestration	0	0	0	0		0
Extra ETS Sequestration	487,645	0	0	487,645		487,645
Value						
$/t	$228	-$58		-$41		-$41
Emission Benefits	$2.5	$38.0	$0.0	$40.5	$0.0	$40.5
Sequestration Benefits	$70.7	$0.0	$0.0	$70.7	$0.0	$70.7
Total Benefits	$73.2	$38.0	$0.0	$111.2	$0.0	$111.2

FLL (2025 Start)

2025	FLL + Tech Payments					
	Sheep & Beef	Dairy	Arable & hort	Private total	Taxpayers	NZ Total
Costs						
Levy payments	-$63.1	-$78.6	-$1.1	-$142.9	$142.9	$0.0
Sequestration pa	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Tech payments (	$0.4	$0.1	$0.0	$0.4	-$0.4	$0.0
Emission reducti	-$2.1	$1.9	$0.0	-$0.2		-$0.2
Sequestration co	-$5.5	-$0.17	0	-$5.7		-$5.7
Total	-$70.4	-$76.9	-$1.1	-$148.3	$142.4	-$5.9
Emission reductions (t)						
CH4	25,105	44,820		69,924		69,924
N2O	1,088	36,600		37,688		37,688
CO2	160	2,003		2,164		2,164
Total	26,353	83,423		109,777		109,777
HWEN Sequestra	0	0		0		0
Extra ETS Seques	241,613		0	241,613		241,613
Value						
$/t	$80	-$23				$2
Emission Benefit	$2.6	$8.3	$0.0	$10.9	$0.0	$10.9
Sequestration Be	$23.9	$0.0	$0.0	$23.9	$0.0	$23.9
Total Benefits	$26.5	$8.3	$0.0	$34.8	$0.0	$34.8

2030	FLL + Tech Payments					
	Sheep & Beef	Dairy	Arable & hort	Private total	Taxpayers	NZ Total
Costs						
Levy payments	-$200.4	-$78.6	-$3.5	-$282.6	$282.6	$0.0
Sequestration pa	$60.2	$2.9	$0.0	$63.1	-$63.1	$0.0
Tech payments (	$9.6	$140.8	$0.0	$150.4	-$150.4	$0.0
Emission reducti	-$4.7	-$102.2	$0.0	-$106.8		-$106.8
Sequestration co	-$60.2	-$1.91	0	-$62.1		-$62.1
Total	-$195.4	-$39.0	-$3.5	-$238.0	$69.0	-$169.0
Emission reductions (t)						
CH4	359,353	1,216,882	0	1,576,235		1,576,235
N2O	5,107	135,244	0	140,351		140,351
CO2	473	54,395	0	54,868		54,868
Total	364,933	1,406,521	0	1,771,454		1,771,454
HWEN Sequestra	581,715	18,469	0	600,184		600,184
Extra ETS Seques	466,850		0	466,850		466,850
Value						
$/t	$13	$73		$60		$60
Emission Benefit	$52.9	$203.9	$0.0	$256.9	$0.0	$256.9
Sequestration Be	$88.8	$0.7	$0.0	$89.4	$0.0	$89.4
Total Benefits	$141.7	$204.6	$0.0	$346.3	$0.0	$346.3

2025	PH + Benchmark					
	Sheep & Beef	Dairy	Arable & hort	Private total	Taxpayers	NZ Total
Costs						
Levy payments	-$63.2	-$77.2	-$1.1	-$141.5	$141.5	$0.0
Sequestration payments	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
EMC payments (multiplier: 5	$0.0	$56.1	$0.0	$56.1	-$56.1	$0.0
Emission reduction costs	-$1.7	-$22.1	$0.0	-$23.8	$0.0	-$23.8
Sequestration costs	-$4.9	-$0.16		-$5.1	$1.0	-$4.1
Total	-$69.8	-$43.4	-$1.1	-$114.3	$86.4	-$27.9
Emission reductions (t)				$0.0		
CH4	6,410	476,100		482,511		482,511
N2O	912	196,097		197,009		197,009
CO2	131	21,282		21,413		21,413
Total	7,454	693,479		700,933		700,933
HWEN Sequestration	0	0	0	0		
Extra ETS Sequestration	212,278	0	0	212,278		212,278
Value						
$/t	$233	$32				$34
Emission Benefits	$0.7	$68.7	$0.0	$69.4	$0.0	$69.4
Sequestration Benefits	$21.0	$0.0	$0.0	$21.0	$0.0	$21.0
Total Benefits	$21.8	$68.7	$0.0	$90.4	$0.0	$90.4

2030	PH + Benchmark					
	Sheep & Beef	Dairy	Arable & hort	Private total	Taxpayers	NZ Total
Costs						
Levy payments	-$63.2	-$77.2	-$3.5	-$143.9	$143.9	$0.0
Sequestration payments	$60.2	$2.9	$0.0	$63.1	-$63.1	$0.0
EMC payments (multiplier: 5	$14.7	$302.4	$0.0	$317.1	-$317.1	$0.0
Emission reduction costs	-$8.3	-$78.5	$0.0	-$86.8		-$86.8
Sequestration costs	-$60.2	-$1.91	0	-$62.1		-$62.1
Total	-$56.8	$147.7	-$3.5	$87.3	-$236.3	-$148.9
Emission reductions (t)				$0.0		
CH4	223,514	1,462,569	0	1,686,083		1,686,083
N2O	2,745	556,330	0	559,076		559,076
CO2	413	65,377	0	65,790		65,790
Total	226,672	2,084,277	0	2,310,949		2,310,949
HWEN Sequestration	581,715	18,469	0	600,184		600,184
Extra ETS Sequestration	436,256	0	0	436,256		436,256
Value						
$/t	$37	$38		$38		$38
Emission Benefits	$32.9	$302.2	$0.0	$335.1	$0.0	$335.1
Sequestration Benefits	$84.3	$0.7	$0.0	$85.0	$0.0	$85.0
Total Benefits	$117.2	$302.9	$0.0	$420.1	$0.0	$420.1

2025	PH + Actions					
	Sheep & Beef	Dairy	Arable & hort	Private total	Taxpayers	NZ Total
Costs						
Levy payments	-$63.2	-$78.3	-$1.1	-$142.5	$142.5	$0.0
Sequestration payments	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
EMC payments (multiplier: 1	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Emission reduction costs	-$1.7	$2.1	$0.0	$0.4	$0.0	$0.4
Sequestration costs	-$4.9	-$0.16		-$5.1	$1.0	-$4.1
Total	-$69.8	-$76.3	-$1.1	-$147.2	$143.5	-$3.7
Emission reductions (t)						
CH4	6,354	47,975		54,329		54,329
N2O	904	2,669		3,573		3,573
CO2	130	2,144		2,275		2,275
Total	7,389	52,788		60,177		60,177
HWEN Sequestration	0	0				
Extra ETS Sequestration	209,446		0	209,446		209,446
Value						
$/t	$234	-$39				-$6
Emission Benefits	$0.7	$5.2	$0.0	$6.0	$0.0	$6.0
Sequestration Benefits	$20.7	$0.0	$0.0	$20.7	$0.0	$20.7
Total Benefits	$21.5	$5.2	$0.0	$26.7	$0.0	$26.7

2030	PH + Actions					
	Sheep & Beef	Dairy	Arable & hort	Private total	Taxpayers	NZ Total
Costs						
Levy payments	-$63.2	-$78.3	-$3.5	-$145.0	$145.0	$0.0
Sequestration payments	$60.2	$2.9	$0.0	$63.1	-$63.1	$0.0
EMC payments (multiplier: 1	$35.2	$115.2	$0.0	$150.4	-$150.4	$0.0
Emission reduction costs	-$9.3	-$75.7	$0.0	-$85.0		-$85.0
Sequestration costs	-$60.2	-$1.91	0	-$62.1		-$62.1
Total	-$37.2	-$37.8	-$3.5	-$78.6	-$68.6	-$147.2
Emission reductions (t)						
CH4	265,989	1,049,803	0	1,315,792		1,315,792
N2O	3,149	43,607	0	46,755		46,755
CO2	412	46,926	0	47,338		47,338
Total	269,550	1,140,336	0	1,409,886		1,409,886
HWEN Sequestration	581,715	18,469	0	600,184		600,184
Extra ETS Sequestration	435,497		0	435,497		435,497
Value						
$/t	$34	$66		$60		$60
Emission Benefits	$39.1	$165.3	$0.0	$204.4	$0.0	$204.4
Sequestration Benefits	$84.2	$0.7	$0.0	$84.9	$0.0	$84.9
Total Benefits	$123.3	$166.0	$0.0	$289.3	$0.0	$289.3

Administration Costs

		NPV in 2022	Equiv Annual Costs	2022	2023	2024	2025	2026	2027	2028	2029	2030	Residual value
Processor-Level ETS	Administrator	$10,893,924	$1,532,667	$1,180,586	$1,923,841	$1,486,511	$1,486,511	$1,486,511	$1,486,511	$1,486,511	$1,486,511	$1,027,314	$459,197
	Processor	$45,495,382	$6,400,749	$0	$3,799,500	$7,599,000	$7,599,000	$7,599,000	$7,599,000	$7,599,000	$7,599,000	$7,599,000	
	Total	$56,389,306	$7,933,416	$1,180,586	$5,723,341	$9,085,511	$9,085,511	$9,085,511	$9,085,511	$9,085,511	$9,085,511	$8,626,314	
FLL Low	Administrator	$162,112,999	$22,807,691	$3,679,427	$16,108,854	$28,358,854	$28,813,563	$23,633,652	$24,351,781	$27,204,528	$27,467,028	$20,883,518	$6,583,511
	Farmer	$87,421,596	$12,299,351	$0	$0	$0	$9,258,724	$17,171,603	$21,407,965	$24,415,193	$21,840,214	$21,840,214	
	Total	$249,534,595	$35,107,042	$3,679,427	$16,108,854	$28,358,854	$38,072,286	$40,805,255	$45,759,746	$51,619,722	$49,307,242	$42,723,732	
FLL High	Administrator	$179,423,053	$25,243,044	$3,679,427	$19,608,854	$34,358,854	$33,872,563	$27,392,152	$25,404,281	$27,302,528	$28,044,528	$20,534,918	$7,509,611
	Farmer	$110,060,903	$15,484,477	$0	$0	$0	$9,258,724	$17,171,603	$26,616,299	$33,790,193	$30,173,547	$30,173,547	
	Total	$289,483,957	$40,727,521	$3,679,427	$19,608,854	$34,358,854	$43,131,286	$44,563,755	$52,020,579	$61,092,722	$58,218,076	$50,708,465	
FLL Tech Low	Administrator	$8,515,154	$1,197,998	$250,000	$1,906,250	$2,480,582	$1,238,853	$829,042	$842,167	$842,167	$829,042	$842,167	
	Farmer	$1,281,815	$180,339	$0	$0	$117,778	$246,406	$257,257	$257,257	$257,257	$257,257	$257,257	
	Total	$9,796,969	$1,378,336	$250,000	$1,906,250	$2,598,360	$1,485,260	$1,086,299	$1,099,424	$1,099,424	$1,086,299	$1,099,424	
FLL Tech High	Administrator	$9,763,471	$1,373,623	$250,000	$2,375,000	$3,105,582	$1,407,353	$853,542	$871,042	$871,042	$853,542	$853,542	
	Farmer	$1,281,815	$180,339	$0	$0	$117,778	$246,406	$257,257	$257,257	$257,257	$257,257	$257,257	
	Total	$11,045,285	$1,553,962	$250,000	$2,375,000	$3,223,360	$1,653,760	$1,110,799	$1,128,299	$1,128,299	$1,110,799	$1,110,799	
Processor Levy	Administrator	$11,753,313	$1,653,575	$1,872,693	$2,615,948	$1,486,511	$1,486,511	$1,486,511	$1,486,511	$1,486,511	$1,486,511	$300,601	$1,185,909
	Processor	$22,609,990	$3,181,001	$0	$1,888,250	$3,776,500	$3,776,500	$3,776,500	$3,776,500	$3,776,500	$3,776,500	$3,776,500	
	Total	$34,363,303	$4,834,576	$1,872,693	$4,504,198	$5,263,011	$5,263,011	$5,263,011	$5,263,011	$5,263,011	$5,263,011	$4,077,101	
EMC Low	Administrator	$132,752,872	$18,677,012	$4,929,427	$24,936,979	$30,818,165	$18,771,085	$15,920,944	$16,085,007	$16,085,007	$15,920,944	$16,085,007	
	Farmer	$30,240,612	$4,254,554	$0	$0	$1,054,352	$4,454,914	$6,801,124	$6,801,124	$6,801,124	$6,801,124	$6,801,124	
	Total	$162,993,484	$22,931,566	$4,929,427	$24,936,979	$31,872,517	$23,225,999	$22,722,068	$22,886,130	$22,886,130	$22,722,068	$22,886,130	
EMC High	Administrator	$207,694,546	$29,220,562	$4,929,427	$40,171,354	$52,610,630	$29,486,465	$24,235,526	$24,541,776	$24,541,776	$24,235,526	$24,541,776	
	Farmer	$76,941,929	$10,824,966	$0	$0	$3,832,670	$12,240,716	$16,816,093	$16,816,093	$16,816,093	$16,816,093	$16,816,093	
	Total	$284,636,474	$40,045,528	$4,929,427	$40,171,354	$56,443,299	$41,727,182	$41,051,618	$41,357,868	$41,357,868	$41,051,618	$41,357,868	

These show FLL system starting in 2025