Carbon Neutral Project – Farmer Information

King Country River Care Incorporated

Report prepared by
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1 Executive Summary

King Country River Care (KCRC) decided it would like to help their farmers better understand the concept of achieving/creating a "carbon neutral" farm operation with the use of "pilot farms" from within the KCRC catchment.

For this project KCRC chose three pilot farms to model and to host field days about their current greenhouse gas (GHG) situation and the results of modelling different scenarios for their farm operation. The three farmers chosen were:

i. **Stephan and Stacey Turner** – a 381 ha sheep and beef property, with approximately 93 ha that is a mix of young trees under management and retired indigenous forest, at Piopio;

ii. **Brent and Lou Scott** – a 1,633 ha sheep and beef property, with approximately 153 ha that is a mix of young trees under management, retired indigenous forest, wetland, and coastal retired areas, at Oparau near Kawhia; and

iii. **Phil Watkins and Jo Stockley** – a 421 ha self-contained dairy property on freehold and lease land, with approximately 55 ha that is a mix of young trees under management, retired riparian area, and indigenous forest, at Piopio.

Being "carbon neutral" refers to the situation where GHG emissions on a carbon dioxide equivalence basis are being equalled by the amount of carbon dioxide being removed from the atmosphere. In New Zealand agriculture systems the main GHGs are carbon dioxide, nitrous oxide, and methane, and the main form of carbon dioxide removal is by woody vegetation "sequestering" carbon as it grows.

In New Zealand farm systems methane emissions are very important because on a carbon dioxide equivalent basis because they commonly account for over 80% of the GHG emissions that occur. They primarily occur as a direct result of (ruminant) animals eating and digesting feed. Reducing methane emissions within a farm system either means eating less feed (which will mostly be associated with farming less stock), or less methane being emitted per unit of feed eaten by the stock.

After consultation with KCRC it was decided that the examination of the pilot farms position relative to being "carbon neutral" would involve the key targets of New Zealand's Climate Change Response (Zero Carbon) Amendment Act 2019 (otherwise known as the "Zero Carbon" Act) being used as key reference points – with these targets being:

i. Net emissions of greenhouse gases in a calendar year, other than biogenic methane, are zero by the calendar year beginning on 1 January 2050 and for each subsequent calendar year.

ii. Emissions of biogenic methane in a calendar year:

- Are 10% less than 2017 emissions by the calendar year beginning on 1 January 2030; and
- Are 24% to 47% less than 2017 emissions by the calendar year beginning on 1 January 2050 and for each subsequent calendar year.

The pilot farms existing base operations, and some different scenarios of their possible future plans, were modelled in Farmax and OverseerFM to calculate their carbon dioxide, nitrous oxide, and methane emissions. Sequestration of carbon was calculated using farmer information regarding their tree resources and the Ministry of Primary Industries Carbon Look-up Tables for Forestry in the Emissions Trading Scheme.

The Biological Emissions Reference Group (BERG) reported on mitigation options they believed would assist reducing GHG emissions in the New Zealand farming context – with reference to reducing methane emissions. This project uses two key methods they reported on – genetics and animal treatments (through either a vaccine or bolus administration, or through a feed additive) – when examining the issue of methane emission reduction.

In summary the key results for these pilot farm operations and the different scenarios that were considered were:

- One farm was already "carbon neutral" when biogenic methane was excluded;
- Achieving **carbon neutrality**, excluding biogenic methane, **was possible** through relatively small changes to the farm system and the impact on profitability was not identified as a major issue – there was a chance it could improve;
- Achieving the **10% methane reduction** target through the farm system changes considered **only occurred with one of the pilot farmers** – greater farm system changes than were considered, or partial use of the new technologies, would be required to achieve the targeted reduction.
- Successful use of new genetics and new animal treatments, across all stock, was required to achieve greater than the 24% methane reduction target. **The 47% methane reduction target was not achieved** in any of the scenarios modelled.

These results confirm the size of the challenge that is ahead of agriculture to meet GHG gas emission targets – especially for methane. These challenges are alongside changes required for water quality improvements and increasing biodiversity. The impact of farm system change now needs to consider not only changes to profitability but also the impact on GHG emissions, water quality, and biodiversity. It is a positive that changes leading to improvements in one of these factors can also lead to improvements in one or both the other two factors.

And while our New Zealand regulatory direction is a little uncertain market expectations for farmer change have become more prevalent. As a result, it seems inevitable that farmers will need to understand, account for, and potentially reduce their GHG emissions profiles, including biogenic methane, to some extent in the short to medium term.

There are several things that farmers can and should do to prepare for, and potentially start to implement, to meet this new challenge. We would recommend that farmers:

- Map and describe the areas of non-pasture vegetation on their farms.
- Understand the sequestration potential of existing and/or proposed forestry areas.
- Improve record keeping to assist with the reporting of emissions and emissions intensity.
- Evaluate the profitability and efficacy of system inputs (supplementary feed, N fertiliser) that increase system dry matter production and use, and ultimately biogenic methane.

- Investigate the potential to utilize low methane genetics in their sheep and cattle breeding programmes.
- Consider emissions impacts/co-benefits when considering how other environmental challenges (like water quality and biodiversity) are addressed.
- Keep learning about, discussing and engaging with this topic. It is coming to a farm near you.

CONTENTS

1	Executive Summary	4
2	Terms of reference	10
3	What does "carbon neutral" on the farm mean?	12
4	The fundamentals of reducing net on-farm GHG emissions	19
5	Modelling approach and process	21
6	The pilot farmers	23
7	Stephan and Stacey Turner, Piopio – Sheep and Beef	25
8	Brent and Lou Scott, Ōpārau – Sheep and Beef	38
9	Phil Watkins and Jo Stockley, Piopio - Dairy	52
10	Discussion	68
11	Conclusion	72
12	Acknowledgments	73
13	Appendices	74

Tables

Table 1:	Turner initial area assumptions	25
Table 2:	Turner - sequestration of the base scenario	26
Table 3:	Turner winter stock numbers	26
Table 4:	Turner base scenario emission and sequestration results	28
Table 5:	Turner scenarios - block areas	29
Table 6:	Turner scenarios - stock numbers	30
Table 7:	Turner scenario stock performance	31
Table 8:	Turner scenario profitability and production summary	31
Table 9:	Turner scenario sequestration	32
Table 10:	Turner net carbon emission results	32
Table 11:	Turner emissions intensity	34
Table 12:	Scott initial area assumptions	38
Table 13:	Scott - sequestration of the base scenario	39
Table 14:	Scott winter stock numbers	39
Table 15:	Scott base scenario emission and sequestration results	41
Table 16:	Scott scenarios - block areas	43

Table 17: Scott scenarios - stock numbers ... 43
Table 18: Scott scenario stock performance ... 44
Table 19: Scott scenario profitability and production summary ... 45
Table 20: Scott scenario sequestration ... 45
Table 21: Scott net carbon emission results ... 46
Table 22: Scott emissions intensity ... 48
Table 23: Watkins initial area assumptions ... 52
Table 24: Watkins - sequestration of the base system ... 53
Table 25: Watkins winter stock numbers ... 53
Table 26: Watkins pattern of milk production ... 54
Table 27: Watkins base system emission and sequestration results ... 55
Table 28: Watkins scenarios - block areas ... 57
Table 29: Watkins scenarios - stock numbers ... 58
Table 30: Watkins scenarios - variable feed inputs ... 58
Table 31: Watkins scenarios – farm system and production summary ... 59
Table 32: Watkins scenario profitability and production summary ... 59
Table 33: Watkins scenario sequestration ... 60
Table 34: Watkins net carbon emission results ... 61
Table 35: Watkins emissions intensity from milk production ... 63
Table 36: Watkins emissions intensity from milk and meat production ... 63
Table 37: 16-year average and year 25 sequestration rates (Carbon Look-up Tables for Forestry in the Emissions Trading Scheme) ... 83

Figures

Figure 1: Explanation of some key climate change terms ... 13
Figure 2: Interacting roles of Government, science, and the market in achieving carbon neutrality ... 15
Figure 3: Key concepts for on-farm carbon zero (He Waka Eka Noa documents) ... 18
Figure 4: Pilot farmer locations ... 23
Figure 5: Turner base system emissions by type ... 28
Figure 6: Turner net carbon outcome excluding biogenic methane ... 33
Figure 7: Turner total methane outcomes ... 34
Figure 8: Turner comparative methane intensity across the scenarios ... 35
Figure 9: Turner net carbon position with all native planting and at the 2050 sequestration rate ... 36
Figure 10: Scott base scenario emissions by type ... 41

Figure 11:	Scott net carbon outcome excluding biogenic methane	46
Figure 12:	Scott total methane outcomes	47
Figure 13:	Scott comparative methane intensity across the scenarios	49
Figure 14:	Scott net carbon position with all native planting and at the 2050 sequestration rate	50
Figure 15:	Watkins base scenario emissions by type	56
Figure 16:	Watkins net carbon outcome excluding biogenic methane	61
Figure 17:	Watkins total methane outcomes	62
Figure 18:	Watkins comparative methane milk production intensity across the scenarios	64
Figure 19:	Watkins comparative methane milk and meat production intensity across the scenarios	64
Figure 20:	Watkins 2050 net carbon position with 80% of riparian area in natives	65

2 Terms of reference

King Country River Care (KCRC) decided it would like to help their farmers better understand the concept of achieving/creating a "carbon neutral" farm operation with the use of "pilot farms" from within the KCRC catchment.

This project and report involves:

i. Defining what can be meant by "carbon neutral" for this project based on New Zealand Government rules alongside considering other in-market interpretations.
ii. Modelling three existing farm operations to determine their existing environmental key performance indicators (KPI's) for greenhouse gas (GHG) emissions of methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2), sequestration, and farm profitability.
iii. Understanding what on-farm changes are currently planned by the pilot farmers and rerun the respective models to quantify the impact of these changes on emissions and sequestration.
iv. Identify if other changes are required to become "carbon neutral" and model these to assess their combined emission and sequestration impacts on the farm business.

This project is intended to help KCRC members and wider community farmers:

i. Better understand what various parties mean by the term "carbon neutral" and what level of rigour is being applied to achieving that status.
ii. Obtain an understanding of the scale of change required for the pilot farm operations to become "carbon neutral" with indications regarding:
    - Feasibility; and
    - The impact and level of importance of new technology currently being developed by different parts of the agricultural industry.

As part of the project process three [one on each pilot farm] on-farm public field days were held to discuss the concept of "carbon neutral" as maybe relevant to them, share the detailed results of the modelling on the host farm and the general results from the other two farms in the project, and what are the possible takeaway messages for the host and attending farmers.

This electronic report, primarily based on the field-day information, will be prepared so KCRC can distribute to its members and the wider public as it chooses.

It was initially anticipated that true "carbon neutral" in a farming operation would include all sources of GHG (in carbon dioxide equivalents) emitted from the farming operation – namely that it would also include the all the carbon dioxide equivalent emissions resulting from animals (i.e. both biogenic methane and biogenic nitrous oxide).

During researching the definition of "carbon neutral" (see section 3) it was noted the Climate Change Response (Zero Carbon) Amendment Act 2019 (otherwise known as the Zero Carbon Act), includes two key points:

i. "Carbon neutral" by 2050 for NZ is on an "except biogenic methane" basis; and

ii. Biogenic methane is covered by the separate agriculture sector targets of a 10% reduction in methane emissions by 2030 and between a 24% to 47% reduction in methane emissions by 2050 – both compared to 2017 emission levels.

In discussion with KCRC it was subsequently determined this project should consider an on-farm approach that is in line with the Zero Carbon Act – that is, if a farm operation is "to do its bit" then this project and the modelling work associated with the pilot farms should involve:

i. Determining what is the carbon dioxide equivalent emissions of long-lived gases (of carbon dioxide and nitrous oxide) from the farming operation, and separately determine what is the level of biogenic methane being emitted.

i. Identifying what level of sequestration is occurring on the farm and how does that compare to the carbon dioxide and nitrous oxide emissions on a carbon dioxide equivalent basis.

ii. Model the farmer's planned changes and compare the results to achieving both a "carbon neutral" (excluding biogenic methane) position and the methane reduction targets, as per the Zero Carbon Act;

iii. If required provide an example of what level of (larger) change is required to achieve the "carbon neutral" (excluding biogenic methane) position, and the methane reduction targets as per the Zero Carbon Act; and

iv. Express results on both a total (whole farm total) basis and on a per kg of product intensity basis.

Although this approach may over-describe what needs to happen at an individual farm level (because of the New Zealand-wide and agricultural sector approaches of the Zero Carbon Act) KCRC believe the project outcomes from this change in focus will be more useful to the famers involved in the project and the wider KCRC membership as they look to understand what is required to become "carbon neutral" and to reduce their methane emissions.

3 What does “carbon neutral” on the farm mean?

3.1 The concept

There are various terms and concepts that are utilised throughout our global society to define the impact of human activities on climate change – for example:

- carbon neutral;
- carbon positive;
- climate neutral;
- net zero; and
- climate positive.

Although these terms are often used interchangeably, and/or have differences in their timeframes and emissions that are being accounted for, Figure 1 on page 13 is simple diagram that explains how these broadly accepted terms relate to each other and fit within the spectrum of change within the subject of climate goals.

In general, carbon neutrality refers to achieving a balance between the amount of greenhouse gas emissions released into the atmosphere (expressed on a carbon dioxide equivalent basis), and the amount of carbon dioxide (expressed on the same carbon dioxide equivalence basis) removed from, or offset, in the atmosphere.

The anthropogenic greenhouse gases (those originating from human activity) being focussed on in relation to global warming and climate change are carbon dioxide, nitrous oxide, and methane – often referred to as “greenhouse gases” (GHG’s). There are some other synthetic gases that are also important, but they are not considered relevant to the typical New Zealand on-farm situation. Carbon dioxide and nitrous oxide are deemed to be long-lived GHG’s, and methane is considered a short-lived GHG.

Although “carbon neutral”, which is the focus of this project, is a globally recognised concept New Zealand has adopted its own version. In New Zealand the Climate Change Response (Zero Carbon) Amendment Act 2019 (otherwise known as the Zero Carbon Act) provides the detail to explaining the New Zealand’s contribution to limiting warming to only 1.5°Celcius above pre-industrial levels and what has been used as the targeted outcomes for this project.

This law essentially commits the country (at a domestic level) to being somewhere between “carbon neutral” and net zero carbon dioxide (see Figure 1) by 2050. Our New Zealand target for emissions reduction is based on the net accounting emissions of GHG’s in a calendar year, **other than biogenic methane** which has separate reduction targets, and that they be net zero by the calendar year beginning on 1 January 2050.

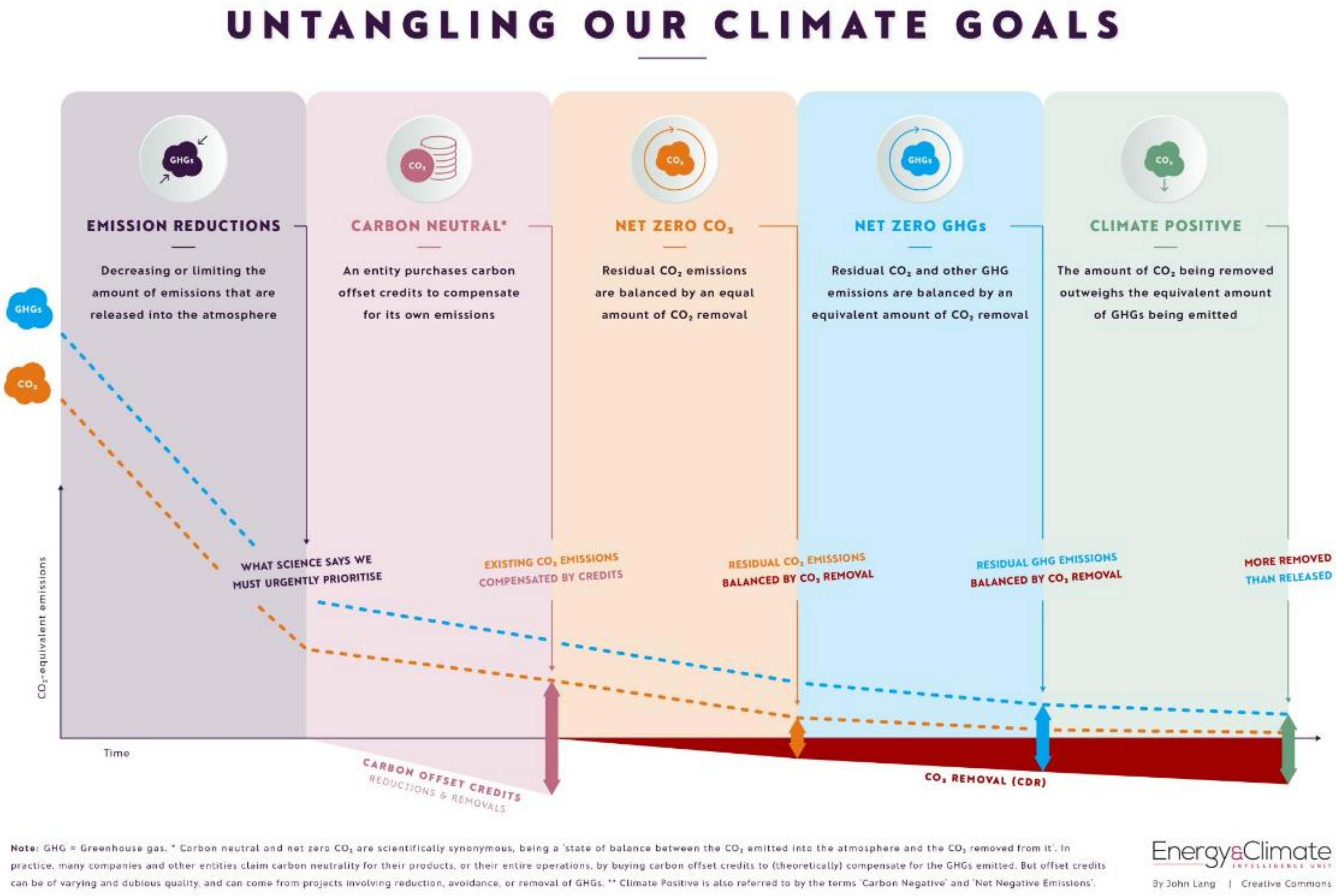

Figure 1: Explanation of some key climate change terms

In the Zero Carbon Act the agriculture sector has separate reduction targets for biogenic methane. These are that methane emissions are:

- 10% less than the 2017 calendar year emissions by the calendar year beginning on 1 January 2030; and
- Between 24% and 47% less than the 2017 calendar year emissions by the calendar year beginning on 1 January 2050.

This different treatment of long-lived GHG's, such as carbon dioxide and nitrous oxide, relative to the short-lived GHG of methane has become known as the "split-gas approach".

The targets of the Zero Carbon Act all apply at Government defined sector levels – "Agriculture" being one of the four sectors. **A key issue is what does this all mean at an individual farm level?**

3.2 Background of world agreements and NZ's response

The Kyoto Protocol was established in 1997 and enforced from 2005 to 2012. New Zealand was one of 192 countries that committed to binding GHG emissions (carbon dioxide, nitrous oxide, and methane) reduction targets for the period 2008-2012.

The protocol's commitments were later identified as being limiting for some groups of nations, particularly in achieving global cooperation. In response to these limitations, the Paris Agreement was adopted in 2015 and came into effect in 2016.

The Paris Agreement represents a more inclusive framework for global climate action, encompassing all nations. The Paris Agreement focussed on limiting the rise in average global temperatures (or "Global Warming") and included the concept of voluntary nationally determined contributions (NDC's). The NDC process allows individual countries to set their own emissions reduction targets (Ministry for the Environment, 2022a).

With respect to the Paris Agreement, New Zealand has made commitments to domestic GHG emission reduction targets. Its first NDC under the Paris Agreement is to reduce net GHG emissions to 50 percent below gross 2005 levels by 2030 (Ag Matters, 2023a).

This target covers emissions from areas of the economy that are grouped as the energy, agriculture, waste, and industrial processes sectors.

This internationally binding commitment <u>is separate</u> from any domestic targets set under the Zero Carbon Act, although it is expected that the achievement of the domestic targets will assist with New Zealand delivering on its internationally agreed targets.

Since the 2023 NZ general election, and the change in Government, there has been an announcement that there will be a different approach to the methane emission issue than that proposed under the now defunct He Waka Eke Noa (HWEN) proposal with statements like:

- *"Later this month, we will introduce legislation amending the Climate Change Response Act 2002 to ensure agriculture does not enter the NZ Emissions Trading Scheme"*
- *"It's time for a fresh start on how we engage with farmers and processors to work on biogenic methane"*

However, there is still:

- The Climate Change Response Amendment Act 2019 that is in place;
- Large (world-wide) public concern about rising global temperatures; and
- Our key agricultural food product customers and banking institutions are required to make changes to their value chains (which New Zealand farmers are part of).

This is likely to continue to be a subject and area of continuing change for some time yet.

3.3 Non-Government considerations

As Figure 2 below shows, it is not just the Government influencing or demanding the need for reduced emissions. The scientific community and the (economic) market are important voices for demanding reductions. All three sectors will be involved in determining the required level of change for individual businesses and how progress is monitored.

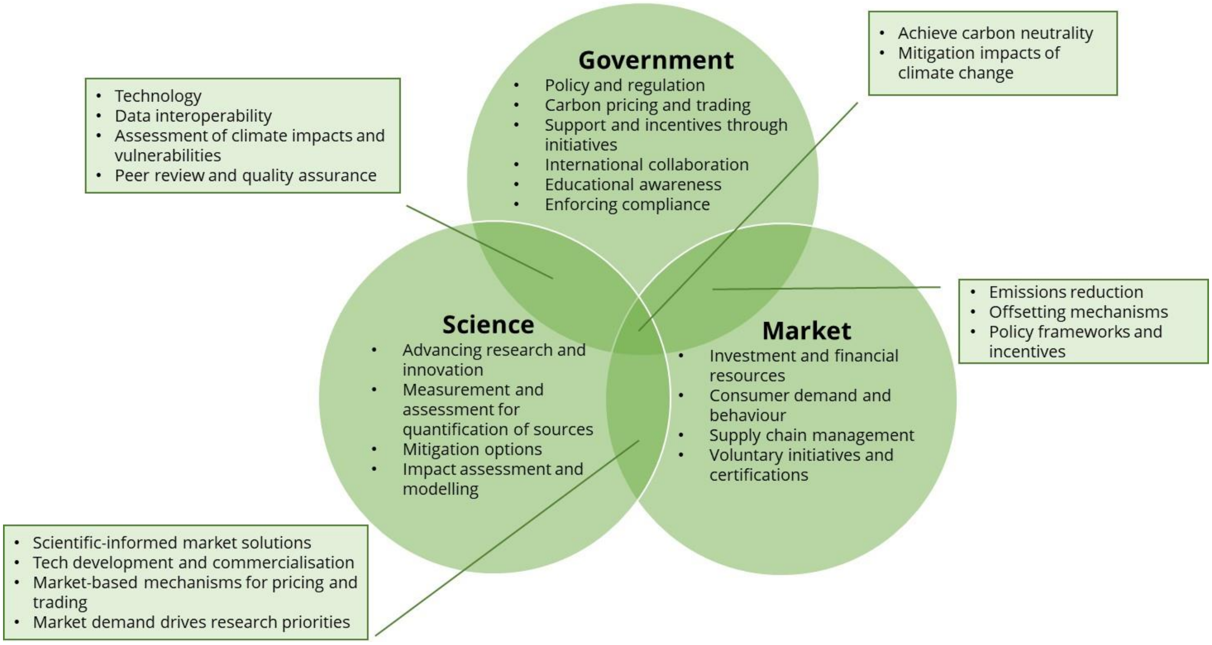

Figure 2: Interacting roles of Government, science, and the market in achieving carbon neutrality

For the agriculture sector, the finance sector (providing debt finance to individual farm businesses) and food companies (buying our farm products) are two key market-based industries requiring planning, change, and reductions at the individual farm level.

GHG emissions have been grouped into three categories for individual businesses – Scope 1, Scope 2, and Scope 3. For a farming business this predominantly means:

- Scope 1: GHG emissions that occur directly on your farm – including from animals, fertiliser use, and fuel use;
- Scope 2: GHG emissions that the business makes indirectly through the purchase of electricity; and

- Scope 3: GHG emissions that come from your value chain – both downstream (e.g., associated with the production of purchased products) and upstream (e.g., processing and transport to market).

Calculations completed by various parties to date show that Scope 2 and Scope 3 emissions on a farm are likely to be small in comparison to Scope 1 emissions.

However, our on-farm emissions are Scope 3 emissions to the food companies (our customers) who buy our products – and for many of them they are finding that, unlike our on-farm situation, their Scope 3 emissions are a large part of their overall GHG emissions profile. And importantly for the New Zealand farmer these large multi-national corporate companies are being asked (often by regulation, sometimes by shareholders) to report the emissions of their business operation - including their Scope 3 emissions – and that they have an emissions reduction plan in place and being enacted.

This means that farmers, as a large source of their Scope 3 emissions, are now being asked by these large multi-national corporate companies' questions like:

- What are levels of GHG emissions in your farm business; and
- What is your plan to reduce them?

There are several examples of on-farm change being required by other parties in the agriculture value chain:

- Large organisations such as Nestlé and Tesco have made commitments to carbon neutrality;
- Nestlé has set a target of net zero GHG emissions by 2050, and they have since committed to move away from investing in carbon offsets and focussing on reducing GHG emissions in their own supply chain and operations to reach the net zero target;
- Silver Fern Farms has a Net Carbon Zero Beef programme that is Toitū Envirocare certified. The programme supports a range of 100% Angus beef products processed by Silver Fern Farms (SFF) that are certified as being linked to a supply chain with net zero carbon emissions. This means that 100% of end-to-end greenhouse gas emissions are measured and then balanced out by verified woody vegetation that is actively absorbing the equivalent amount of carbon dioxide (Silver Fern Farms, n.d.).
- Banks are offering discounted "green loan" interest rates and are starting to request "farm plans" that consider management of (or reductions in) GHG emissions to comply with the banking sector's new sustainable finance protocols (Sustainable Agriculture Finance Initiative, "SAFI", 2021).

3.4 GHG flows on the farm

On-farm (Scope 1 and Scope 2) GHG emissions come from:

- biogenic methane;
- biogenic nitrous oxide;
- fertiliser use – especially nitrogen fertilisers and lime;
- animal manure storage;

- electricity use;
- (fossil) fuel use; and
- cultivation of soil.

This has led to many discussions about what systems should be used to convert methane to an equivalent value of carbon dioxide for the purposes of "carbon accounting". The current global carbon accounting framework uses "GWP100" as its measure of *emissions* and this is also used in the Overseer and Farmax models that are used for this project.

It is acknowledged there is continuing farming sector discussion on whether or how "GWP*", a measure of *warming*, should be used but that is outside the considerations of this report.

In terms of existing and pending compliance processes and pending costs associated with on-farm GHG emissions there are, and will continue to be, different mechanisms in use – for example:

- The Emissions Trading Scheme (ETS) is a market-based approach to manage some GHG emission and sequestration balances through emissions accounting. The scheme accounts for carbon emissions from burning fossil fuels (coal, oil, gas), industrial processes that release GHGs, and from waste disposal; and carbon sequestration from forestry. Farmers involved in the ETS are mainly involved with registering eligible forests (exotic and native), claiming credits in the form of New Zealand Units (NZUs) associated with their forests sequestering carbon, and then either retaining or selling these NZUs.
- He Waka Eke Noa (HWEN) was a partnership with industry, Māori, and the government that was established in 2019 that aimed to develop and "implement a framework by 2025 to reduce agricultural greenhouse gas emissions and build the agriculture sectors resilience to climate change" (Primary Sector Climate Action Partnership website). The aim was "to develop a system for measuring, managing, and reducing agricultural greenhouse gas emissions, rather than pricing emissions at the processor level in the ETS". During 2022 the HWEN partnership submitted a proposal to the Government and then the Government prepared a response for consultation. This partnership was subsequently disestablished by the incoming administration after the 2023 election. At the time of writing this report industry and the Government are still consulting over the terms under which agricultural GHG emissions will be managed, including the establishment of the Methane Review Ministerial Advisory Panel.

This project and report are not concerned with these industry systems as this project is more about the outcome within the farm boundaries. However, going forward farmers will need to be aware of what is counted, or eligible for consideration, for complying with any internal NZ compliance system that gets implemented, versus what is required, or can count, for different market-based schemes they may be involved with.

3.5 What does this mean on the farm?

At a basic level for this project carbon neutrality will be based on the process outlined in Figure 3 where "carbon neutral" is defined as being when the farmer has balanced the farm's net carbon dioxide equivalent emissions from long-lived gases by either reducing them to zero or is offsetting these emissions from an on- or off-farm source – but the project is excluding biogenic methane.

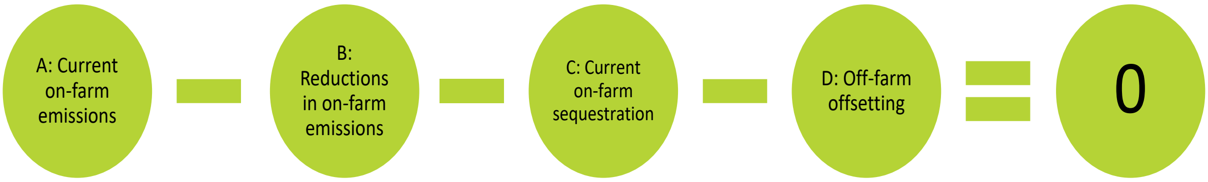

Figure 3: Key concepts for on-farm carbon zero (He Waka Eka Noa documents)

Under the Zero-Carbon Act no actions are required at the individual farm, but individual farms are likely to be required to provide information (i.e. report on emissions) so national and agricultural sector outcomes can be calculated.

Reduction in methane emissions will continue to be sought – a key question is whether a farm-based charge on methane emissions will be implemented to help achieve this reduction, and whether this will be applied against total methane emissions or just across the emissions above an agreed reduced level. Both options have pros and cons.

Separate to the Government regulations farmers will likely continue to be asked by key market partners about their GHG emission position and what are they doing to reduce it. And how will this be assessed or be verified?

3.6 Summary

Carbon neutral refers to achieving a balance between the amount of carbon dioxide equivalent GHG emissions released into the atmosphere and the amount of carbon dioxide removed from the atmosphere.

New Zealand's Zero Carbon Act commits the country to being carbon neutral by 2050 - **other than biogenic methane,** which has separate reduction targets of:

- 10% less than the 2017 calendar year emissions by the calendar year beginning on 1 January 2030; and
- Between 24% and 47% less than the 2017 calendar year emissions by the calendar year beginning on 1 January 2050.

It is not just the NZ Government requiring a reduction in on-farm emissions – lending institutions and the food companies purchasing our meat and milk products are all requiring reduced GHG emissions from their supply chains. Agriculture, through their on-farm GHG emissions, is a large Scope 3 source of GHG emissions for these businesses.

4 The fundamentals of reducing net on-farm GHG emissions

4.1 Introduction

Reducing net on-farm emissions will either involve:

- Reducing emissions; or
- Increasing sequestration.

A key point of clarification when discussing "reducing emissions" is whether the discussion is about reducing total emissions or is it about reducing the emissions intensity - the amount of GHG emitted per kg of production. Without this clarification statements about lower emissions can be confusing.

In the terms of the Zero Carbon Act the requirements are either about net reductions of total carbon dioxide and nitrous oxide emissions or reductions of total methane – even if the production system becomes more efficient on a per unit of production basis, it is the total emissions that are being targeted.

Market related requirements/goals are more likely to consider emissions intensity and whether this is decreasing as part of the farmer's plan. However, reductions in total net, or total emissions may still be important to the relevant market scheme being considered and are still likely to be an important mechanism for achieving reductions in emissions intensity for many farm operations.

Carbon dioxide emissions come from the use of fuel, electricity, the breakdown of nitrogen fertiliser and lime used, and the purchase of various other farm inputs.

Nitrous oxide emissions occur as part of the nitrogen cycle – the feeder of the nitrous oxide output comes from both the nitrogen component of urine and dung from animals, and the nitrogen component of fertilisers. Of these three sources urine is the biggest contributor – so again animals are the key source of nitrous oxide emissions in a livestock farming system.

The highest percentage of the GHG emissions in a livestock operation is what are termed **"biogenic methane" emissions**. Nearly all methane emissions from the animals (sheep, cattle, and deer) are, at least under the current protocols, directly related to what the animal eats – and on average this has been determined to be approximately **21.6 g of methane per kg DM eaten** in the average New Zealand farming situation. A small percentage is associated with the management of the animal's manure – mainly seen in dairy farming systems within the effluent storage process.

Under the Zero Carbon Act sequestration from vegetation cannot be used as an offset to achieve the methane reduction targets – only to reduce the net emissions of carbon dioxide and nitrous oxide. [This does not mean that income earned from a sequestration activity cannot be used to pay any future fee associated with a methane emission.]

4.2 Fundamentals to reduce GHG emissions

At a basic level a farm operation has the following types of options available to reduce gross GHG emissions, commonly referred to as mitigations:

- Use less inputs (including direct and indirect use of fossil fuels);

- Use less feed – either grown or purchased – which if per head production is maintained will fundamentally mean less animals are farmed, or lower per head performance results;
- Identify, select, and retain animals that produce less methane per unit of feed eaten without reducing their production ability;
- Use inputs/additives that reduce the amount of methane produced per unit of feed eaten.

Increasing sequestration can be used to reduce the net long-lived GHG emissions outcome. This would be achieved by increasing the area of young growing "woody-vegetation" by either planting new plants, making changes to on-farm management to allow existing young plants to grow more than they otherwise would, or making changes to allow pastoral areas to regenerate into woody-vegetation. The key determinants for sequestration are "additionality" and "permanence".

4.3 For this project the following approach to achieving emissions targets has been used.

The farmer plans:

- If the pilot farmers have plans for a change in stock numbers and/or stock classes, and retirement and planting of some parts of the farm these are modelled first.
- Results are then calculated for their impact on the carbon dioxide and nitrous oxide emissions and the methane position separately.

If the farmer plans do not achieve neutrality for on-farm carbon dioxide and nitrous oxide emissions and sequestration, and the required reduction of methane emissions, then further changes in stock numbers and classes and the pastoral area farmed are considered. These further options are most likely to be in a similar vein to the farmer plans. The ideal aim of these changes will be to achieve at least the 2030 10% methane reduction target.

The third stage of analysis involves applying the anticipated results of the new technology options considered by the Biological Emissions Reference Group (BERG) 2018 report [outlined in more detail in the appendices – section 13.3 on page 77] and considering how these technologies work in relation to achieving both the 2023 methane reduction target of 10% and the 2050 methane reduction target of 24% to 47%.

4.4 Summary

In this project the changes considered in the stock policy, farm area, and stock numbers are driven by the farmers existing plans.

The impact of new technology involving methane inhibitors or vaccines and specially bred low methane emitting sheep and cattle have been used for this project, but only after farmer-initiated system change has been examined.

5 Modelling approach and process

5.1 Introduction

Information provided by the farmer was the key source of the farm system information modelled in Farmax and OverseerFM

The key output required of the modelling is the comparison, or relativity, of the different scenarios compared to the farmer's current base system.

This means whilst all attempts were made to be accurate with the base system it is the comparative results that are the most important even if the base system is not modelled to 100% accuracy – and indeed it can be argued that "100% accuracy" is not achievable anyway.

Under the modelling process a "status quo" base farm scenario is required. Key attributes of a "status quo" situation are:

- Opening and closing stock numbers are the equal; and
- The stock numbers and performance levels represent what the farmer has and/or is planning to do in normal circumstances.

This information was obtained through a combination of in person conversations and emails with the farmer. The information was then entered into Farmax and OverseerFM as summarised in the Appendices [section 13.1 on page 74].

The calculation of carbon sequestration and GHG emission reductions from outside inputs or new technology was completed outside these two models.

5.2 Modelling process

In summary the modelling steps involved were:

i. Using the farmer information to develop status quo opening and closing stock numbers.

i. Using the mapping function in OverseerFM to calculate areas for different blocks on the farm. Tree [forestry] and pasture blocks were the emphasis.

ii. Entering the block area and farming system information into Farmax to determine the resulting pasture production and approximate level of minimum and maximum pasture covers of the farm system - which are then used as constraints that the alternative scenarios must operate within.

iii. Using the Farmax income and operating expenditure assumptions so the "profitability" of each of the pilot farms scenarios can be compared.

iv. The detailed farm system information derived from Farmax was then entered into OverseerFM to calculate the GHG emissions and key environmental KPI results.

For consideration of different scenarios, a similar process is followed:

i. If and as required, alter the block areas in OverseerFM.

ii. Adjust the block areas in Farmax and change the stock numbers of the stock classes targeted for definite change.

iii. For any stock classes that are being considered as “flexible” (i.e., being used to “fill the gap”) their numbers are changed so no extra pasture is required to be grown, and the maximum and minimum pasture covers were like the base system.

6 The pilot farmers

6.1 Introduction

KCRC wanted the following considered when selecting the pilot farmers:

- Location – involvement of the Kawhia Harbour catchment part of the KCRC group;
- Dairy – with several dairy farms in the community and the Mōkau sub-catchment it was important to have a dairy operation included;
- Sheep and beef policy variation – a breeding cow-based cattle policy to be involved;
- Independence – not involved with the KCRC committee;
- Next generation – include some of the "younger" farmers in the area.

With these considerations three King Country (Figure 4) pilot farmers were chosen by KCRC:

- Sheep and beef operation near Piopio;
- Dairy operation near Piopio; and
- Sheep and beef operation near Ōpārau.

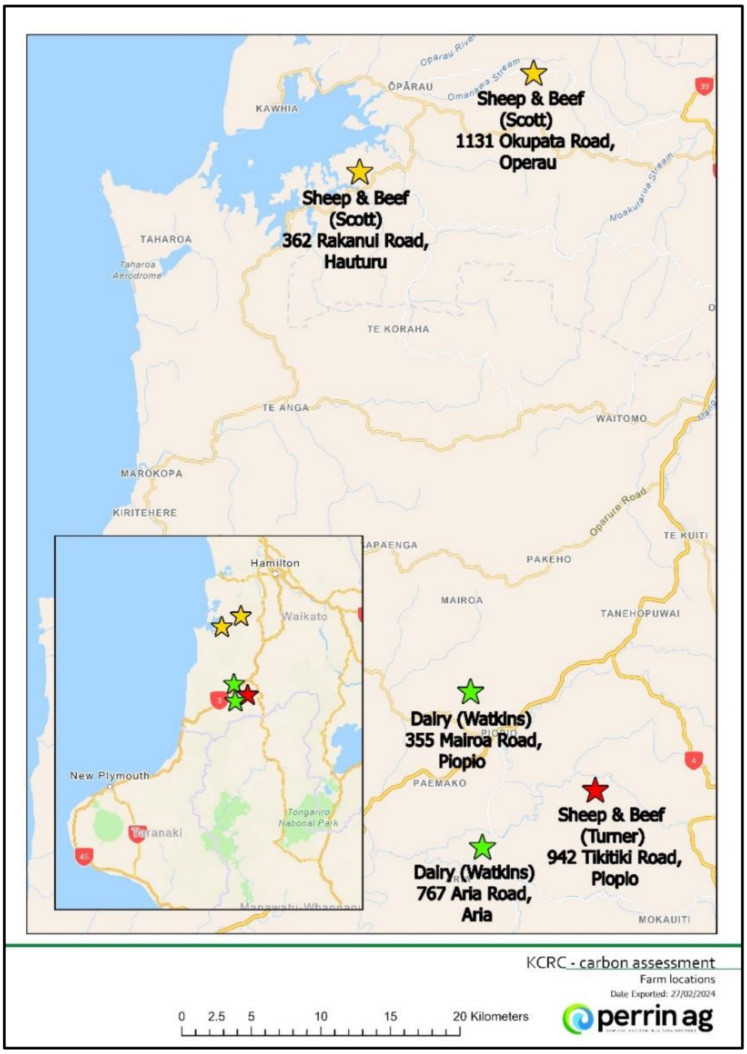

Figure 4: Pilot farmer locations

6.2 Brief introduction to the three pilot farmers

There are more detailed descriptions of the farming operation in the respective sections for each farmer but below is a brief outline for each pilot farmer operation.

Stephan and Stacey Turner:

- Sheep and beef near Piopio;
- 381 ha total with approximately 287 ha of pasture, with most of the balance being native bush with a small area of pine and exotic hardwood trees;
- Farm policy involves a breeding-finishing sheep policy, a small terminal-mated Friesian x Hereford breeding cow herd where the progeny is retained and, along with other bought in R1 dairy x beef cattle, are sold as 15 to 18-month store cattle, and a bull finishing component; and
- No cropping and minimal nitrogen and supplement use.

Phil Watkins and Jo Stockley:

- Self-contained dairy operation near Piopio;
- Total of 421 ha involving approximately a 265 ha milking platform, 95 ha dairy support area, 5 ha of other pastoral grazing use, and 56 ha of bush, retired, and other ineffective areas;
- The milking herd is milked as a mix of twice a day milking (TAD), once a day milking (OAD), and 7-in-10-day milking systems based on stock class and stage of the season; and
- There is a comprehensive cropping, maize and pasture silage programme to supplement the pastoral feeding programme. Nitrogen use is approximately 85 kg N/ha on the milking platform.

Brent and Lou Scott:

- Sheep and beef near Ōpārau;
- 1,633 ha total with approximately 1,483 ha in pasture and most of the remaining 150 ha is native bush;
- Farm policy involves a breeding-finishing sheep policy and an Angus breeding-finishing policy with all progeny retained, plus 100 R2 beef cattle purchased, for finishing at two years to two and half years of age; and
- Minimal nitrogen and cropping programmes with some baled silage made.

7 Stephan and Stacey Turner, Piopio – Sheep and Beef

7.1 Introduction

The original part of the property has been in the Turner family since 1978 when Stephan's grandparents and father purchased the property, and it consisted of approximately "400 acres" of pasture. Stephan was born on the property and he and Stacey started farming the property from the 1st July 2023 through a mix of ownership and leasing. They are striving to make it their long-term family home.

7.2 The current farm operation

The 381.3 ha property is located at 942 Tikitiki Road, Piopio. Stephan has considered the farm to be approximately "290 ha" effective. After the OverseerFM block mapping process the farm area breakdown in Table 1 is used for the initial stage of modelling.

Table 1: Turner initial area assumptions

Farm Area			Base Scenario
	Flat		60.5
	Hill country		226.4
	Total Pasture Area		**286.9**
	Unfenced native		17.1
	Blackwoods		6.1
	Fenced native		60.8
	Pines		9.0
	New native		0.0
	New Douglas Fir/Redwoods		0.0
	New Pines		0.0
	Total Retired Area		**93.0**
	Other - houses and buildings		1.4
	Total Property Area		**381.3**

Based on the methodology being used for the project [section 13.2 on page 76] the annual sequestration calculated for these planted areas is described in Table 2 and totals 364.8 tonnes of carbon dioxide per year.

Table 2: Turner - sequestration of the base scenario

Vegetation Type	Forest Type	Age *	Sequestration (tonnes CO_2/ha/yr)	Base Scenario
Unfenced native	Indigenous forest (pre-1990)	>50	0.0	17.1
Blackwoods	Hardwoods	ave. 16	27.2	6.1
Fenced native	Indigenous forest (pre-1990)	>50	0.0	60.8
Pines	Pinus radiata (post 1989)	ave. 16	22.1	9.0
New native	Indigenous forest (post-1989)	ave. 16	6.8	0.0
New Douglas Fir/Redwoods	Douglas fir	ave. 16	12.1	0.0
New pines	Pinus radiata (post 1989)	ave. 16	22.1	0.0
Total Area in Trees				**93.0**
Average annual carbon sequestration - tonnes carbon dioxide per year				**364.8**

(used for determining the annual sequestration rate in calculations)*

The base scenario stock numbers (Table 3) and policy represents Stephan's planned stock policy which is based on a mix of what has been farmed in recent years and the direction he wishes to take. On the stock unit per head basis shown in the table the overall stocking rate equates to 10.75 SU/ha.

Table 3: Turner winter stock numbers

Stock Numbers - 30th June		SU/Hd	Base Scenario
	MA ewes	1.2	1,100
	Ewe hoggets	1.0	340
	Sale hoggets	0.9	100
	Rams	0.8	16
	Total sheep		**1,556**
	MA cows	6.0	75
	R2 heifers (autumn born replacements)	5.0	15
	R1 heifers	4.5	33
	R2 bulls (autumn born yearlings)	6.0	60
	R1 bulls	5.0	0
	R2 steers	6.5	0
	R1 steers	4.5	60
	Breeding bulls	6.0	3
	Total cattle		**246**
	Sheep SU		1,763
	Cattle SU		1,322
	Total SU		3,085
	Sheep %		57%
	Stocking rate		**10.75**

The sheep policy is a breeding-finishing policy involving:

- Breeding replacement ewe lambs;
- Approximately 300 five- and six-year-old ewes are mated to terminal rams on the 16th of March to start lambing 11th August;
- The MA ewes and two-tooth ewes are mated 12th April to start lambing 7th September;
- The ewe hoggets will be weighed during April and the "heavier ones" (all above 38 kg in 2023) go to the ram around the 10th of May for an early October lambing;
- A consistent lambing percentage of 145% survival to sale is targeted from the ewes and 75% for ewe hogget lambing – for a total of 1,850 lambs;
- Lambs will be sold, finished or store, through the summer and autumn at average of approximately 16 kg carcass weight (cwt), with 100 lambs carried through balance date; and
- Shearing is planned to take place in January for lambs, September for ewe hoggets, and November and March for the ewes.

The cattle policy is based on:

- A breeding herd with replacement heifers purchased as autumn born Friesian x Hereford weaner heifers in the late winter, a selling store 15-month heifer and steer policy, and a Friesian bull finishing policy.
- The breeding programme comprises of 75 Friesian x Hereford cows mated to terminal sire bulls with all the progeny retained. These will be joined by approximately 28 R1 dairy beef steers that are purchased in the autumn – resulting in just over 90 yearling steers and heifers to be wintered. It is planned to sell these cattle at 350 kg to 400 kg liveweight from November through to March.
- The bull finishing policy involves the purchase of 60 autumn born weaner bulls in July/August. These will be farmed for just under 18 months and finished at approximately 310 kg cwt.

For supplementary feed there is a contingency allowance for approximately 60 bales of hay or silage to be made. There is an allowance of four tonnes of urea to be self-applied as required but no cropping is planned.

Based on Stephan's current plans there is an average allowance of 270 kg/ha of "superphosphate", but actual applications will be subject to soil tests, contour, land-use, and economics.

7.3 Net CO_2 and N_2O position and methane emissions

Under the modelling assumptions, and after the biogenic methane emissions are deducted, this base scenario is sequestering 243.9 tonnes more carbon than the combined carbon dioxide and nitrous oxide emissions (Table 4) that have been calculated.

Table 4: Turner base scenario emission and sequestration results

	Base Scenario
Total GHG emissions (CO_2-e tonnes/yr) - Scope 1 and Scope 2 only	1,160.3
less	
Methane (CO_2-e tonnes/yr)	1,039.4
Total GHG emissions (CO_2-e tonnes/yr) excluding biogenic methane	**120.9**
Estimated Carbon sequestration occurring on farm (CO_2-e tonnes/yr) - this "project year" only	**364.8**
Net carbon position (-ve number requires reduction in emissions or increase in sequestration to achieve net carbon zero position (excluding biogenic methane) as per Zero Carbon Act.	**243.9**

While this is very positive from a net carbon position under the terms of NZ's Zero Carbon Act, Figure 5 shows that nearly 90% of the Turner GHG emissions are methane – which has the separate reduction targets. The methane reduction result will be a key aspect to examine in the different farm scenarios.

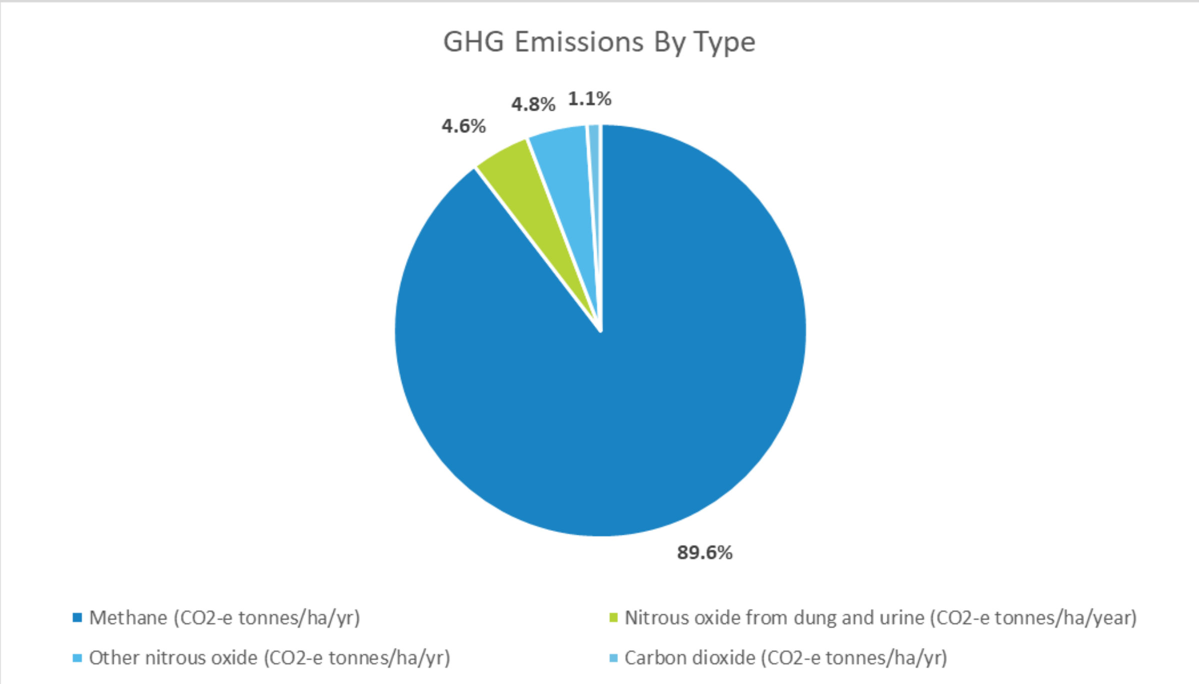

Figure 5: Turner base system emissions by type

7.4 The different scenarios considered

The details of the new scenarios are described in comparison to the base scenario and are based on planting plans that Stephan and Stacey have been considering.

Scenario 1:

- New planting 1.0 ha of natives and 3.5 ha of Douglas-fir; and

- Selling all non-replacement lambs prior to the 30th June (so removing the sale hoggets from the winter numbers), reducing cow numbers by 25 (33%) and replacing them and their progeny with more bought in dairy beef R1 steers that are sold as R2 cattle.

Scenario 2:

- New planting 1.0 ha of natives and 7.2 ha of Douglas-fir; and
- Removing the sale hoggets from the winter numbers, reducing ewe and ewe hogget numbers by 160 (11%), removing the cow herd entirely, and replacing them and their progeny with more bought in dairy beef R1 steers and bulls that are mostly sold as R2 cattle – except for 55 R2 steers which are sold as 2½ year cattle.

Scenario 3:

- As per Scenario 2 but a further 10 ha is planted – this time in pine trees – based on what the Farmax feed budget suggests is possible.

The different block areas and stock numbers are shown in Table 5 and Table 6 respectively. The stock units and stocking rate for each system have been calculated – while not the exactly the same, the stocking rate of the different scenarios are within 5% of the base system. This variation is due to stock numbers being derived after considering the Farmax feed budget process rather than using stock units to derive the stock numbers.

Table 5: Turner scenarios - block areas

Farm Area		Base Scenario	Scenario 1	Scenario 2	Scenario 3
	Flat	60.5	59.5	59.5	59.5
	Hill country	226.4	222.9	219.2	209.2
	Total Pasture Area	**286.9**	**282.4**	**278.7**	**268.7**
	Unfenced native	17.1	17.1	17.1	17.1
	Blackwoods	6.1	6.1	6.1	6.1
	Fenced native	60.8	60.8	60.8	60.8
	Pines	9.0	9.0	9.0	9.0
	New native	0.0	1.0	1.0	1.0
	New Douglas Fir/Redwoods	0.0	3.5	7.2	7.2
	New Pines	0.0	0.0	0.0	10.0
	Total Retired Area	**93.0**	**97.5**	**101.2**	**111.2**
	Other - houses and buildings	1.4	1.4	1.4	1.4
	Total Property Area	**381.3**	**381.3**	**381.3**	**381.3**

Table 6: Turner scenarios - stock numbers

Stock Numbers - 30th June	SU/Hd	Base Scenario	Scenario 1	Scenario 2	Scenario 3
MA ewes	1.2	1,100	1,100	1,000	1,000
Ewe hoggets	1.0	340	340	280	280
Sale hoggets	0.9	100	0	0	0
Rams	0.8	16	16	16	16
Total sheep		**1,556**	**1,456**	**1,296**	**1,296**
MA cows	6.0	75	50	0	0
R2 heifers (autumn born replacements)	5.0	15	10	0	0
R1 heifers	4.5	33	22	0	0
R2 bulls (autumn born yearlings)	6.0	60	60	60	60
R1 bulls	5.0	0	0	20	20
R2 steers	6.5	0	0	55	55
R1 steers	4.5	60	108	120	120
Breeding bulls	6.0	3	3	0	0
Total cattle		**246**	**253**	**255**	**255**
Sheep SU		1,763	1,673	1,493	1,493
Cattle SU		1,322	1,313	1,358	1,358
Total SU		3,085	2,986	2,851	2,851
Sheep %		57%	56%	52%	52%
Stocking rate		**10.75**	**10.57**	**10.23**	**10.61**

7.5 Results

Stock performance and profitability:

Table 7 shows that meat production is at least maintained on a total basis – and production per hectare has increased. This reflects a combination of the planting occurring on some of the steeper land (which was modelled as growing slightly less pasture than the better contour areas) and the net production effect of the stock classes from which numbers have been reduced from compared to those where the stock numbers have been increased.

Table 7: Turner scenario stock performance

Production	Base Scenario	Scenario 1	Scenario 2	Scenario 3
Lambing % ex ewes (STS)	145%	145%	147%	147%
Lambs from ewe hoggets	257	257	212	212
Lamb carcass weight (kg)	16.1	15.9	15.8	15.8
Number of steers and heifers sold store	92	129	64	64
Average steer and heifer sale lwt (kg lwt)	385	364	358	358
Number of steers finished	0	0	55	55
Average steer carcass weight (kg)	0	0	319	319
Number of bulls finished	60	60	80	80
Average bull carcass weight (kg)	310	310	308	308
Cattle purchased (excluding breeding bulls)	-105	-159	-204	-204
Total meat and fibre production - kg	**69,594**	**69,159**	**71,586**	**71,586**
Meat and fibre - kg/ha	**243**	**245**	**257**	**266**

The income and expenditure shown in Table 8 relates to only the livestock operation – no income or expenditure has been included for the planted trees.

As the pastoral area reduces if the stock policy stays structurally the same then the operating surplus has reduced. However, if as steeper land is removed from the operation, the breeding stock is reduced and finishing stock is increased then the operating surplus increased.

Table 8: Turner scenario profitability and production summary

Production and Profitability	Base Scenario	Scenario 1	Scenario 2	Scenario 3
Total meat and fibre production	**69,594**	**69,159**	**71,586**	**71,586**
kg product/ha pasture	243	245	257	266
Relative total production to Base situation	100%	99%	103%	103%
Relative kg product/ha to Base situation	100%	101%	106%	110%
Profitability				
Total revenue - sales less purchases	$322,813	$313,968	$324,789	$324,789
Total farm expenses	-$218,573	-$215,930	-$210,930	-$210,930
Farm Operating Surplus (EBITDr)	**$104,240**	**$98,038**	**$113,859**	**$113,859**
Relative to Total $	100%	94%	109%	109%
$/ha of farm operation	$363	$347	$409	$424
Relative to $/ha Base situation	100%	96%	112%	117%
$/kg product	$1.50	$1.42	$1.59	$1.59
Relative to Base situation	100%	95%	106%	106%

Sequestration:

As the area planted increases the amount of sequestration will also increase (Table 9).

Table 9: Turner scenario sequestration

Vegetation Type	Forest Type	Age *	Sequestration (tonnes CO_2/ha/yr)	Base Scenario	Scenario 1	Scenario 2	Scenario 3
Unfenced native	Indigenous forest (pre-1990)	>50	0.0	17.1	17.1	17.1	17.1
Blackwoods	Hardwoods	ave. 16	27.2	6.1	6.1	6.1	6.1
Fenced native	Indigenous forest (pre-1990)	>50	0.0	60.8	60.8	60.8	60.8
Pines	Pinus radiata (post 1989)	ave. 16	22.1	9.0	9.0	9.0	9.0
New native	Indigenous forest (post-1989)	ave. 16	6.8	0.0	1.0	1.0	1.0
New Douglas Fir/Redwoods	Douglas fir	ave. 16	12.1	0.0	3.5	7.2	7.2
New pines	Pinus radiata (post 1989)	ave. 16	22.1	0.0	0.0	0.0	10.0
Total Area in Trees				**93.0**	**97.5**	**101.2**	**111.2**
Average annual carbon sequestration - tonnes carbon dioxide per year				**364.8**	**414.0**	**458.7**	**679.7**

Net-carbon position:

Given the base scenario had a positive net carbon outcome it is not surprising the different scenarios, with more planting and slightly less stock, also had improved positive net carbon outcomes once biogenic methane is removed (Table 10 and Figure 6).

Table 10: Turner net carbon emission results

	Base Scenario	Scenario 1	Scenario 2	Scenario 3
Total GHG emissions (CO_2-e tonnes/yr) - Scope 1 and Scope 2 only	1,160.3	1,090.9	1,036.8	1,025.3
less				
Methane (CO_2-e tonnes/yr)	1,039.4	980.3	937.2	925.8
Total GHG emissions (CO_2-e tonnes/yr) excluding biogenic methane	**120.9**	**110.6**	**99.5**	**99.5**
Estimated Carbon sequestration occurring on farm (CO_2-e tonnes/yr) - this "project year" only	**364.8**	**414.0**	**458.7**	**679.7**
Net carbon position (-ve number requires reduction in emissions or increase in sequestration to achieve net carbon zero position (excluding biogenic methane) as per Zero Carbon Act.	**243.9**	**303.4**	**359.2**	**580.2**

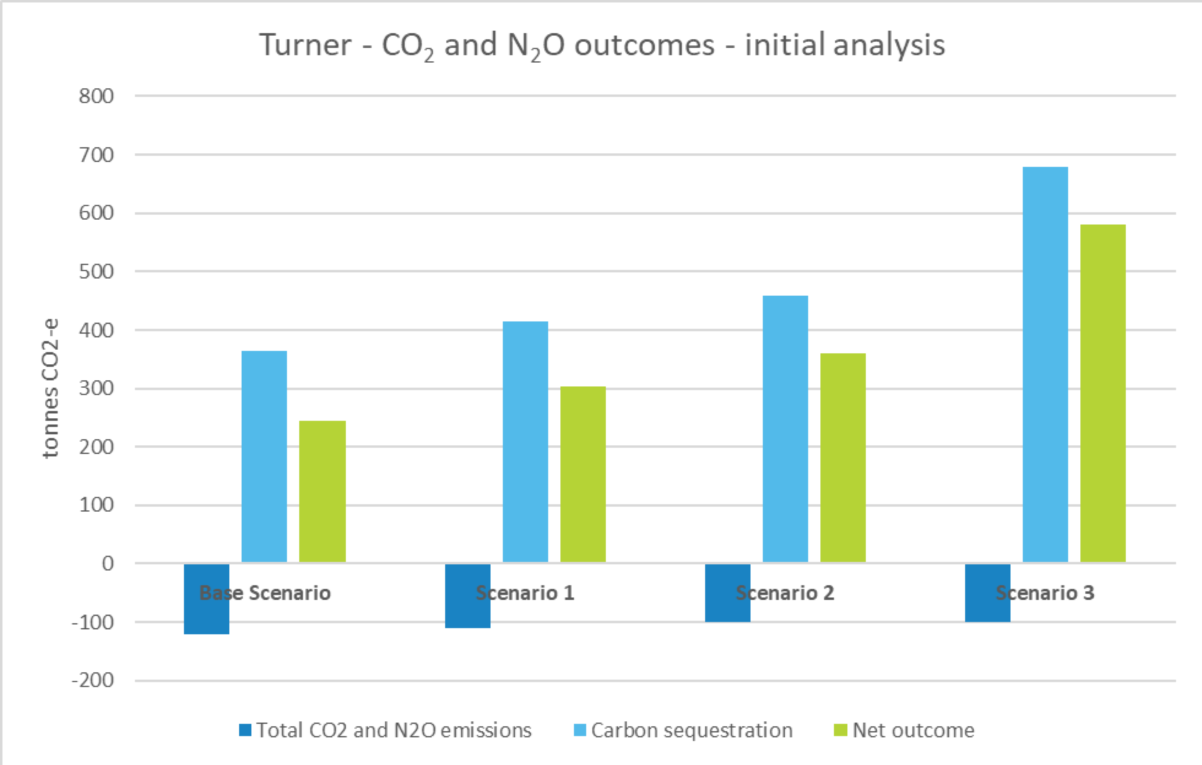

Figure 6: Turner net carbon outcome excluding biogenic methane

Methane reduction:

The level of methane reduction has been considered in comparison to the three reduction targets noted in the Zero Carbon Act: -10%, and the range of -24% to -47%.

The key conclusions drawn from the results shown in Figure 7 are:

- The planned stock number and stock policy changes considered can achieve reduced methane emissions at around the 10% reduction level;
- To achieve near the 24% methane reduction the stock number and stock policy changes also need the future genetics benefits to be working at the 5% reduction level and the future vaccine/inhibitor technology to be working at the 10% reduction level; and
- When the future genetics is working at 15% reduction and the future vaccine/inhibitor technology is working at 30% over the stock number and stock policy changes considered the 47% reduction target is still not achieved – but it is close at 43%.

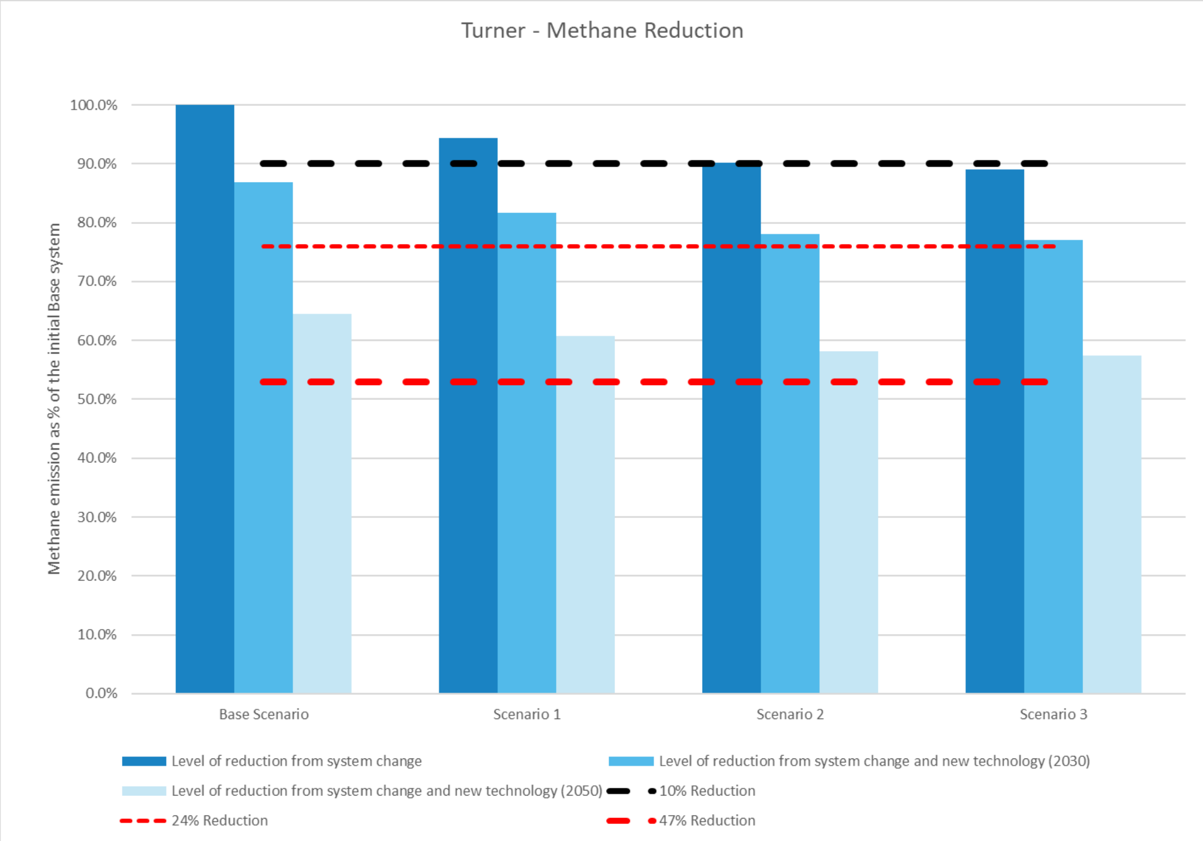

Figure 7: Turner total methane outcomes

Emissions intensity:

As per the information back in Table 7 and Table 8 (on page 31) the level of meat and fibre production has changed across the different scenarios – and in this case it has increased. Therefore, the total emissions for each scenario have different volumes of production to be spread across so when the level of emissions per kg of meat and fibre is considered there is a different emissions reduction profile achieved (Table 11).

Table 11: Turner emissions intensity

Intensity Calculations	Base Scenario		Scenario 1		Scenario 2		Scenario 3	
Total **GHG emissions** (Scope 1 and Scope 2) per kg of meat and wool (kg CO_2-e/kg product)	100%	16.67	94.6%	15.77	86.9%	14.48	85.9%	14.32
Total **long-lived gas** (Scope 1 and Scope 2) emissions (excluding biogenic methane) per kg of meat and wool (kg CO_2-e/kg product)	100%	1.74	92.1%	1.60	80.0%	1.39	80.0%	1.39
Total **Methane** (Scope 1 and Scope 2) emissions per kg of meat and wool (kg CH_4/kg product)	100%	0.60	94.9%	0.57	87.7%	0.52	86.6%	0.52

Scenario 3 had the lowest level of total GHG emissions. As per Table 10 the total Scope 1 and Scope 2 GHG emissions were 1,025 tonnes of CO_2-e/year compared to the base scenario of 1,160 tonnes of CO_2-e/year – i.e. 88% of the base scenario. On an intensity basis [kg CO_2-e/kg product] there is a greater drop achieved with Scenario 3 emissions per kg of product being at 85.9% of the base scenario.

This lower level is made up of the carbon dioxide and nitrous oxide emissions operating at 80% and the methane emissions operating at 86.6% of the base scenario.

In terms of methane intensity (Figure 8) Scenario 1's 5% reduction is very similar to the reduction in total methane. However, due to the extra production being achieved for Scenario 2 and 3 there is a greater reduction in the methane emissions intensity result for these changes.

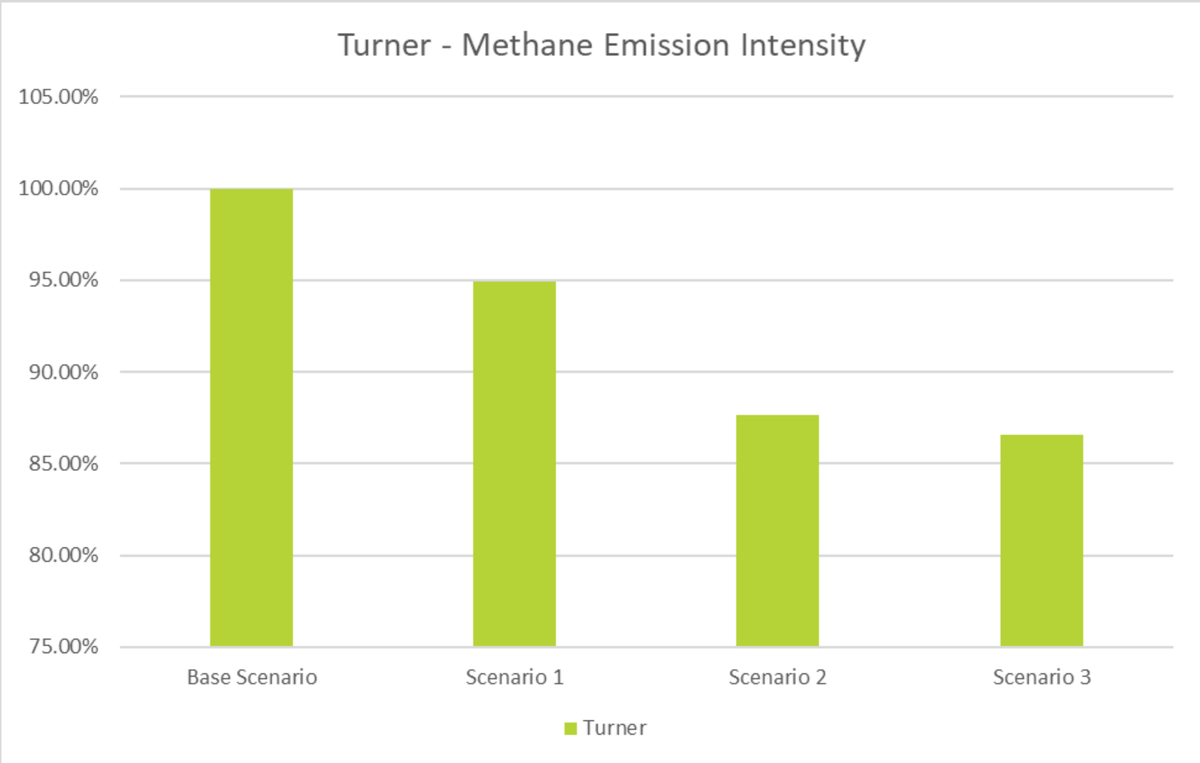

Figure 8: Turner comparative methane intensity across the scenarios

7.6 Conclusion

Taking the approach of the Zero Carbon Act, of excluding biogenic methane**, the Turner base scenario is already in a positive position for being "carbon neutral".** The planned planting the Turner's have will only put the operation in an improved "carbon positive" position.

The new planting assumed for this project considered trees that have a shorter lifetime and faster initial rates of carbon sequestration. Because the operation is already carbon neutral, and if the time frame is 2050, this gives the Turner's more flexibility with their planting programme – they may wish to take a longer-term approach and could plant just natives which should have a much longer lasting carbon sequestration impact.

Figure 9 shows that in 2050, if all their planned new planting was done as natives, they would still be in a very positive carbon position (excluding biogenic methane).

However, the higher establishment cost of natives will likely be a significant consideration.

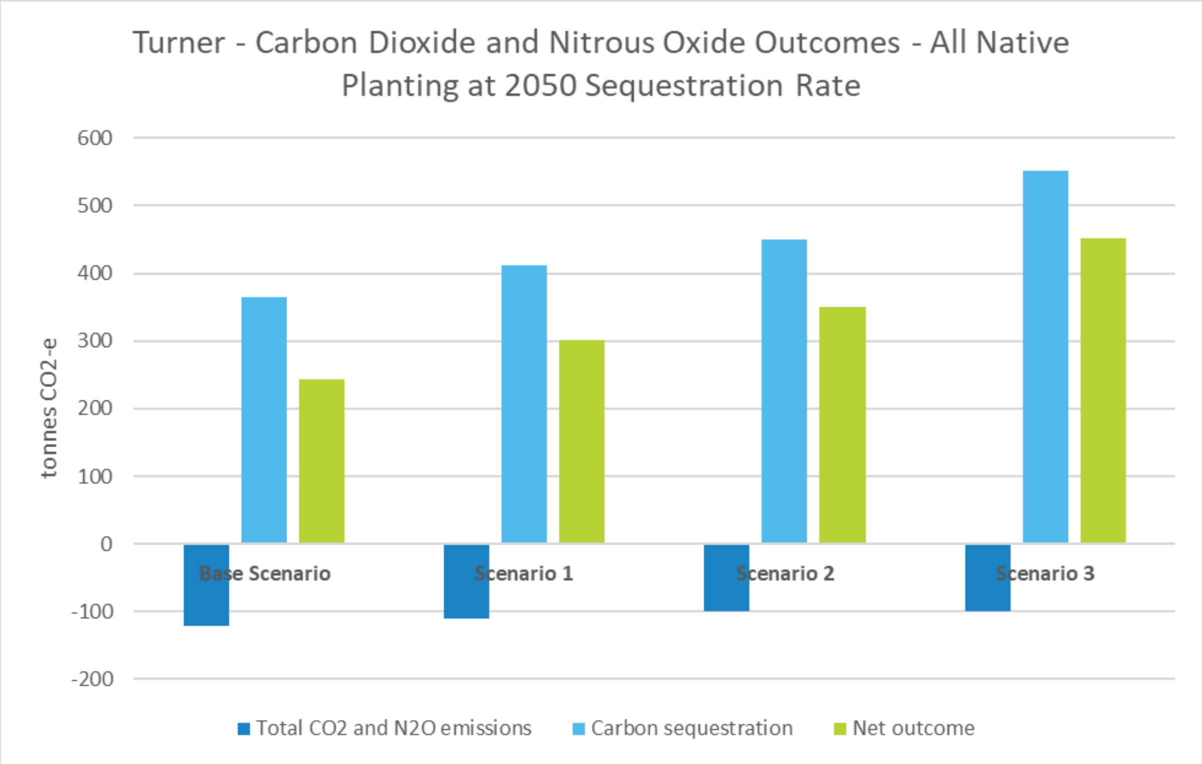

Figure 9: Turner net carbon position with all native planting and at the 2050 sequestration rate

Achieving **the methane reduction target of 10% by 2030 also appears to be feasible** – but, minimising, or having no impact on profitability will rely on being able to get an acceptable balance between reducing stock numbers and changing stock classes for increased productivity.

Achieving **the higher 24% to 47% methane reduction is going to require much greater change** that will also likely involve the success of new technologies such as lower methane producing genetics (that still achieve the same level of per head production) and animal treatments or feed additives that work in a way that is acceptable to consumers and at a cost that does not lower profitability.

7.7 What can the Turner's do now?

Although Government compliance processes may not require being carbon neutral and the achievement of the methane reduction targets at an individual farm level, increasingly there are market related requests for carbon and methane emission reduction plans at the farm level. **Irrespective of future Government compliance Stephan and Stacey will need to consider this aspect of their farm operation.**

A key aspect to remember is that the net carbon position will change from year to year – it will depend on their farm system (actual stock numbers, stock transaction dates, cropping and other relevant inputs) for that year, and the type and age of trees on the property. All these factors will lead to a different result each year.

Preparing their farm business for this future should involve creating reliable and easy to access information including:

- Mapping and describing the areas of non-pasture vegetation on the farm;
- Learning how this vegetation will be classed for sequestration and who will consider the different types of vegetation as eligible for sequestration;
- What will be the current and future the sequestration rates be for the different vegetation blocks;
- Recording the required information to calculate meat and fibre production – they can make sure weights for all their sale and purchase transactions are entered into their existing financial management system - and don't forget in and out weights for any grazing stock. [If you do not use a computerised financial management package just keep an accurate manual list of all your stock transactions.]

Stephan and Stacey should also start to learn about what tools and models are out there to calculate their emissions every year. (You may already be using a tool (e.g. Farmax, OverseerFM). They may not have to choose one yet but some background reading in the meantime may help later.

And, even if it just generates some interesting discussion, when they have their next conversation with their processor or key supplier they could ask them if they will be looking for an emissions reduction plan from them in the future and/or ask do they offer some pricing premium for having one now - and if the answer is yes get some understanding of what detail is required for the plan and what benefits they will pass on.

On-farm emissions, especially methane, is likely to be an ongoing regulatory topic of discussion for the Government of the day – with the current difficulties around reducing methane emissions, listen to these discussions, and contribute your thoughts where you can.

8 Brent and Lou Scott, Ōpārau – Sheep and Beef

8.1 Introduction

The Scott farm operation involves two properties:

- Omanawa - 1131 Okupata Road at Ōpārau; and
- Rakaunui - 362 Rakaunui Road at Hauturu.

Omanawa has been in the Scott family since 1978 when Brent's parents purchased the property and Rakaunui was purchased in 2019. Brent grew up on the Omanawa property and he and Lou have been farming the property since 2009.

8.2 The current farm operation

The two properties total 1,633 ha. The OverseerFM block mapping process has provided farm block areas as per Table 12.

Table 12: Scott initial area assumptions

		Omanawa	Rakanui	Total	Summary
Total - ODC information		**1,194.65**	**438.63**	**1,633.28**	**1,633.3**
Pasture	Hill	871.9	163.1	1,035.0	**1,482.5**
	Rolling	223.4	224.1	447.5	
	Total Pasture	**1,095.3**	**387.2**	**1,482.5**	
Ineffective	Native bush	95.4	7.3	102.7	**153.5**
	Retired coastal	0.0	23.1	23.1	
	Plantation	0.0	5.0	5.0	
	Wetland	0.0	5.0	5.0	
	Estuary area	0.0	15.0	15.0	
	House/buildings	1.4	1.3	2.7	
	Other	0.0	0.0	0.0	
	Total Ineffective	**96.8**	**56.7**	**153.5**	
Total OverseerFM mapping		**1,192.10**	**443.90**	**1,636.00**	**1,636.0**

The Rakaunui property is mainly used for the fattening cattle and a group of earlier lambing terminal mated ewes.

Based on the methodology being used for the project the annual sequestration calculated for these planted areas is described in Table 13 and totals 160.1 tonnes of carbon per year.

Table 13: Scott - sequestration of the base scenario

Vegetation Type	Forest Type	Age	Sequestration (tonnes CO_2/ha/yr)	Base Scenario
Omanawa native bush	Indigenous forest (pre-1990)	>50	0.0	95.4
Rakaunui bush (to be fenced)	Indigenous forest (post 1989)	<50	6.8	7.3
Rakanui retired coast (bush)	Indigenous forest (pre-1990)	>50	0.0	23.1
Rakanui retired coast "estuarine"	N/A		0.0	15.0
Rakanui retired wet area	N/A		0.0	5.0
Rakanunui existing pines	Pinus radiata (post 1989)	ave. 16	22.1	5.0
New planting - natives	Indigenous forest (post 1989)	ave. 16	6.8	0.0
New planting - pines	Pinus radiata (post 1989)	ave. 16	22.1	0.0
Total Area in Trees				**150.8**
Average annual carbon sequestration - tonnes carbon per year				**160.1**

The base scenario stock numbers (Table 14) and policy represents the status quo numbers of Brent's current stock policy. On the stock unit per head basis shown in the table the overall stocking rate equates to 9.15 SU/ha.

Table 14: Scott winter stock numbers

Stock Numbers - 30th June	SU/Hd	Base Scenario
MA ewes	1.3	3,000
Ewe hoggets	1.0	850
Sale hoggets	0.9	400
Rams	0.8	50
Total sheep		**4,300**
MA cows	6.0	410
R2 heifers (VIC)	6.0	105
R2 heifers (finishing)	5.5	180
R1 heifers	4.5	239
R2 steers	7.0	285
R1 steers	5.0	239
Breeding bulls	6.0	12
Total cattle		**1,470**
Sheep SU		5,150
Cattle SU		8,418
Total SU		13,568
Sheep %		38%
Stocking rate		**9.15**

The sheep policy is a breeding-finishing policy involving:

- Mating 500 early lambing terminal mated ewes on the 5th March, 2,500 mixed age and two-tooth ewes on 1st April, and 900 ewe hoggets on the 20th April.

- Lambing expectations on a survival to sale basis are 140% from the ewes and 700 lambs from the ewe hoggets for a total of 4,900 lambs;
- The 400 sale hoggets that are wintered usually include approximately 250 bought in lambs, 100 own carryover mixed sex lambs, and 50 cull ewe hoggets (of the 900 ewe hoggets mated) identified after scanning.
- Weaning for the ewes starts in late November and is completed in December with an approximate average lamb liveweight of 30+ kg;
- Lambs are finished and sold from late November through to the end of June with an average carcass weight of around 20 kg. Approximately 60% of the early lambs are sold as they are weaned, with only a couple of hundred later born lambs sold at weaning;
- The 400 winter lambs are finished at similar weights through the late winter/early spring.
- Shearing is planned to take place in January for the lambs, early May and early November (with lambs at foot) for ewe hoggets, May and November/December for the ewes.

The cattle policy is a breeding-finishing policy involving:

- An Angus breeding herd with the R2 heifers starting to calve on the 10th September and the MA cows starting on the 25th September;
- Weaning takes places in the first half of April with an average weaning weight of approximately 250 kg. All the weaners are retained (with the male calves steered) through to finishing at two to two and half years of age;
- Another 100 R2 cattle are purchased – 50 steers in November and 50 heifers in March, and they are added to the finishing progeny;
- Finishing the heifers and steers from mid-spring through to the end of summer – which is normally October through to the end of February. The heifers normally kill out at 260 to 270 kg cwt and the steers at around 330+ kg cwt.

The supplementary feeding policy involves making approximately 400 bales (of 10 to 12 square bale equivalents) of silage. Approximately 40% is made on Omanawa and the balance at Rakaunui. The bales are fed to the cows and R2 fattening cattle from the end of July to mid-September.

Cropping is not a major part of the system, but four to six hectares has been sown in chicory for lamb finishing.

Fertiliser applications have been predominantly superphosphate based with an average application of approximately of 300 kg/ha. There are also small-targeted amounts of DAP, nitrogen, and muriate of potash applied – mainly for the crop and silage areas.

8.3 Net CO_2 and N_2O position and methane emissions

Under the modelling assumptions, and even after the biogenic methane emissions are deducted, this base scenario has more carbon dioxide and nitrous oxide emissions (Table 15) on a carbon equivalent basis than what is being sequestered, with net emissions of 368.3 tonnes.

Table 15: Scott base scenario emission and sequestration results

	Base Scenario
Total GHG emissions (CO_2-e tonnes/yr) - Scope 1 and Scope 2 only	4,803.3
less	
Methane (CO_2-e tonnes/yr)	4,274.9
Total GHG emissions (CO_2-e tonnes/yr) excluding biogenic methane	**528.4**
Estimated Carbon sequestration occurring on farm (CO_2-e tonnes/yr) - this "project year" only	**160.1**
Net carbon position (-ve number requires reduction in emissions or increase in sequestration to achieve net carbon zero position (excluding biogenic methane) as per Zero Carbon Act.	**-368.3**

The different farm scenarios will need to consider both the net carbon position and the level of methane emissions. With 89% (Figure 10) of the Scott emissions being from methane the methane reduction result will be a key aspect to examine in the different farm scenarios.

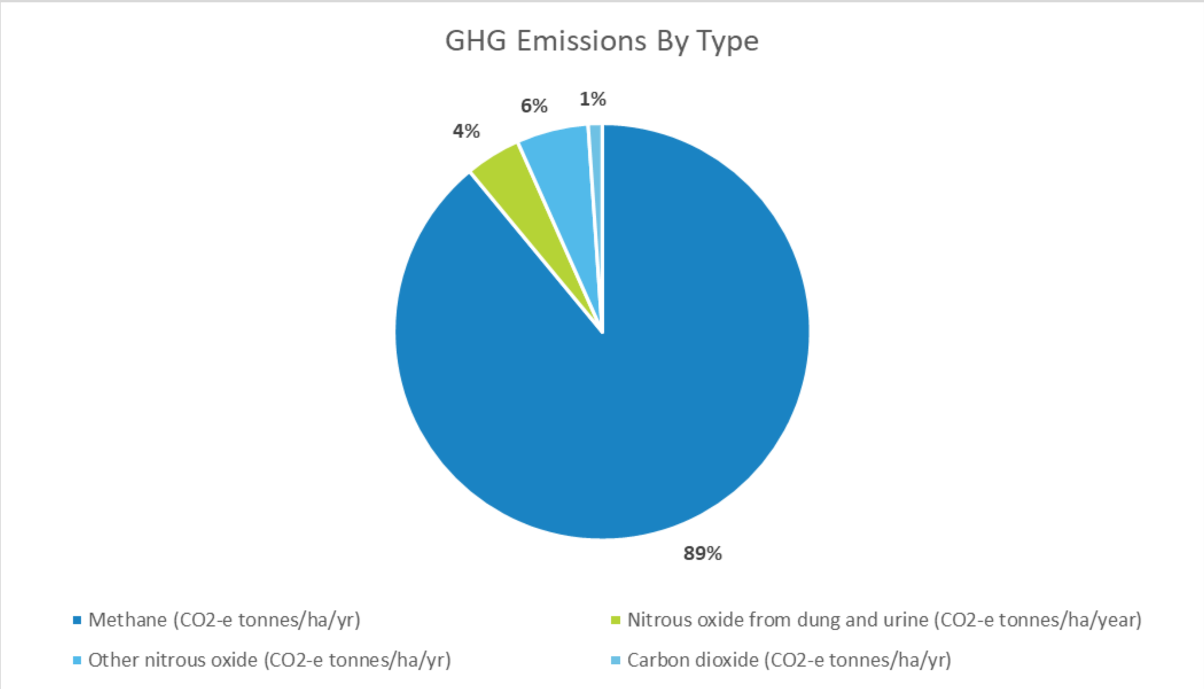

Figure 10: Scott base scenario emissions by type

8.4 The different scenarios considered

The details of the new scenarios are described in comparison to the Base Scenario and are mostly based on planting and stock policy changes that Brent has been considering – plus, given the size of the property, an extra-large tree planting example.

Scenario 1:

- New planting 2.0 ha of natives in selected places and doubling the pine plantation area with another 5.0 ha planted;

- Keeping the stock numbers the same as the extra area planted would represent less than 0.5% of the pastoral area – and it would involve lower pasture growing areas of the farm; and
- Mate another 300 ewes to terminal rams, lift lamb production by 375 lambs, and not buy in any lambs for the 400 sale hoggets wintered.

Scenario 2:

- The same new planting as per Scenario 1 - 2.0 ha of natives in selected places and doubling the pine plantation area with another 5.0 ha planted;
- The same higher lamb production as per Scenario 1; and
- Reducing in-calf cow and R2 heifer numbers by 100 and buy in 140 mixed sex weaner beef cattle at the normally achieved weaner weights – these are assumed not to be potentially lower methane emitting dairy beef cattle, but they could be. The purchase of the 100 mixed R2 cattle still occurs.

Scenario 3:

- The same initial new planting as per Scenario 1 and Scenario 2 but then with an extra 100 ha of planting – made up of 10 ha of native planting and 90 ha of plantation pines; and
- Reduced cow and R2 heifer numbers as per Scenario 2. With the smaller area of hill country the cattle purchasing now involves 70 weaner steers and the 100 mixed sex R2 cattle.

The different block areas and stock numbers are shown in Table 16 and Table 17 respectively. The stock units and stocking rate for each system have been calculated – while not the exactly the same the stocking rates of the different scenarios are within 3% of the base scenario. This variation is due to stock numbers being derived after considering the Farmax feed budget process rather than using stock units to derive the stock numbers.

When the larger plantation area is completed, it is unlikely the poorest 90 ha of the farm will be able to be planted – but it has been assumed this 90 ha is from part of the lower pasture producing portion of the farm.

Table 16: Scott scenarios - block areas

Farm Area		Base Scenario	Scenario 1	Scenario 2	Scenario 3
Omanawa hill		871.9	869.9	869.9	789.9
Omanawa rolling		223.4	223.4	223.4	223.4
Rakaunui hill		163.1	158.1	158.1	138.1
Rakaunui rolling		224.1	224.1	224.1	224.1
Total Pasture		**1,482.5**	**1,475.5**	**1,475.5**	**1,375.5**
Omanawa native bush		95.4	95.4	95.4	95.4
Rakaunui bush (to be fenced)		7.3	7.3	7.3	7.3
Rakanui retired coast (bush)		23.1	23.1	23.1	23.1
Rakanui retired coast "estuarine"		15.0	15.0	15.0	15.0
Rakanui retired wet area		5.0	5.0	5.0	5.0
Rakanunui existing pines		5.0	5.0	5.0	5.0
New planting - natives		0.0	2.0	2.0	12.0
New planting - pines		0.0	5.0	5.0	95.0
Total Retired Areas		**150.8**	**157.8**	**157.8**	**257.8**
Other - houses and buildings		2.7	2.7	2.7	2.7
Total Property Area		**1,636.0**	**1,636.0**	**1,636.0**	**1,636.0**

Table 17: Scott scenarios - stock numbers

Stock Numbers - 30th June	SU/Hd	Base Scenario	Scenario 1	Scenario 2	Scenario 3
MA ewes	1.3	3,000	3,000	3,000	3,000
Ewe hoggets	1.0	850	850	850	850
Sale hoggets	0.9	400	400	400	400
Rams	0.8	50	50	50	50
Total sheep		**4,300**	**4,300**	**4,300**	**4,300**
MA cows	6.0	410	410	330	330
R2 heifers (VIC)	6.0	105	105	85	85
R2 heifers (finishing)	5.5	180	180	227	157
R1 heifers	4.5	239	239	264	194
R2 steers	7.0	285	285	312	312
R1 steers	5.0	239	239	264	264
Breeding bulls	6.0	12	12	12	12
Total cattle		**1,470**	**1,470**	**1,494**	**1,354**
Sheep SU		5,150	5,150	5,150	5,150
Cattle SU		8,418	8,418	8,503	7,803
Total SU		13,568	13,568	13,653	12,953
Sheep %		38%	38%	38%	40%
Stocking rate		**9.15**	**9.20**	**9.25**	**9.42**

8.5 Results

Stock performance and profitability:

Table 18 shows that meat production is at least maintained on a total basis – until the larger area is planted.

Although total production was lower in Scenario 3, production per hectare increased. This reflects the planting occurring on some of the steeper land (which was modelling as growing slightly less pasture than the better contour areas) and the net production effect of the stock classes from which numbers have been reduced from compared to those where the stock numbers have been increased.

Table 18: Scott scenario stock performance

Production	Base Scenario	Scenario 1	Scenario 2	Scenario 3
Lambing % ex ewes (STS)	140%	148%	148%	148%
Lambs from ewe hoggets	700	850	850	850
Lamb carcass weight (kg)	20.5	19.7	19.7	19.7
Number of steers and heifers finished	465	465	539	469
Average heifer carcass weight (kg)	272	272	271	270
Average steer carcass weight (kg)	331	331	328	328
Lambs purchased	250	0	0	0
Cattle purchased (excluding breeding bulls)	100	100	240	170
Total meat and fibre production	**280,934**	**284,261**	**281,206**	**270,512**
Meat and fibre/ha	**189**	**193**	**191**	**197**

The income and expenditure shown in Table 19 relates to only the livestock operation – no income or expenditure has been included for the planted trees.

The operating surplus of the Base Scenario and Scenarios 1 and 2 are all similar on a total basis. As the pastoral area reduces if the stock policy stays structurally the same then the operating surplus has mostly reduced.

For this operation the operating surplus per hectare has stayed very similar to the base scenario - +/-3% of the base system.

Table 19: Scott scenario profitability and production summary

Production and Profitability		Base Scenario	Scenario 1	Scenario 2	Scenario 3
	Total meat and fibre production	**280,934**	**284,261**	**281,206**	**270,512**
	kg product/ha pasture	189	193	191	197
	Relative total production	100%	101%	100%	96%
	Relative kg product/ha	100%	102%	101%	104%
Profitability					
	Total revenue - sales less purchases	$1,386,050	$1,399,049	$1,375,491	$1,320,293
	Total farm expenses	-$910,353	-$909,079	-$901,049	-$886,411
	Farm Operating Surplus (EBITDr)	**$475,697**	**$489,970**	**$474,442**	**$433,882**
	Relative farm operating surplus	100%	103%	100%	91%
	Farm operating surplus $/ha	$321	$332	$322	$315
	Relative $/ha	100%	103%	100%	98%
	$/kg product	$1.69	$1.72	$1.69	$1.60
	Relative $/kg product	100%	102%	100%	95%

Sequestration:

As the area planted increases the amount of sequestration will increase (Table 20).

Table 20: Scott scenario sequestration

Vegetation Type	Forest Type	Age	Sequestration (tonnes CO_2/ha/yr)	Base Scenario	Scenario 1	Scenario 2	Scenario 3
Omanawa native bush	Indigenous forest (pre-1990)	>50	0.0	95.4	95.4	95.4	95.4
Rakaunui bush (to be fenced)	Indigenous forest (post 1989)	<50	6.8	7.3	7.3	7.3	7.3
Rakanui retired coast (bush)	Indigenous forest (pre-1990)	>50	0.0	23.1	23.1	23.1	23.1
Rakanui retired coast "estuarine"	N/A		0.0	15.0	15.0	15.0	15.0
Rakanui retired wet area	N/A		0.0	5.0	5.0	5.0	5.0
Rakanunui existing pines	Pinus radiata (post 1989)	ave. 16	22.1	5.0	5.0	5.0	5.0
New planting - natives	Indigenous forest (post 1989)	ave. 16	6.8	0.0	2.0	2.0	12.0
New planting - pines	Pinus radiata (post 1989)	ave. 16	22.1	0.0	5.0	5.0	95.0
Total Area in Trees				**150.8**	**157.8**	**157.8**	**257.8**
Average annual carbon sequestration - tonnes carbon per year				**160.1**	**284.2**	**284.2**	**2,341.2**

Net-carbon position:

As seen in Table 21 and Figure 11, Scenario 2 with the reduced cow numbers and more bought in cattle for finishing had a slightly lower total carbon dioxide and nitrous oxide emissions. The extra planting equated to less than 0.5% of the area in pasture. The net effect of these changes did not get this operation into a carbon neutral position – even after excluding biogenic methane.

Scenario 3, with another 100 ha of planting, showed another 4% reduction in these emissions compared to Scenario 2, which has the same lower number of breeding cows, despite reducing the pastoral area by a comparative 6.8%. This is the impact of planting a poorer part of the farm so the stock unit reduction with this area is less than the average stocking rate over the whole property. The relatively large increase in new trees means a large increase in sequestration so the property moves into a carbon positive position (with sequestration being greater than the carbon dioxide and nitrous oxide emissions).

Table 21: Scott net carbon emission results

	Base Scenario	Scenario 1	Scenario 2	Scenario 3
Total GHG emissions (CO_2-e tonnes/yr) - Scope 1 and Scope 2 only	4,803.3	4,764.0	4,616.8	4,431.9
less				
Methane (CO_2-e tonnes/yr)	4,274.9	4,235.6	4,106.4	3,942.8
Total GHG emissions (CO_2-e tonnes/yr) excluding biogenic methane	**528.4**	**528.4**	**510.4**	**489.2**
Estimated Carbon sequestration occurring on farm (CO_2-e tonnes/yr) - this "project year" only	**160.1**	**284.2**	**284.2**	**2,341.2**
Net carbon position (-ve number requires reduction in emissions or increase in sequestration to achieve net carbon zero position (excluding biogenic methane) as per Zero Carbon Act.	**-368.3**	**-244.2**	**-226.2**	**1,852.1**

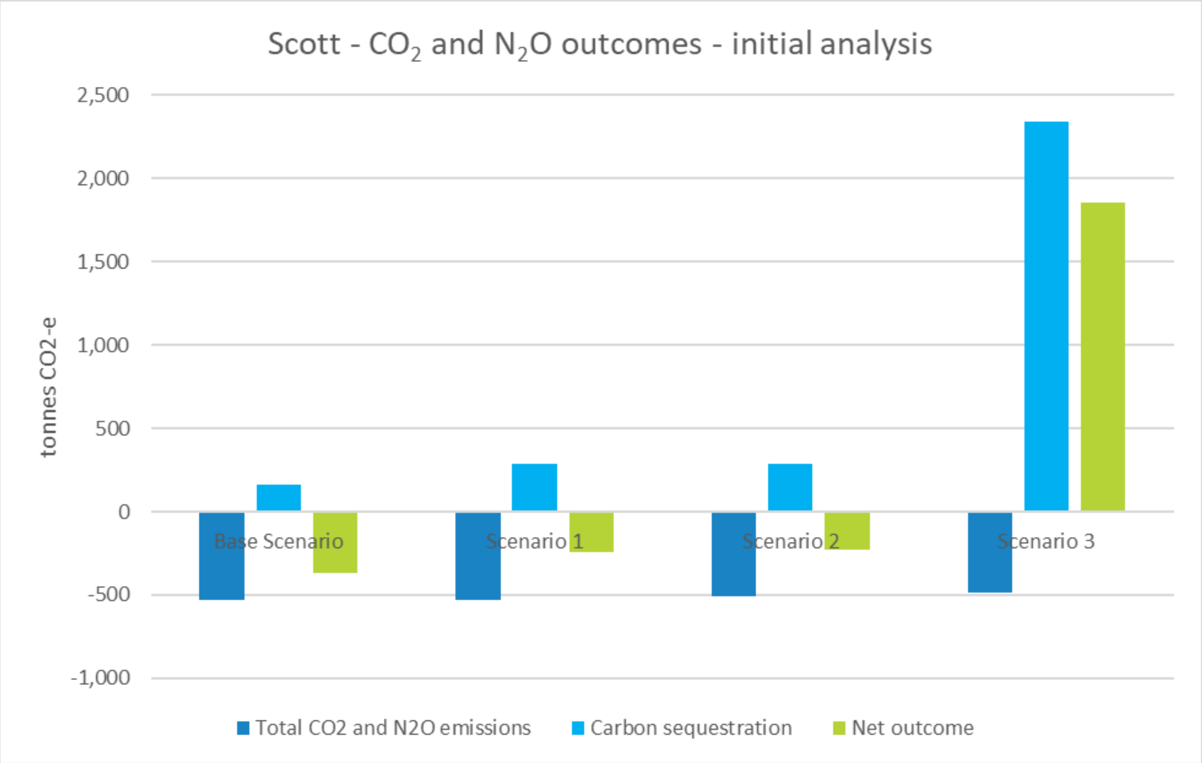

Figure 11: Scott net carbon outcome excluding biogenic methane

Methane reduction:

The level of methane reduction has been considered in comparison to the three reduction targets noted in the Zero Carbon Act: -10%, and the range of -24% to -47%.

The key conclusions drawn from the results shown in Figure 12 are:

- The planned stock number and stock policy changes considered have not achieved the methane emissions reduction target of 10% - even when a total of 107 ha (7%) of the farm has been planted;
- The stock number and stock policy changes also need some of the future genetics benefits to working at the 5% reduction level (over the sheep only) and the future vaccine/inhibitor technology to be working at the 10% reduction level to achieve the 10% methane reduction target – but the 24% reduction target has not been achieved; and
- When the future genetics is working at 15% reduction (over the sheep only) and the future vaccine/inhibitor technology is working at 30% over the considered stock number and stock policy changes the 47% reduction is not achieved – the combined affects have achieved a 40% methane reduction.

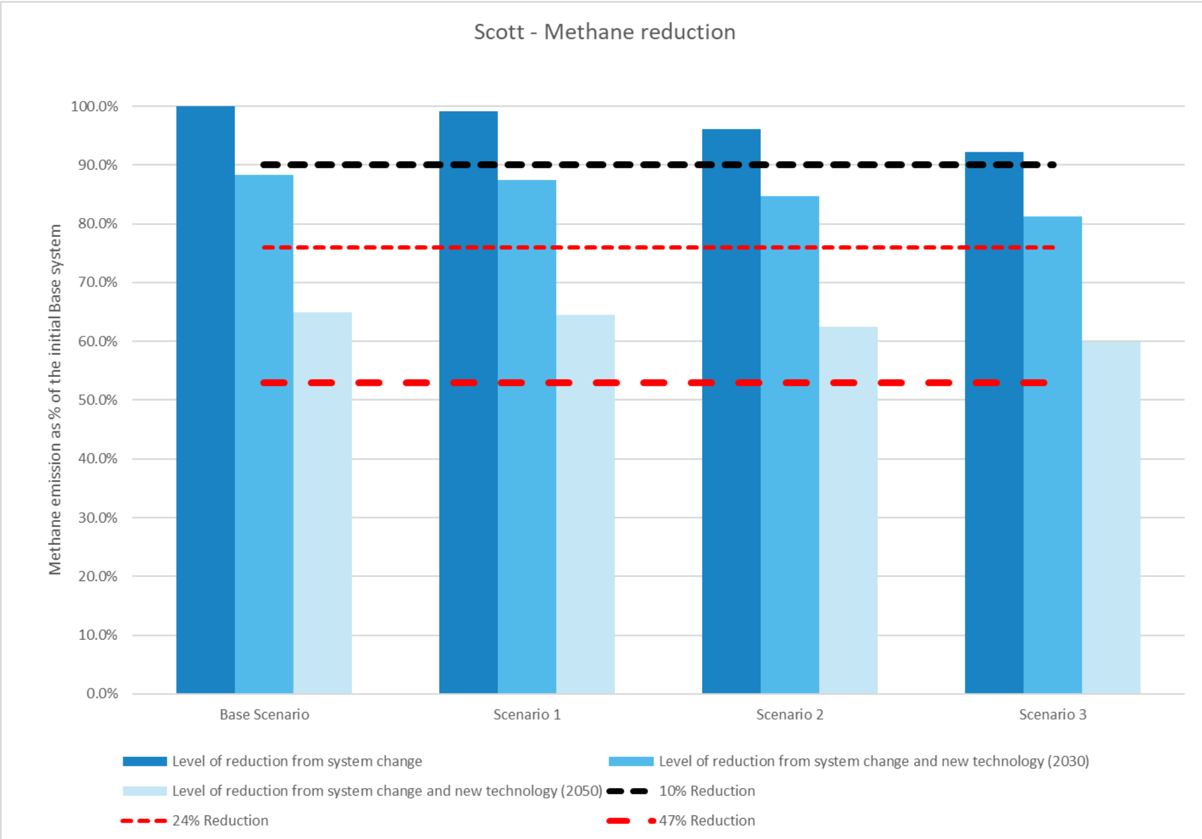

Figure 12: Scott total methane outcomes

Emissions intensity:

As per the information back in Table 18 and Table 19 (on pages 44 and 45 respectively) the level of meat and fibre production has changed across the different scenarios – a bit of up and down. Therefore, the total emissions for each scenario have different volumes of production to be spread across so when the level of emissions per kg of meat and fibre is considered there is a different emissions reduction profile achieved.

Scenario 3 had the lowest level of total GHG emissions. As per Table 21 the total Scope 1 and Scope 2 GHG emissions were 4,432 tonnes of CO_2-e/year compared to the base scenario of 4,803 tonnes of CO_2-e/year – i.e. 92% of the base scenario. On an intensity basis [kg CO_2-e/kg product] the reduction is not so large due to the lower level of production being achieved from the smaller farm area.

Table 22: Scott emissions intensity

Intensity Calculations	Base Scenario		Scenario 1		Scenario 2		Scenario 3	
Total **GHG emissions** (Scope 1 and Scope 2) per kg of meat and wool (kg CO_2-e/kg product)	100%	17.10	98.0%	16.76	96.0%	16.42	95.8%	16.38
Total **long-lived gas** (Scope 1 and Scope 2) emissions (excluding biogenic methane) per kg of meat and wool (kg CO_2-e/kg product)	100%	1.88	98.8%	1.86	96.5%	1.82	96.1%	1.81
Total **Methane** (Scope 1 and Scope 2) emissions per kg of meat and wool (kg CH_4/kg product)	100%	0.61	97.9%	0.60	96.0%	0.58	95.8%	0.58

In terms of methane emission intensity, the reduction was less than the reduction in total methane due to the production changes that occurred with the different scenario's.

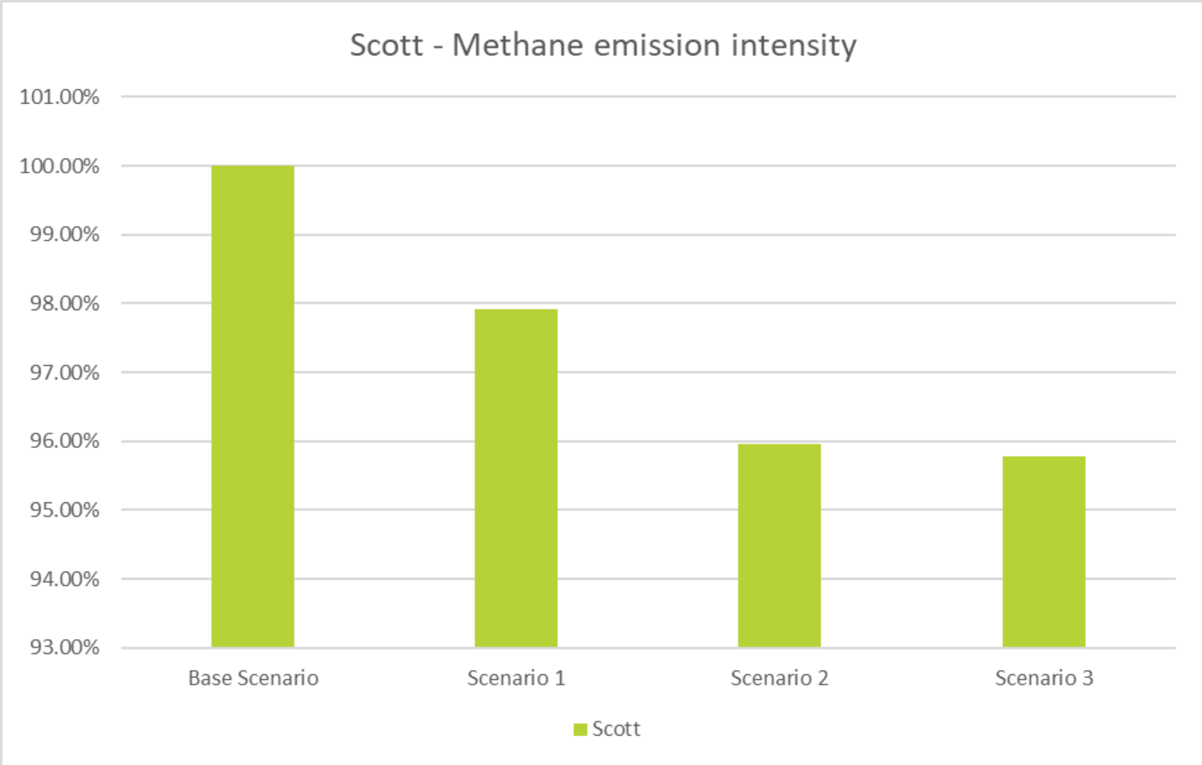

Figure 13: Scott comparative methane intensity across the scenarios

8.6 Conclusion

Taking the approach of the Zero Carbon Act, of excluding biogenic methane**, the Scott base scenario is currently not in a positive position for being "carbon neutral".**

A planting programme can get the operation into a carbon neutral position as per the Zero Carbon Act – it will require more than the 7 ha but less than the 107 ha that were considered in the scenario's modelled.

However, **the reduced stock numbers and stock policy changes considered** alongside the 107 ha of planting **were not enough to achieve the initial methane emissions reduction target of 10%.**

The farm operating surplus related to the pastoral area as the $/ha operating surplus was very similar across all the scenarios modelled. Maintaining the total farm operating surplus, excluding any gains/losses from the tree planting, will require other changes (than those modelled) to the stock policy.

Achieving **the higher 24% to 47% methane reduction is going to require much greater change** and will likely involve the success of new technologies such as lower methane producing genetics (that still achieve the same levels of per head production) and animal treatments or feed additives that work in a way that are acceptable to consumers and at a cost that does not lower profitability.

The planting considered for the initial scenario analysis considered trees that have a shorter lifetime and faster initial rates of carbon sequestration. If parts of the farm are identified as best being planted, instead of remaining in pasture and being grazed with livestock, and are up near the 100+ ha and if the timeframe for achieving "carbon neutrality" is 2050, then this gives the Scott's more flexibility with their planting programme – they may wish to take a longer-term approach and could plant just natives which should have a much longer lasting carbon sequestration impact.

Figure 14 shows that in 2050, if all their planned new planting was done as natives, they would still be a very positive carbon position (excluding biogenic methane).

However, the higher establishment cost of natives will likely be a significant consideration.

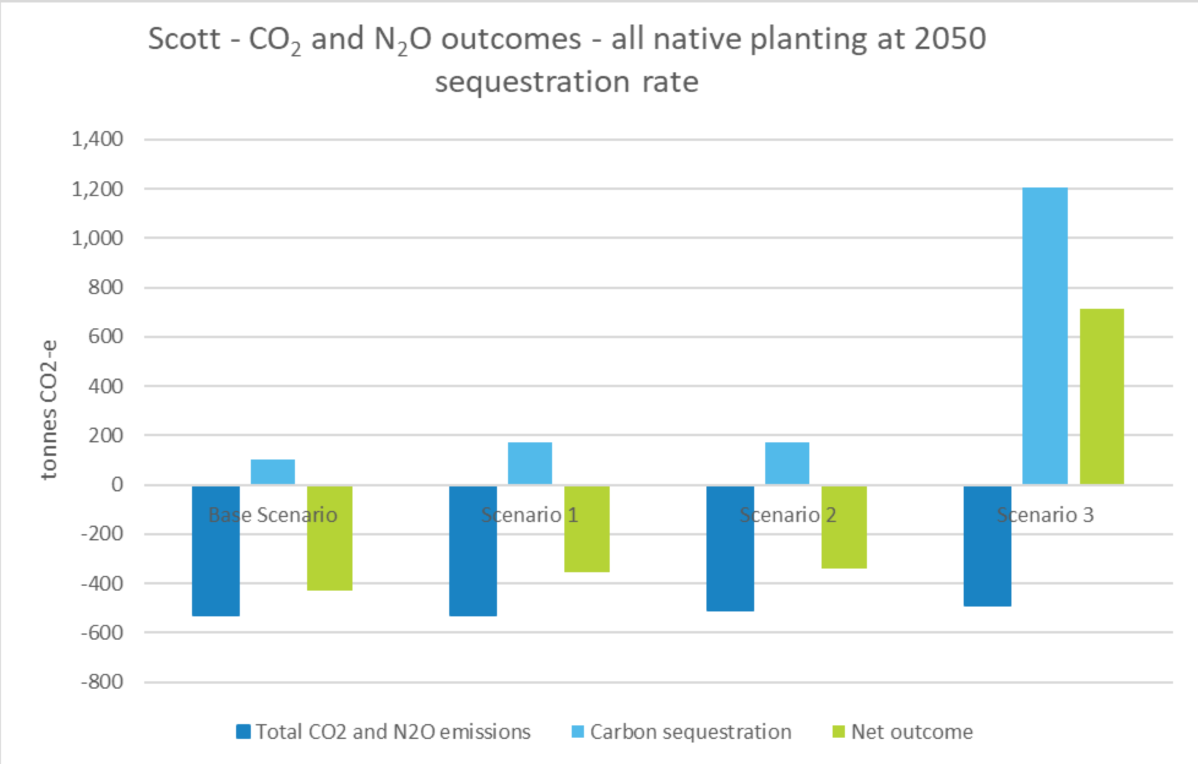

Figure 14: Scott net carbon position with all native planting and at the 2050 sequestration rate

8.7 What can the Scott's do now?

Although Government compliance processes may not require being carbon neutral and the achievement of the methane reduction targets at the individual farm level, increasingly there are market related requests for carbon and methane emission reduction plans at the farm level. **Irrespective of future Government compliance Brent and Lou will need to consider this aspect of their farm operation.**

A key aspect to remember is that the net carbon position will change from year to year – it will depend on their farm system (actual stock numbers, stock transaction dates, cropping and other relevant inputs) for that year, and the type and age of trees on the property. All these factors will lead to a different result each year.

Preparing their farm business for this future should involve creating reliable and easy to access information including:

- Mapping and describing the areas of non-pasture vegetation on the farm;
- Learning how this vegetation will be classed for sequestration and who will consider the different types of vegetation as eligible for sequestration;

- What will be the current and future the sequestration rates be for the different vegetation blocks;
- Recording the required information to calculate meat and fibre production – they can make sure weights for all their sale and purchase transactions are entered into their existing financial management system - and don't forget in and out weights for any grazing stock. (If you do not use a computerised financial management package keep an accurate manual list of all your stock transactions).

Brent and Lou could also start to learn about what tools and models are out there to calculate their emissions every year. (You may already be using a tool - e.g. Farmax, OverseerFM). They may not have to choose one yet but some background reading in the meantime may help later.

And, even if it just generates some interesting discussion, when they have their next conversation with their processor or key supplier they could ask them if they will be looking for an emissions reduction plan from them in the future and/or ask do they offer some pricing premium for having one now - and if the answer is yes get some understanding of what detail is required for the plan and what benefits they will pass on.

On-farm emissions, especially methane, is also likely to be an ongoing regulatory topic of discussion for the Government of the day – with the current difficulties around reducing methane emissions, listen to these discussions, and contribute your thoughts where you can.

9 Phil Watkins and Jo Stockley, Piopio - Dairy

9.1 Introduction

The farm operation involves approximately:

- A 365 ha milking platform and runoff area based on freehold and lease properties on Mairoa Road, Piopio; and
- A 56 ha leased runoff block on Aria Road near the Waiere power station between Piopio and Aria.

The Mairoa Road property has been in the Watkins family since 1983 when Phil's parents, Raymond and Lisa, purchased the property. It was converted from sheep and beef to dairy in 1996. The neighbouring lease was converted into the dairy operation in 2017.

The family moved to the farm when Phil was four. After a stint away, studying and working in NZ and overseas, Phil came back to the farm in 2013 with Jo joining Phil on the farm in 2021.

9.2 The current farm operation

The total property area of 421 ha has been measured in OverseerFM as involving the blocks detailed in Table 23. In summary there is approximately 365 ha of pasture and greater than 40 ha of retired land.

Table 23: Watkins initial area assumptions

Farm Area		Base
	Milking platform	265.4
	Runoff - dairy support	95.0
	Other pasture	5.0
	Total Pasture Area	**365.4**
	Older bush	18.2
	Recent retired areas	6.6
	New retired areas	0.0
	Riparian - fenced	17.0
	Total Retired Area	**41.8**
	Other	13.7
	Total Property Area	**420.9**

Over 88 ha of the milking platform is used for spreading effluent from the cowshed. Most of this occurs under irrigation while some effluent is sprayed on by a contractor onto other paddocks to empty the pond after periods of higher rainfall. The solids from the sand trap are spread onto future cropping paddocks by a muck spreader.

There is a feed pad in use. This is used by the herd during January to May for approximately two hours per day for them to be fed their maize silage.

Based on the methodology being used for the project the annual sequestration calculated for the planted areas is described in Table 24 and totals 44.9 tonnes of carbon per year.

Table 24: Watkins - sequestration of the base system

Vegetation Type	Forest Type	Age	Sequestration (tonnes CO_2/ha/yr)	Base Scenario
Older bush	Indigenous forest (pre-1990)	>50	0.0	18.2
Existing retired areas	Indigenous forest	ave. 16	6.8	6.6
New retired areas	Indigenous forest	ave. 16	6.8	0.0
New - pines	Pinus radiata (post 1989)	ave. 16	22.1	0.0
New - Douglas-fir	Douglas-fir	ave. 16	12.1	0.0
Riparian - not planted	Indigenous forest	0	0.0	17.0
Total Area in Trees				**41.8**
Average annual carbon sequestration - tonnes carbon per year				**44.9**

In recent years there has been some winter milking occurring with 80 to 100 cows, but this has just been phased out. The base scenario modelled involves wintering 640 cows and R2 heifers to calve with 160 R1 replacement heifers farmed – which is a 25% replacement rate. Approximately 54 beef cross dairy calves are reared – 45 are Wagyu X calves that are sold as 95 kg weaners, and the balance are "white-heads" that are then farmed on Phil's parent's small block. There a few hobby horses and sheep grazing around the house and driveway areas, but these have not been considered in the modelling.

Total meat production from this livestock system has been calculated at 32,516 kg of meat.

As per Table 25 this system results 2.4 cows per hectare on the milking platform and an average stocking rate of 2.2 head/ha across the whole farm area.

Table 25: Watkins winter stock numbers

Stock Numbers - 30th June		**Base**
	Cows and R2 Heifers (VIC)	640
	R1 Heifers	160
	R1 Beef x Dairy	0
	Total dairy cattle	**800**
	Cows/ha milking platform	2.41
	Yearlings/ha runoff	1.68
	Total cattle/ha of dairy operation	**2.22**

The dairy herd is a Jersey x Friesian herd. The current genetic rating of the herd is a BW of 227/48 and a PW of 291/63.

Yearling heifers are mated to Jersey bulls on the 8th October for 14th July start of calving. Cow mating is based on a start of calving on the 21st July under an "all AI" regime. This involves:

- Prior identification of 120 "poorer" cows, that are not wanted for breeding replacement heifers, and mating them to 120 Wagyu straws from the 8th October;
- Three weeks of sexed semen at six straws per day (126 straws) from 15th October with balance of the cows mated to the "bull of the day";

- After five weeks of dairy semen mating Hereford straws are used for one week; and
- Then short-gestation Kiwi-cross straws are used until the end of mating which is usually immediately prior to Christmas.

The milking frequency is a mixed system involving:

- First calving heifers start and remain on a once-a-day milking (OAD) for the whole season;
- MA cows start on twice a day milking (TAD);
- In early December the MA cows go onto a "10 in 7" roster (based on TAD on Monday, Wednesday, and Friday and OAD on Tuesday, Thursday, Saturday, and Sunday); and
- As the summer progresses OAD milking will most likely be implemented for the MA cows – this last season they went onto OAD prior to Christmas due to a staff change.

Dry off dates vary with the autumn pasture growth rates and pasture covers but in general:

- Usually up to 50 cows per month are dried off in March and April; and
- The balance of the cows are dried off over May.

Seasonal milk production is represented in Table 26.

Table 26: Watkins pattern of milk production

	Month	kg MS	Distribution
	Jul	1,700	0.8%
	Aug	15,800	7.6%
	Sep	24,500	11.9%
	Oct	28,900	14.0%
	Nov	25,600	12.4%
	Dec	23,300	11.3%
	Jan	22,300	10.8%
	Feb	18,600	9.0%
	Mar	20,500	9.9%
	Apr	15,300	7.4%
	May	10,200	4.9%
	Jun	0	0%
	Total	**206,700**	**100%**
Milking Platform:			
	Area:	265	
	kg MS/ha:	780	
Per cow production:			
	Number:	640	
	kg MS/cow:	323	

Cropping and pasture renewal involves:

- Growing 10 ha of maize silage at the Aria runoff which then gets put into annual ryegrass – and this is repeated on the same paddocks.

- Growing 3 ha of maize silage on the milking unit under a maize silage-annual-maize silage-permanent pasture rotation which means about a six-year rotation length on the paddocks that are suitable for maize silage.
- Growing 7 ha of turnips sown late October/November for summer grazing – this is resown into permanent pasture. These paddocks get effluent applied as the starter fertiliser.

Supplementary feeding normally involves making grass silage on 15 ha of the Piopio runoff area and 35 ha on the milking platform. This is predominantly fed out in the milking paddocks during February to April. Approximately 4 ha of maize silage is bought in and added to the 13 ha grown on the farm. This is fed out on the feed pad in two main periods of the year:

- 130 tonnes dry matter in July to September; and
- The balance from late January to later in May when the cows are dried off.

Fertiliser and nitrogen are applied by a mix of plane, truck and own equipment. The nitrogen applications involve:

- 18 kg N/ha applied in August over the milking platform and Mairoa runoff areas in combination with pro-gib and thistle spray application;
- 30 kg N/ha to 35 kg N/ha in November/December when DAP is used as part of the main fertiliser application; and
- 37 kg N/ha in May when 80 kg/ha of urea is applied over the whole farming operation.

Phosphate, potassium, and sulphur nutrients are generally applied as:

- A mix that includes the late spring nitrogen and 32 kg/ha of phosphate, 35 kg/ha of potassium, and 24 kg/ha of sulphur; and
- 400 kg/ha of 30% Potassic Super on the runoff areas in November/December after any silage is made.

9.3 Net CO_2 and N_2O position and methane emissions

Under the modelling assumptions, and even after the biogenic methane emissions are deducted, this base scenario has significantly more carbon dioxide and nitrous oxide emissions (Table 27) on a carbon equivalent basis than what is being sequestered. The net emissions are 530.1 tonnes of carbon dioxide equivalent.

Table 27: Watkins base system emission and sequestration results

	Base Scenario
Total GHG emissions (CO_2-e tonnes/yr) - Scope 1 and Scope 2 only	2,777.9
less	
Methane (CO_2-e tonnes/yr)	2,203.0
Total long-lived gas emissions (CO_2-e tonnes/yr) - excluding biogenic n	**574.9**
Estimated Carbon sequestration occurring on farm (CO_2-e tonnes/yr)	**44.9**
Net carbon position (-ve number requires further reduction in emissions or increase in sequestration to achieve net carbon zero position (excluding biogenic methane) as per Zero Carbon Act.	**-530.1**

The different farm scenarios will need to consider both the net carbon position and the level of methane emissions. With 79% (Figure 15) of the Watkins' emissions being from methane the methane reduction result will be a key aspect to examine in the different farm scenarios.

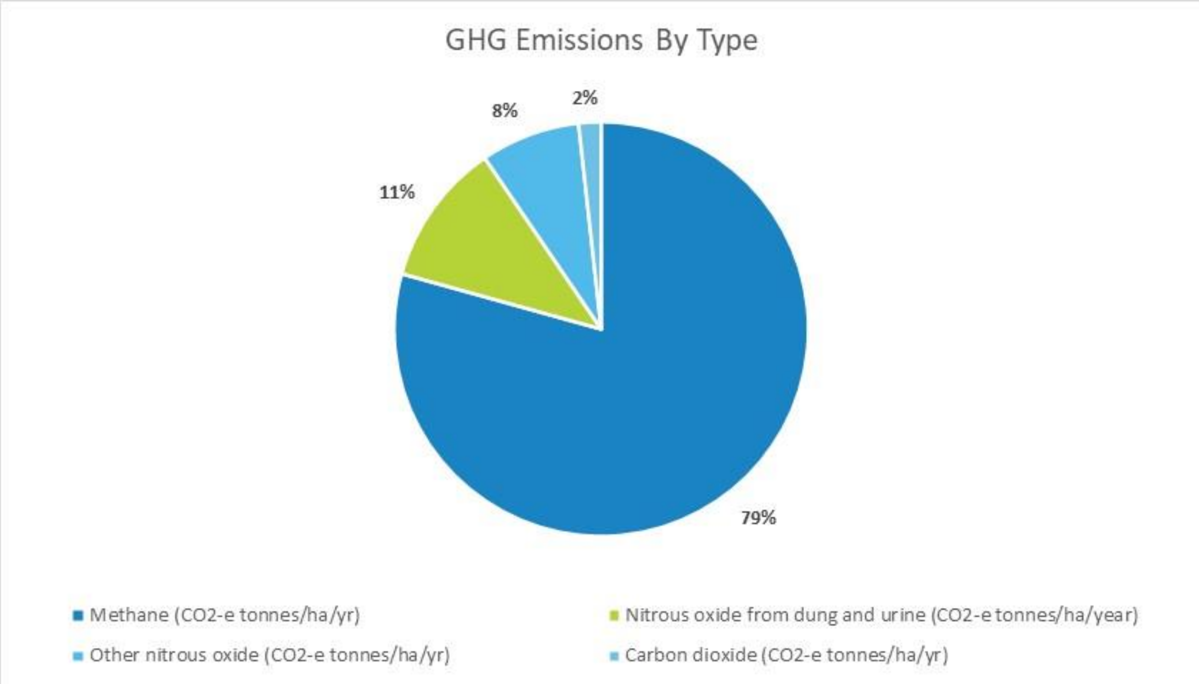

Figure 15: Watkins base scenario emissions by type

9.4 The different scenarios considered

The details of the new scenarios are described in comparison the Base Scenario and are mostly based on planting and stock policy changes that Phil has been considering.

Scenario 1:

- New planting 2.0 ha of natives in selected places on the milking platform;
- Keeping the stock numbers the same, as the extra area planted represents less than 1.0% of the milking platform – and it would likely involve poorer performing areas of the milking platform; however
- A small increase in nitrogen has been allowed for the 2 ha that has been removed from production – and milk production per cow is maintained.

Scenario 2:

- The same new natives planting as per Scenario 1;
- Further planting of two of the steepest paddocks on the milking platform involving 8.0 ha. Modelling has been based on half this area planted as pines and half as Douglas-fir trees;
- Keeping the stock numbers the same as although the total extra area planted represents 3.8% of the milking platform it does involve poorer growing areas of the milking platform;
- The small increase in nitrogen that was allowed for in Scenario 1 has been retained; and

- Another 68 tonnes of maize silage have been purchased – this is just over an extra 100 kg, or plus 22%, more per cow (and builds on the purchased maize silage component that is already part of the system) therefore milk production per cow is maintained.

Scenario 3:

- The same planting as per Scenario 2;
- A further 6 ha of planting is completed on the runoff area of the operation – which due to the land classes in the different runoff areas this planting has been modelled to occur on the adjacent Mairoa lease area;
- Stock numbers are reduced by 20 cows and 5 R1 heifers; and
- Nitrogen applications are reduced to the base scenario per hectare rate and maize silage use is reduced back to the original total tonnage use – which means an extra 3% maize silage per cow above the base scenario.

Scenario 4:

- No extra planting is completed;
- The milking platform is reduced by 20 ha of the steepest paddocks and cow numbers are reduced by 45 cows and R1 heifer numbers are reduced by 10. The cows and heifers are replaced by retaining the Wagyu X cattle that are normally sold as weaners, for another 12 months and are sold as R2 store cattle in December.
- With production per cow modelled to be maintained nitrogen and maize silage inputs could be lowered slightly as a result of the stock changes

The different block areas and stock numbers are shown in Table 28 and Table 29 respectively. Table 30 shows the different nitrogen and maize silage inputs for each scenario.

Table 28: Watkins scenarios - block areas

Farm Area	Base Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Milking platform	265.4	263.4	255.4	255.4	243.9
Runoff - dairy support	95.0	95.0	95.0	89.0	116.5
Other pasture	5.0	5.0	5.0	5.0	5.0
Total Pasture Area	**365.4**	**363.4**	**355.4**	**349.4**	**365.4**
Older bush	18.2	18.2	18.2	18.2	18.2
Recent retired areas	6.6	6.6	6.6	6.6	6.6
New retired areas	0.0	2.0	10.0	16.0	0.0
Riparian - fenced	17.0	17.0	17.0	17.0	17.0
Total Retired Area	**41.8**	**43.8**	**51.8**	**57.8**	**41.8**
Other	13.7	13.7	13.7	13.7	13.7
Total Property Area	**420.9**	**420.9**	**420.9**	**420.9**	**420.9**

Table 29: Watkins scenarios - stock numbers

Stock Numbers - 30th June	Base Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Cows and R2 heifers (VIC)	640	640	640	620	595
R1 heifers	160	160	160	155	150
R1 beef x dairy steers and heifers	0	0	0	0	45
Total dairy cattle	**800**	**800**	**800**	**775**	**790**
Cows/ha milking platform	2.41	2.43	2.51	2.43	2.44
Yearlings/ha runoff	1.68	1.68	1.68	1.74	1.67
Total cattle/ha of dairy operation	**2.22**	**2.23**	**2.28**	**2.25**	**2.19**

Table 30: Watkins scenarios - variable feed inputs

Variable Inputs	Base Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Nitrogen (for pasture)					
August nitrogen - tonnes N	5.506	6.296	6.152	5.218	2.754
Spring base fertiliser	7.854	7.793	7.546	7.546	7.192
Autumn nitrogen	13.248	14.104	13.809	12.659	9.192
Total Nitrogen Applied to Pasture	**26.608**	**28.193**	**27.507**	**25.423**	**19.138**
kg N/ha of dairy operation	73.8	78.7	78.5	73.8	53.1
Relative to Base Scenario	100%	106%	103%	96%	72%
Maize Silage (tDM)					
Grown	234	234	234	234	234
Purchased	72	72	140	72	0
Total Maize Silage	**306**	**306**	**374**	**306**	**234**
kg DM/cow wintered	478	478	584	494	393
Relative to Base Scenario	100%	100%	122%	100%	76%

9.5 Results

Stock performance and profitability:

For the scenarios considered, Table 31 shows, subject to the level of feed inputs, that milk production was maintained on either a total or per hectare basis. Meat production was subject to the number of cattle farmed.

Table 31: Watkins scenarios – farm system and production summary

Production	Base Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Milking area	265 ha	263 ha	255 ha	255 ha	244 ha
Runoff area	95.0 ha	95.0 ha	95.0 ha	89.0 ha	116.5 ha
Cows/milking ha	2.41	2.43	2.51	2.43	2.44
kg N/ha	74 kg	79 kg	79 kg	74 kg	53 kg
Maize silage/cow	478 kg	478 kg	584 kg	494 kg	393 kg
Milk production - kg MS	206,784	206,779	206,745	200,718	192,779
Milk production - kg MS/cow	323	323	323	324	324
Milk production - kg MS/milking platform ha	779	785	809	786	790
Meat production - kg meat	32,516	32,516	32,516	31,464	36,412

The income and expenditure shown in Table 32 relates to only the livestock operation – no income or expenditure has been included for the planted trees.

The farm operating surplus for the different scenarios was very close – Scenario 3 with lower stock numbers due to a 4% reduction in the pastoral area showed a 4% reduction in the farm operating surplus.

Table 32: Watkins scenario profitability and production summary

Production and Profitability	Base Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Production					
Milk	206,784	206,779	206,745	200,718	192,779
Meat	32,516	32,516	32,516	31,464	36,412
Total milk and meat	**239,300**	**239,295**	**239,261**	**232,182**	**229,191**
kg MS/ha of milking platform	779	785	809	786	790
Relative total kg MS	100%	100%	100%	97%	93%
Relative kg MS/ha	100%	101%	104%	101%	101%
kg MS + meat/ha off pastoral area	655	658	673	665	627
Relative total kg MS + kg meat	100%	100%	100%	97%	96%
Relative kg MS + kg meat/ha	100%	101%	103%	101%	96%
Profitability					
Total Revenue - milk and livestock	$1,736,610	$1,736,566	$1,736,297	$1,686,770	$1,659,332
Total farm expenses	-$955,675	-$958,740	-$977,043	-$939,654	-$888,606
Farm Operating Surplus (EBITDr)	**$780,935**	**$777,826**	**$759,254**	**$747,116**	**$770,726**
Relative farm operating surplus	100%	100%	97%	96%	99%
Farm operating surplus $/ha	$2,167	$2,170	$2,167	$2,169	$2,139
Relative to $/ha	100%	100%	100%	100%	99%
$/kg MS	$3.78	$3.76	$3.67	$3.72	$4.00
Relative $/kg MS	100%	100%	97%	99%	106%

Sequestration:

Unsurprisingly as the area planted increases the amount of sequestration increased (Table 33).

Table 33: Watkins scenario sequestration

Vegetation Type	Forest Type	Age	Sequestration (tonnes CO_2/ha/yr)	Base Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Older bush	Indigenous forest (pre-1990)	>50	0.0	18.2	18.2	18.2	18.2	18.2
Existing retired areas	Indigenous forest	ave. 16	6.8	6.6	6.6	6.6	6.6	6.6
New retired areas	Indigenous forest	ave. 16	6.8	0.0	2.0	2.0	2.0	0.0
New - pines	Pinus radiata (post 1989)	ave. 16	22.1	0.0	0.0	4.0	7.0	0.0
New - Douglas-fir	Douglas-fir	ave. 16	12.1	0.0	0.0	4.0	7.0	0.0
Riparian - not planted	Indigenous forest	0	0.0	17.0	17.0	17.0	17.0	17.0
Total Area in Trees				**41.8**	**43.8**	**51.8**	**57.8**	**41.8**
Average annual carbon sequestration - tonnes carbon per year				**44.9**	**58.5**	**195.3**	**297.9**	**44.9**

Net-carbon position:

As seen in Table 34 and Figure 16, Scenario 4, although with only the second lowest total cattle numbers, had the lowest total carbon dioxide and nitrous oxide emissions. This reflects the lower fertiliser N inputs, lower feed inputs, and consequently the lower volume of feed used by this system with the lowest milking cow numbers.

Scenario 3, with the most extra area planted, had the highest level of sequestration occurring on the farm.

The net result, of considering both lower emissions and higher sequestration, means that Scenario 3 has the best net carbon result – but for this pilot farm scenario the emissions are still greater than sequestration.

One interesting aspect of Scenario 3 is that part of the planting, and hence the sequestration, has been described as occurring on lease land. For this exercise the operation has been considered "one activity". The reality is that in most situations **the lessee will not be able to claim sequestration on lease land** unless the landowner has given permission for that to occur – and that might be unlikely unless both parties agree other terms of the lease, including the lease fee, make that situation agreeable to both parties.

Table 34: Watkins net carbon emission results

	Base Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total GHG emissions (CO_2-e tonnes/yr) - Scope 1 and Scope 2 only	2,777.9	2,783.8	2,771.2	2,695.4	2,620.5
less					
Methane (CO_2-e tonnes/yr)	2,203.0	2,202.1	2,196.7	2,129.3	2,086.0
Total long-lived gas emissions (CO_2-e tonnes/yr) - excluding biogenic n	**574.9**	**581.7**	**574.5**	**566.1**	**534.5**
Estimated Carbon sequestration occurring on farm (CO_2-e tonnes/yr)	**44.9**	**58.5**	**195.3**	**297.9**	**44.9**
Net carbon position (-ve number requires further reduction in emissions or increase in sequestration to achieve net carbon zero position (excluding biogenic methane) as per Zero Carbon Act.	**-530.1**	**-523.2**	**-379.2**	**-268.2**	**-489.7**

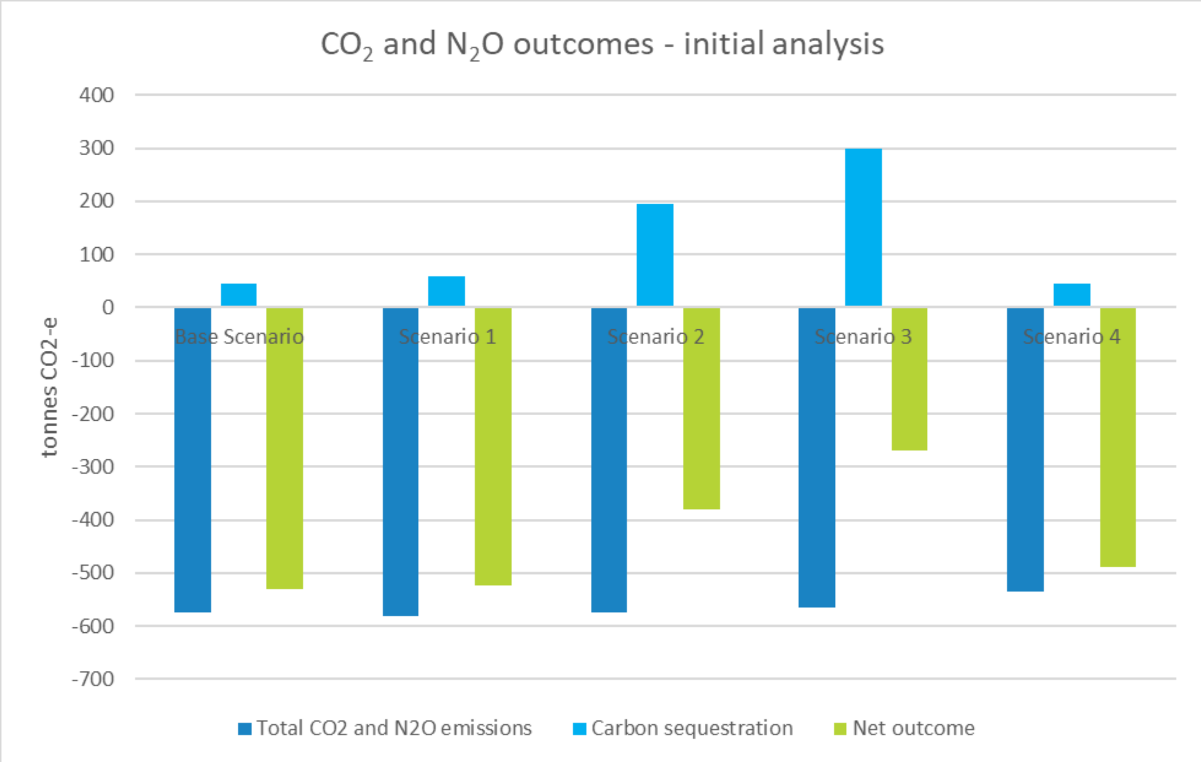

Figure 16: Watkins net carbon outcome excluding biogenic methane

Methane reduction:

The level of methane reduction has been considered in comparison to the three reduction targets noted in the Zero Carbon Act: -10%, and the range of -24% to -47%.

The key conclusions drawn from the results shown in Figure 17 are:

- The planned stock number and stock policy changes considered have not achieved the methane emissions reduction target of 10%;

- The stock number and stock policy changes also need some of the future genetics benefits to working at the 5% reduction level and the future vaccine/inhibitor technology to be working at the 10% reduction level to achieve the 10% methane reduction target – but the 24% reduction target has not been achieved; and
- When the future genetics is working at 15% reduction and the future vaccine/inhibitor technology is working at 30% reduction over the considered stock number and stock policy changes the 47% reduction is not achieved – but the combined affects have nearly achieved a 40% methane reduction.

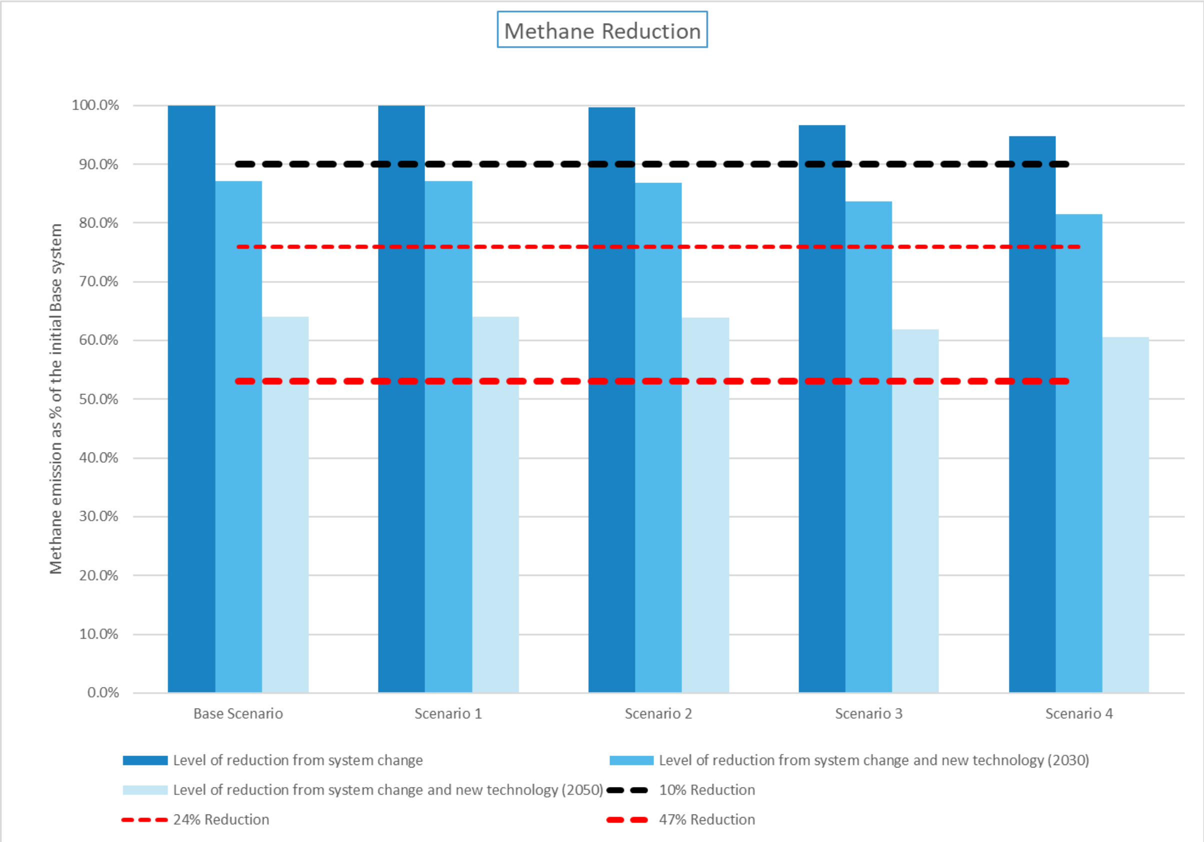

Figure 17: Watkins total methane outcomes

Emissions intensity:

As per the information back in Table 31 and Table 32 (on pages 59) the level of milk solids and meat production has changed across the different scenarios – a bit of up and down. In a dairy operation milk is the main unit of production – but there is still a significant amount of meat produced. The emissions intensity has therefore been considered across both milk production by itself and with milk and meat production combined.

Therefore, the total emissions for each scenario have different volumes of production to be spread across so when the level of emissions per kg of milk solids or, milk solids and meat is considered there is a different emissions reduction profile achieved.

Key points from the emissions intensity against milk production only results, shown in Table 35 and Figure 18:

- Total GHG emissions per kg MS were very similar across the different scenarios, but the intensity was lowest (best) in Scenario 2 where milk production was maintained from a slightly lower pastoral area, and Scenario 4 was highest (worst) because a lower proportion of stock (and hence feed used) was associated with milk production;
- Carbon dioxide and nitrous oxide emissions per kg MS were also very similar; and
- Methane intensity went up for Scenario 4 as although less feed was used this was lowest milk producing option.

Key points from the emissions intensity against milk and meat production results, shown in Table 36 and Figure 19 are:

- Scenario 4 had the lowest (best) intensity result where lower total emissions (from less feed inputs required) and the increased meat production made up for the lower level of milk production;

Overall for this operation and the scenarios considered the changes in emission intensity were very small.

Table 35: Watkins emissions intensity from milk production

Intensity calculations - milk only	Base Scenario		Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Total **GHG emissions** (Scope 1 and Scope 2) per kg of milk solids (kg CO_2-e/kg MS)	100%	13.43	100.2%	13.46	99.8%	13.40	100.0%	13.43	101.2%	13.59
Total **long-lived gas** (Scope 1 and Scope 2) emissions (excluding biogenic methane) per kg of milk solids produced (kg CO_2-e/kg MS)	100%	2.78	101.2%	2.81	99.9%	2.78	101.4%	2.82	99.7%	2.77
Total **Methane** (Scope 1 and Scope 2) emissions per kg of milk solids produced (kg CH_4/kg MS)	100%	0.43	100.0%	0.43	99.7%	0.43	99.6%	0.42	101.6%	0.43

Table 36: Watkins emissions intensity from milk and meat production

Intensity calculations - meat and milk	Base Scenario		Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Total **GHG emissions** (Scope 1 and Scope 2) per kg of milk solids + meat (kg CO_2-e/kg MS+meat)	100%	11.61	100.2%	11.63	99.8%	11.58	100.0%	11.61	98.5%	11.43
Total **long-lived gas** (Scope 1 and Scope 2) emissions (excluding biogenic methane) per kg of milk solids + meat produced (kg CO_2-e/kg MS+meat)	100%	2.40	101.2%	2.43	99.9%	2.40	101.5%	2.44	97.1%	2.33
Total **Methane** (Scope 1 and Scope 2) emissions per kg of milk solids and meat produced (kg CH_4/kg MS+meat)	100%	0.37	100.0%	0.37	99.7%	0.37	99.6%	0.37	98.9%	0.36

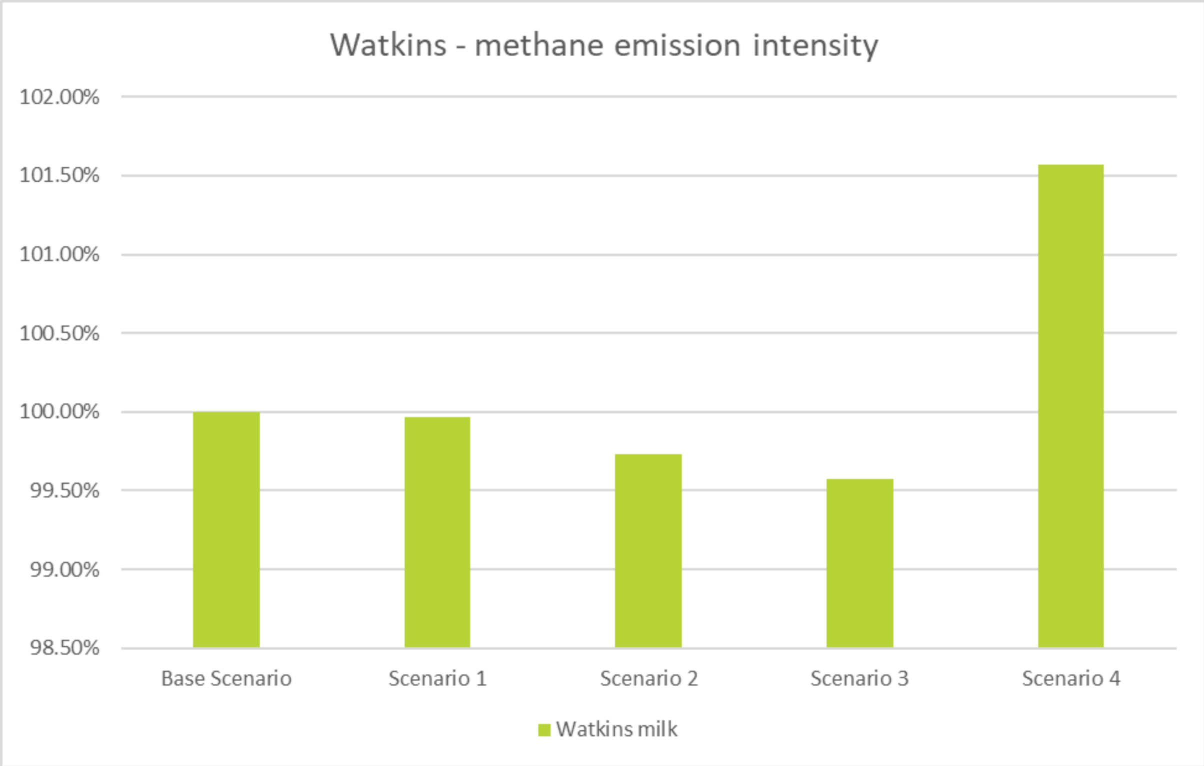

Figure 18: Watkins comparative methane milk production intensity across the scenarios

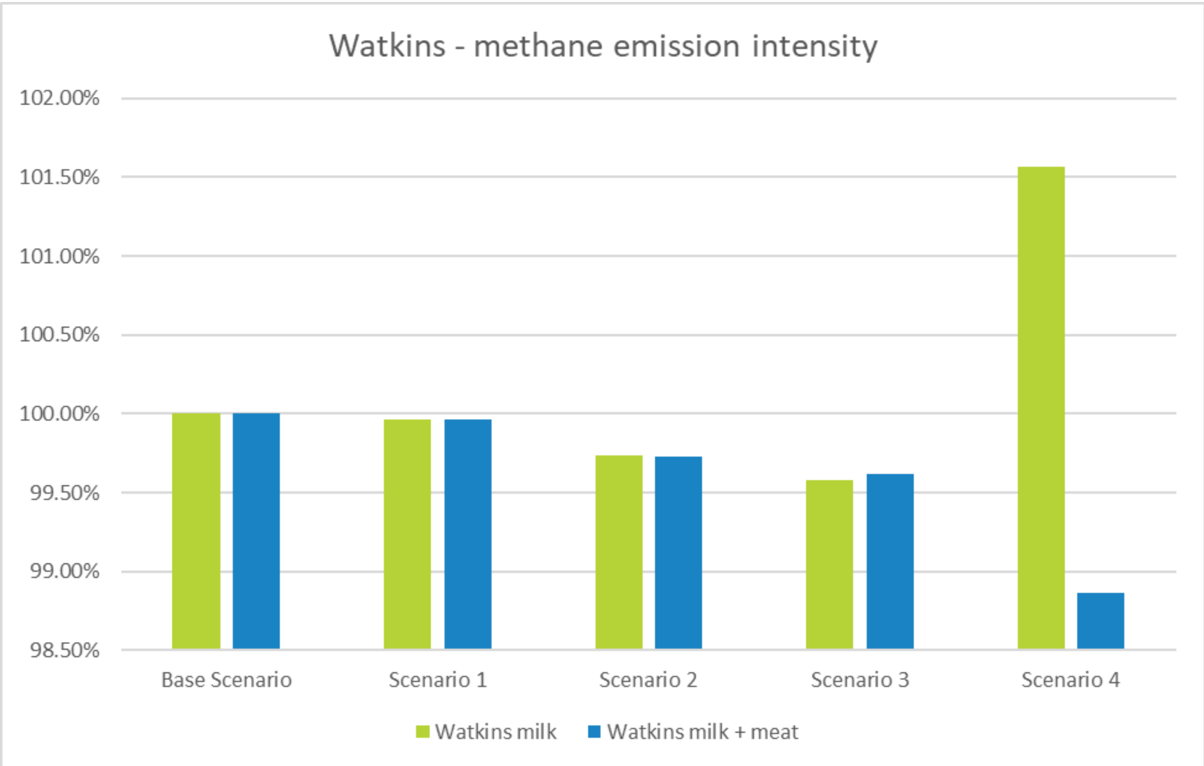

Figure 19: Watkins comparative methane milk and meat production intensity across the scenarios

9.6 Conclusion

Taking the approach of the Zero Carbon Act, of excluding biogenic methane, the four scenarios modelled did not include a system where a carbon neutral position was identified.

However, under the assumptions used there were 17 ha of riparian area that was counted as not planted and not contributing to any sequestration. Is this real, and/or is this area an opportunity?

Figure 20 shows in 2050, when all the trees will be older, and with 80% of the riparian area in natives and sequestering carbon then Scenario 3 (with the other new planting area of 16 ha and 20 less cows) would be in a carbon positive position (excluding biogenic methane).

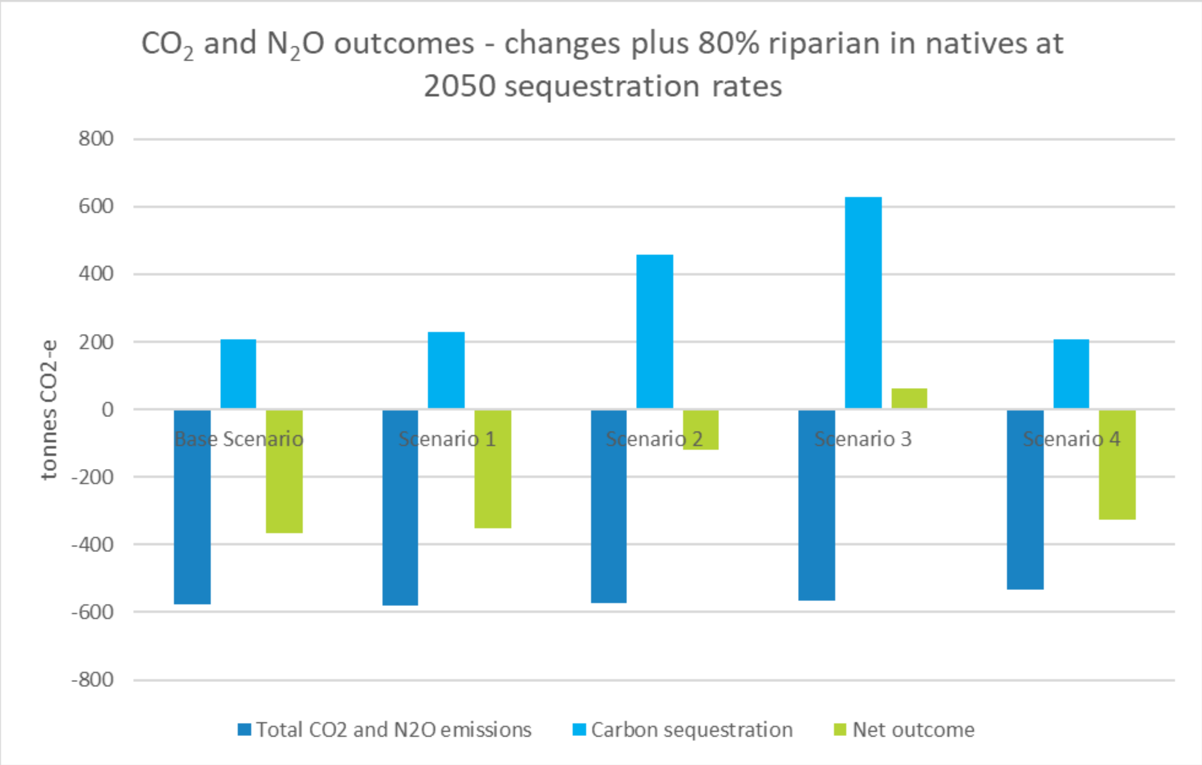

Figure 20: Watkins 2050 net carbon position with 80% of riparian area in natives

Therefore, **a planned planting programme can get the operation into a carbon neutral position** as per the Zero Carbon Act – it will likely require approximately 16 ha of faster growing trees if most of the riparian area, that is already fenced off, can be planted (or is) in vegetation that sequesters carbon as per indigenous forest plantings.

However, **the reduced stock numbers and stock policy changes** alongside the planting options that were modelled **were not enough to achieve the methane emissions reduction target of 10%.** Being able to use the riparian area for sequestration does not change this outcome.

At the level of system change considered the operating surplus achieved did not change significantly – other factors are likely to have as big, or bigger, influence on profitability.

Achieving **the higher 24% to 47% methane reduction is going to require much greater system change.** Although this dairy operation is not a high user of imported feed other examples of "greater system change" that could have been analysed include reductions of:

- The amount of imported feed used - which is the purchased maize silage and nitrogen used;
- The maize silage grown on the Aria lease block; and
- Moving the replacement heifer rate to nearer 20% (from the current 25%) – provided the feed saved does not go into milking cows.

Irrespective of those types of options achieving the 24% to 47% methane reduction is likely to require the success of new technologies such as lower methane producing genetics (that still achieve the same levels of per head production) and animal treatments or feed additives that work in a way that are acceptable to consumers and at a cost that does not lower profitability.

9.7 What can the Watkins' do now?

Although Government compliance processes may not require being carbon neutral and the achievement of the methane reduction targets at the individual farm level, increasingly there are market related requests for carbon and methane emission reduction plans at the farm level – and the dairy industry is currently at the forefront of this messaging. **Irrespective of future Government compliance Phil and Jo will need to consider this aspect of their farm operation.**

A key aspect to remember is that the on-farm net carbon position will change from year to year – it will depend on their farm system (actual stock numbers, stock transaction dates, cropping and feed inputs) for that year, and the type and age of trees on the property. All these factors will lead to a different net emissions result each year.

Phil and Jo also can review what the 17 ha of retired riparian area is contributing to the carbon position of the farm. It is obviously contributing to improving water quality – is there the opportunity for it to also contribute more to carbon sequestration (and biodiversity) or has that investment already been completed?

Preparing their farm business for this future should involve creating reliable and easy to access information including:

- Mapping and describing the areas of non-pasture vegetation on the farm;
- Learning how this vegetation will be classed for sequestration and who will consider the different types of vegetation as eligible for sequestration;
- What will be the current and future the sequestration rates be for the different vegetation blocks;
- When analysing different levels of feed use within the farm system for contributing to profit also analyse the different outcomes for the net carbon position so both aspects can be considered together.
- Recording the required information to calculate meat production – they can make sure weights for all their sale and purchase transactions are entered into their existing financial management system - and don't forget in and out weights for any grazing stock. (If you do not use a computerised financial management package just keep an accurate manual list of all your stock transactions). Milk production will be easy!
- A similar system is required for feed inputs – including nitrogen use. This is likely to already be a farm QA requirement.

Phil and Jo should also start to learn about what tools and models are out there to calculate their emissions every year. (You may already be using a tool - e.g. Farmax, OverseerFM). They may not have to choose one yet but some background reading in the meantime may help later.

And, even if it just generates some interesting discussion, when they have their next conversation with their processor or key supplier they could ask them if they will be looking for an emissions reduction plan from them in the future and/or ask do they offer some pricing premium for having one now - and if the answer is yes get some understanding of what detail is required for the plan and what benefits they will pass on.

On-farm emissions, especially methane, is also likely to be an ongoing regulatory topic of discussion for the Government of the day – with the current difficulties around reducing methane emissions, listen to these discussions, and contribute your thoughts where you can.

10 Discussion

In New Zealand, much of the agriculture on-farm discussion on the wider topic of reducing GHG emissions, including methane reduction, has been in response to current and proposed Government regulations. Since the 2023 general election there has been at least a perception that immediate pressure from the Government on farmers to reduce their total emissions has and will ease.

However, over this time there has been increasing evidence that this pressure is and will be replaced by the requirements of some of our key agriculture product markets and customers. **The need for GHG emission, including methane, management and reduction plans has not gone away and is real.**

A key driver of the initiation of this project was to help King Country farmers understand how they might become, or already be, "carbon neutral". Through completing this project there are three key determinants to achieving this outcome that have been identified and highlighted:

- What is the specification of "carbon neutral" being targeted;
- What area do farmers have in young growing woody vegetation and what percentage of the farm does it involve; and
- How fast is the vegetation sequestering carbon – which is determined by the type of vegetation and its age.

As demonstrated in the analysis of the three pilot farms approximately 90% of the farm GHG emissions in NZ agriculture farming systems are from methane and this methane is directly related to the number of animals and the amount of feed consumed by the farm operation. Fundamentally it is hard to reduce methane emissions without reducing either of these two things – and if you are not importing feed onto the farm this then effectively means growing less pasture and grazing less stock. This is a real challenge.

Carbon neutrality

To be carbon neutral, GHG emissions need to be countered by the removal of carbon from the atmosphere [where carbon sequestration through growing "trees" is currently the main method of removal] on a carbon dioxide equivalence basis. So, the lower the emissions the less sequestration is required. And conversely increasing sequestration helps move towards the carbon neutral position.

So, what counts as GHG emissions when trying to work out whether the farming system is carbon neutral? How far away are the goal posts? Which in most of our farm situations means the real question is "are we counting methane emissions"?

The reality is the rest of world is counting these methane emissions – and this is seen in the conversations that our key customers are having with our key processors and industry bodies.

This project has considered the on-farm GHG emissions in two parts:

- The longer-lived gases of carbon dioxide and nitrous oxide; and
- The shorter-lived gas of methane.

This project examines the impact of the farm system changes our pilot farmers are considering in comparison to the Climate Change Response (Zero Carbon) Amendment Act 2019 which has set three important targets:

- Net emissions of greenhouse gases in a calendar year, other than biogenic methane, are zero by the calendar year beginning on 1 January 2050 and for each subsequent calendar year;
- Emissions of biogenic methane in a calendar year:
    i. Are 10% less than 2017 emissions by the calendar year beginning on 1 January 2023; and
    ii. Are 24% to 47% less than 2017 emissions by the calendar year beginning on 1 January 2050 and for each subsequent calendar year.

What did we find and what does that mean?

Being carbon neutral (as defined above), while excluding methane, was a realistic outcome for our farmers – and should be for many others.

Three key determinants are how much area of young growing woody vegetation there is and how much is it sequestering in that year (based on what type of vegetation and what age is it), and what percentage of the farm does it represent.

The Turners had 15 ha of young trees and 287 ha (or 5% of this area) of pasture and their annual rate of sequestration was greater than their annual emissions. The Scott's were looking to establish 19 ha of young trees with 1,475ha of pasture (1.3% of the previous pastoral area) and their annual emissions were still going to be greater than their annual sequestration.

A hot topic for tree planting is pines versus natives. What should or should not be planted, what earns money and what does not, and the cost of establishment. The key points are:

- Pines, and other fast growing exotic trees, have faster rates of sequestration for probably at least the first 50 years of their life;
- There is the perception that some of these tree types, as a plantation, will slow down their sequestration rate because they will "fall over" as they get older;
- Indigenous forest type trees may keep sequestering carbon for longer;
- There is a train of thought that some native species with some silviculture management will sequester carbon at considerably faster rates than the MPI Carbon Look-up Tables currently provide for; and
- What timeframe are you trying to be "carbon neutral" by?

If you are attempting to be carbon neutral as soon as possible and extra planting is required to achieve this then it will be hard to go past planting exotic type trees – they are cheaper and easier to establish, and their rates of sequestration are high. Pine trees are the "exemplar" of these criteria.

But if your priorities are different and involve taking a longer-term approach, say looking at a 2050-time horizon, then based on the results of the pilot farm scenarios establishing an indigenous forest can significantly contribute to a carbon neutral position. There will be increased establishment cost considerations.

It does highlight that the saying of "the right tree in the right place" can be a valid consideration.

The situation for achieving the methane reduction targets was completely different for our farmers. The farm system changes explored and any reduction in livestock numbers from the level of extra planting that achieved a carbon neutral position could easily not achieve the 10% methane reduction target. This project was not intended to evaluate the GHG reduction efficacy of an exhaustive selection of mitigations on the case study properties and it is acknowledged that other system changes not yet being considered by the farmers could contribute to further emissions reductions, although these would all have ultimately resulted in reduced DM intake, lower overall livestock numbers and likely [further] reduced profitability.

Essentially, unless there is a large decrease in stock numbers involved in the farm system change then achieving the 24% to 47% reduction targets will rely on new technologies that reduce the amount of methane emitted per unit of feed consumed. The role of new genetics will help – but by itself the level of reduction is not enough. Feed additives and/or animal treatments are likely to be required – and if the farming operation does not feed supplementary feed everyday then an animal treatment would seem to be required.

Significant investment is being made in this area now. However, an unanswered question that was raised at the farmer field days for this project – "will our discerning customer (who does not like meat and milk from animals that have had antibiotic or growth hormone treatments) really be keen to buy at a premium price these products from animals that have had a methane reduction vaccine?"

The inference though is if these new technologies are not available to use then methane reduction then land-use change by the agriculture sector will be required – with options being activities like:

- Horticulture and vegetable cropping;
- Arable cropping;
- Timber forestry;
- Non-timber forestry and eco-tourism;
- Urban development; and
- General retirement of land.

Other considerations

Reducing agriculture GHG emissions is unlikely to occur in isolation of other regulatory considerations. For example, the desire (and pressure) to improve water quality will continue. On-farm management practices will have a role to play but an increasing body of research indicates that land use change away from [intensive] pastoral agriculture will also be required to achieve current water quality standards.

In this regard, it is important that when farmers are considering or evaluating the impact (particularly profit impacts) of system changes or land use change that are primarily intended to improve their GHG emissions footprint, they also evaluate the impact of these changes on contaminant loss to water and contribution to biodiversity – or vice versa.

Most farmers in the King Country are not yet exposed to significant restrictions on nutrient or sediment losses to water in a regulatory sense, but these could yet occur. Many of the system changes that will reduce N loss to water will also have a co-benefit of reducing a farm's emissions profile, particularly actions that reduce N surplus (with a commensurate reduction in nitrous oxide losses from urine patches) and the retirement of highly erodible land (that may result in reduced livestock numbers and a reduction in methane emissions, as well as increased carbon dioxide sequestration).

The establishment of indigenous forests to sequester carbon is also likely to have a biodiversity benefit. The cost of native forest establishment is, of course, significantly higher than for exotic forestry, even when utilising emerging techniques like the Tīmata method[1]. At this stage, there is no mechanism to monetize biodiversity value, such as a market for biodiversity credits, although the central government had been exploring the potential for such a framework. Were such a concept to be successfully implemented, then the establishment of indigenous afforestation might become less financially challenging for landowners.

[1] https://ourlandandwater.nz/outputs/the-timata-method-a-low-cost-way-to-retire-farmland-into-native-forest/

11 Conclusion

For the three pilot King Country farms in this study, all of them had current plans for farm system and land use change that would increase carbon dioxide sequestration, take them closer to or beyond "carbon neutrality" (net zero long lived gases) and reduce methane emissions. Such changes would all make a positive contribution to the achievement of the overall domestic and sectoral emissions reduction targets set by the so called Zero Carbon Act.

However, achievement of the 2050 methane reduction targets without the need for wholesale change away from pastoral livestock production seems likely to require both the adoption of low methane genetics and methane-reducing animal interventions (such as feed additives, boluses or a vaccine). Indeed, these were still not sufficient to achieve the potential upper limits of the agriculture sector's statutory methane reduction targets.

Recognising they are from only three farms; the results of the pilot case studies are consistent with the prevailing understanding regarding pastoral farming operations' capacities to lower their greenhouse gas footprint. That is, that farmland provides opportunities to establish forestry to assist in achieving net zero long-lived gases and substantially reducing methane, in the absence of effective technology requires a significant reduction in livestock numbers which essentially means land use change.

While the domestic regulatory direction is a little uncertain, despite the prevailing existence of the Zero Carbon Act and commitments to bipartisanship in this regard, market expectations for farmer change have become more prevalent. As a result, it seems inevitable that farmers will need to understand, account for and potentially reduce their GHG emissions profiles, including biogenic methane, to some extent in the short to medium term.

While a "perfect" solution seems unlikely to emerge, there are several things that farmers can and should do to prepare for and potentially start to implement to meet this new challenge. We would recommend that farmers:

- Map and describe the areas of non-pasture vegetation on their farms.
- Understand the sequestration potential of existing and/or proposed forestry areas.
- Improve record keeping to assist with the reporting of emissions and emissions intensity.
- Evaluate the profitability and efficacy of system inputs (supplementary feed, N fertiliser) that increase system dry matter and ultimately biogenic methane.
- Investigate the potential to utilize low methane genetics in their sheep and cattle breeding programmes.
- Consider emissions impacts/co-benefits when considering how other environmental challenges (like water quality and biodiversity) are addressed.
- Keep learning about, discussing and engaging with this topic. It is coming to a farm near you!

12 Acknowledgments

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ii. **Project sponsors:**

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- Greenlea Premiere Meats;
- Silver Fern Farms;
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- King Country Rivercare.

iii. **Field day sponsors:**

- Fonterra;
- Greenlea Premiere Meats; and
- Silver Fern Farms.

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- Biological Emissions Reference Group;
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- Farm Ltd and the team behind Farmax Red Meat and Farmax Dairy.

v. **King Country Rivercare:**

- Coordinator Lana McCormick for organising successful field-days at each of the pilot farms; and
- KCRC member farmers for supporting the field-days.

vi. **Local farmers:**

- For supporting the field-days and reading all or part of this report!
- And for the passion they show and care they take about the environment in and "around" their farm property

13 Appendices

13.1 Modelling protocols and assumptions

OverseerFM (Stage 1)

The pastoral area in each operation has been determined by the block mapping process in OverseerFM. The total area was obtained through land title information – which is mostly sourced from rates invoices and/or web-based maps from the relevant local councils.

Farmers generally have an effective (pastoral) area that they use but for the project the OverseerFM block mapping process was used to determine the pastoral area on the following basis:

i. Key non-effective areas as informed by the farmer and easily seen on the publicly available online aerial mapping tools were blocked; and

ii. The pastoral area was then approximately divided into flat/easy country and hill country.

These block areas were used in both OverseerFM and Farmax for the modelling of the farmer's base system. It was determined that consistent areas across both models was more important than having every area of bush versus pasture 100% correct.

Farmax

The block areas were entered in Farmax as determined by the OverseerFM process described in section. The hill country blocks were set up to have 80% of the pasture production of the flats/rolling blocks.

The following information was entered based on the information provided by the farmer:

- Stock numbers;
- Timing of events;
- Production levels – reproduction and sale weights;
- Cropping programme;
- Supplementary feed programme; and
- Nitrogen use.

The annual stock numbers, stock liveweight, and supplementary feed reconciliations are checked to ensure a status quo situation.

Once the farm system inputs are completed the "Modify" function in the model is used" adjust[2] the pasture growth rates for the farm system the farmer is operating.

[2] This function automatically adjusts default pasture growth rates to match the livestock demand and in doing so makes the farm *just* feasible.

The resulting pasture growth rates, minimum and maximum pasture covers that are calculated will then become limiting factors to consider when the other farm system scenarios are modelled – i.e., the new scenarios must fit within these parameters and be biophysically realistic (so-called Farmax "feasible") to be considered a comparable option to be reported against.

Although this project is mainly concerned with GHG emissions, income and expenditure is an important consideration for most farming businesses. With the emphasis on the GHG emission position this project was not completed to critique the income, farm expenditure, or profitability of the pilot farmer. However, Farmax income and farm operating expenditure calculations were used to provide a comparative result for the scenarios being tested by the respective pilot farms.

The following approach within Farmax was used to establish comparative income and operating expenditure for the analysis:

- Sheep and beef income was determined by using the Farmax "Auto-NI Prices May 2024".
- The "Beef + Lamb NZ; NI Hill Country" option, but with the "as incurred" function used for feed conservation, nitrogen use, and cropping, was used to calculate Total Farm Working Expenses.
- Milk income was generated using the "Auto Fonterra" information.
- Dairy cattle income was calculated using the latest available prices – which was the "Auto-NI Prices Jan 2024".
- Standardised dairy operating expenses were calculated using predominantly using a combination of Farmax database information, on-farm activities, and dairy consultancy feedback *(pers. comm. Rob Brazendale, Senior Consultant Perrin Ag)*.

For this report the outputs used from the Farmax modelling will be:

- Stock numbers - for the new scenarios; and
- Comparative financial results of the livestock system at an "Operating Surplus" level – based on the difference between the Farmax calculated "Total Revenue" and "Total Farm Working Expenses".

OverseerFM (stage 2)

The second stage of OverseerFM usage involves entering the farm system details (e.g. livestock numbers, area revisions, changes to feed and/or crop inputs) as represented in Farmax for the status quo base system and the different scenarios being tested.

Sale liveweights or carcass weights have been entered in OverseerFM so there is a match with the Farmax assumptions. It is acknowledged this is not the protocol process used by some regional councils (e.g., Waikato Region Council). Other stock weight information (e.g. mature body weight) has been left as per the default OverseerFM process. This has been completed across all scenarios for each farmer – and it is the relativity of the scenarios for each farmer that is important.

This OverseerFM modelling has been used as the source of GHG emissions reported for each farmer scenario. OverseerFM reports all emissions on a carbon dioxide equivalent basis, but the project is looking at methane as a separate discussion point.

For the methane discussions the methane emissions have been converted from a carbon dioxide equivalent figure to a weight of methane using a (multiplication) conversion factor of 25 (i.e. a unit of carbon dioxide emitted equals 1/25th of unit of methane emitted on a GWP100 basis).

13.2 On-farm sequestration

On-farm sequestration of carbon occurs as woody vegetation on the farm grows. Any death, decay, or harvesting will need to be considered as these occurrences are a reduction in carbon being sequestered.

The pilot farm on-farm sequestration calculations will be an estimated representation of what is occurring on the farm – it is not about what is eligible, or not, under the New Zealand Emissions Trading Scheme (New Zealand ETS). Nor is it about what might be acceptable or not under the now defunct HWEN proposal or market placed schemes.

When in a compliance situation (and this project is not that) farmers will need to undertake whatever sequestration calculation processes are required to meet New Zealand ETS, industry, or market scheme criteria. This will likely include more accurate area measurement and age assessment of the possibly eligible vegetation than this project allows for.

The project’s sequestration calculations have been completed using the information from the farmers about the type of vegetation they have on their farm, the block areas measured from the OverseerFM block mapping process, and the Ministry for Primary Industries (MPI) “Carbon Look-up Tables” guide to determine the applicable rate of carbon sequestration occurring per year.

These calculations have been completed outside the Farmax and Overseer models for flexibility and transparency.

Even if the area of woody vegetation does not change from year to year it needs to be remembered that the level of sequestration occurring on farm may change every year due to the differing annual sequestration rate subject to the age of the vegetation.

A key factor in the total sequestration occurring on our pilot farms is the age of the indigenous forest and whether it is sequestering carbon, or due to its age is it in a stable state due to the decay and growth within the forest being equal.

The MPI Carbon Look-up Tables shows carbon sequestration for indigenous forests for 50 years – and at that stage it is reported as sequestering carbon at one tonne of CO2 per hectare per year. The Tane’s Tree Trust carbon calculator (www.toolkit.tanestrees.org.nz/carbon-calculator/) appears to go for 80 years – but this is for areas of new native planting rather than already established native bush. Silver Fern Farms do not consider mature areas of bush in their carbon zero beef programme, nor are these forests eligible for sequestration under the NZ ETS. So, **this project has assumed stands of older bush on the farm are not sequestering carbon**.

How the sequestration from the older indigenous forest on the farms is allowed to be considered and the age of any plantation trees will be significant in determining the size of the carbon positive or negative position of the farm operation.

This project also looks at a particular "year in time" for comparing sequestration to emissions. The reality is the situation will change from year to year due to both emissions and sequestration changing from year to year. To provide comparative sequestration rates for different scenario's the following approach has been taken:

- No sequestration has been assumed for areas of older bush;
- Plantations have been considered as one of the five different forest types as outlined in the MPI Carbon Look-up Tables:
  - Indigenous;
  - *Pinus radiata*;
  - Douglas-fir;
  - Exotic softwood; and
  - Exotic hardwood.
- Because new areas of pine trees planted for timber harvesting have 16 years of eligible sequestered carbon under the current ETS rules, for new planted areas in the farm scenarios the calculations completed in this report have been based on the average annual sequestration rate for the first 16 years of the plantation's life; and
- Because the Zero-Carbon Act date for being carbon neutral is 2050 some calculations have been completed for any extra planted areas being planted in natives and the sequestration calculated with the native trees being 25 years old (which will be the approximate age of the trees if they are planted at the time this project was completed).

13.3 Assumptions for methane reduction [mitigation] options

Outside the Farmax and OverseerFM modelling processes consideration will be given to options that will specifically target reduced methane emissions. The following points cover in broad terms what is available as per the Biological Emissions Reference Group (BERG) 2018 report.

i. Methane inhibitors and vaccines:

- Though operating through different pathways both these options aim to reduce the growth of methanogens in the rumen and reduce the production of methane while the rumen digestion process is underway.
- It is therefore considered likely that only one of these options will be used on farm at any one time.
- For paddock based grazing operations the success of these options will likely require a slow-release (i.e., bolus) or long-term efficacy (i.e., vaccine) delivery mechanism.
- Other challenges for viable use will be cost, required frequency of treatment, and how this option is recognised (by the regulator or market) as reducing methane emissions.
- The report completed for the BERG considered product development in this area would see methane emission reduction of at least 10% by 2030 and 30% by 2050 from the use of methane inhibitors (where the high end of results was 30% by 2030 and 50% by 2050. This was for the treated animals only.

- Vaccines would seem to offer the opportunity for a more acceptable treatment frequency for pastoral based livestock systems but BERG considered the current results from vaccines making their use and impact less certain.
- For this project the use of the inhibitors or vaccines (i.e., not both) is considered with the lower end emission reduction results used – 10% reduction by 2030 and 30% reduction by 2050.

ii. Breeding for low emission animals:

- Several ram breeders have been undertaking on-farm measurements[3] of methane emissions from selected sheep (mainly ram hoggets in ram breeding flocks) to identify lower methane emitting sheep and genetics within their flock that are still achieving their normal production targets.
- Initial results are indicating there is a 10% difference in methane production between the low and high emitting sheep – so selecting the low-emitting sheep would ultimately result in a 5% reduction below the current average.
- The dairy genetics industry is now engaged in this process. The general dairy industry will have the advantage of a more centralised genetics and sire breeding production system involving greater use artificial insemination (AI) which should mean greater and faster access to the new genetics for farmers.
- The work being completed by the beef sire sector is unknown.
- Beef farmers farming dairy beef animals will (potentially) get benefits through the dam side of the dairy beef animal – 50% of the dam genetics should be passed on.
- The report prepared for BERG has indicated/assumed that low-emitting flocks and herds will be emitting methane 5% below the current average by 2030 and by 15% 2050. This would require full use and conversion of the flock/herd to achieve these reduction levels.
- Challenges will be having high integrity breeding programmes in place by sire producers that ensure other beneficial production traits are not impacted, the time involved with converting the flock or herd, and having this mechanism recognised as reducing methane emissions.
- For this project it is assumed that breeding for low-emitting stock that do not suffer a reduction in other production traits is an available option and a 5% reduction in methane emissions is possible by 2030 and a 15% reduction by 2050 for the sheep and dairy components of the operation. Half this level of reduction is used for any dairy beef component of the beef cattle on farm.
- In calculating the impact of any inhibitor/vaccine treatments the genetics reduction is calculated first. The inhibitor/vaccine impact is then applied to this lower level of animal emissions.

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[3]With AgResearch's specially designed portable accumulation chambers (AgPAC) that are taken onto farms on trailers

iii. Low emission feeds:

- Fodder beet and forage rape are recognised as having lower levels methane emissions from the animals grazing them.
- For fodder beet to be effective the diet needs to be greater than 70% to 75% fodder beet. Forage rape has been shown to have a 30% reduction in methane emissions when it is 100% of the diet. This impact is reported as being proportional to the percentage of the daily diet. In most pastoral systems these feeds are only used for 60 to 120 days for selected stock classes (lambs or calves, or dry dairy cows) so the impact on the whole farm system will likely be minimal. This option has not been considered for the pilot farms in this project.
- Other feeds (for example plantain and GM ryegrass) are recognised as reducing nitrate leaching which may then reduce nitrous oxide emissions. GM ryegrass may reduce methane emissions, but further work is required to validate this.
- Because nitrous oxide is a smaller part of the GHG emissions, and this section is concentrating on the methane component of GHG emissions, low emitting feeds have not been considered as a mitigating option in this project. This does not mean that some feeds (e.g. plantain) are not important in the nitrogen loss story or that they may not have future methane reduction advantages.

iv. Nitrification and urease inhibitors:

- These work by slowing the conversion of nitrogen, in nitrogen fertilisers or animal dung and urine, into nitrate and nitrous oxide.
- In recent years their use has mostly been associated with nitrogen fertiliser applications (urease inhibitors) and applications targeted at reducing nitrate leaching in the winter months (nitrification inhibitor e.g., DCD).
- It would appear the greatest potential is for a nitrification inhibitor that is focussed on reducing nitrogen losses from urine patches.
- Based on the BERG report conclusions this option has not been used in this project.

v. Reduced nitrogen fertiliser use:

- Theoretically less nitrogen use will mean less pasture grown and less nitrogen cycling which will reduce nitrous oxide emissions – but unless stock numbers are reduced, milk production is reduced, or stock is sold lighter or earlier there will not be a reduction in methane emissions.
- This will depend on how nitrogen fertilisers are used on the farming operation – with large (over a high percentage of the farm) and regular applications through the year will result in a significant reduction in pasture production and feed eaten by the farming system. The impact of smaller applications may be less certain.
- If applicable lower levels of nitrogen application will be considered in this project.

vi. Increasing per head performance:

- Unless this is associated with producing and/or using less feed in the overall farm system there will be a limited, if any, reduction in total methane emissions.

- However, it is possible that the emissions intensity will be lowered, and profitability increased.
- As this project is concerned primarily with total emissions increasing per head performance is not used as a standalone reduction option for this project.

vii. Manure management:

- GHG emissions occur as methane is produced from anaerobic storage ponds for effluent, and from nitrous oxide emissions when the effluent is spread on the land.
- Possible reduction options include the use of bio-digesters to capture (and use) the methane and applying the manure under best practice guidelines.
- BERG reports the possible gains are small and so this aspect has not been considered for this project.

viii. De-intensification:

- This will involve changing the farm system to grow less feed (for example reducing cropping/regrassing programmes, or reducing the soil fertility), or buying in less feed, and then reducing the stock numbers to match the lower level of feed in the system.
- The ability to use this option will depend on the farm system in place.
- In most sheep and beef operations the existing level of farming intensity means this option is limited. De-intensification options may need to involve reduced macro-nutrient fertiliser applications and/or reduced subdivision so less feed is produced and/or harvested, and stock numbers are reduced in line with these changes. For some hill country operations this could be an option.
- This option has not been tested with the pilot farms in this project.

ix. Once-A-Day (OAD) milking

- This will only have an impact through the cows requiring less feed due to lower levels of production (if that is the outcome).
- OAD milk could well be a viable outcome because of making other changes to the operation.
- This has not been considered as option for this project.

x. Removal of beef breeding cows:

- This is option for the agricultural sector as at a high level it has dairy cows that produce calves that could be reared and farmed instead of the beef cows and their progeny. This option would also provide the beef cattle farmer access to lower methane beef genetics through the dairy dam side of the dairy beef animal. Many sheep and beef operations are involved in this process already.
- However, because of the likely substitution of the beef cows for other stock/cattle the methane reduction will be limited or none unless other feed reduction changes are also completed on the farm.
- The success of the swapping out beef cows for bought in younger cattle will depend on the farmer’s ability to achieve the same level of pasture utilization without the beef cows.

- There could well be an emissions intensity improvement depending on the level of weight gain achieved with the bought in cattle.
- The sheep and beef pilot farms have considered a reduction in their cow numbers so this option is included in this project.

xi. Trees:

- Trees obviously sequester carbon – but they do not directly reduce GHG emissions.
- When trees are planted on a farm the stock numbers may stay the same or be reduced - it will depend on the percentage of farm area, and the relative quality, of the land being planted.
- If stock numbers are not reduced there will be no change to methane and nitrous oxide emissions.
- Two important issues with trees are how long will the sequestration continue for, and what is the rate of sequestration. In general, the faster the rate of sequestration the shorter the period sequestration will last for. For pine trees that are going to be harvested they will only be counted as sequestering carbon on a net basis lifetime basis for approximately 16 years. Carbon sequestered after the 16th year needs "to be saved" for the emissions that will occur when and after the trees are harvested – so from 16-year-old trees in one rotation through to 16-year-old trees in the next rotation the level of sequestration is deemed equal to the level of emissions.
- This being the case, to have a truly multi-intergenerational ability to sequester carbon from trees, ultimately a slower growing native based forest arguably needs to be established and managed for long-term growth. Obviously other trees (such as "Douglas-fir", "exotic softwoods", and "exotic hardwoods" as per the terminology used in the MPI Look-up tables) are being planted.
- The reality is though that these other tree types will likely last many people's "generational" requirements.

xii. Soil carbon:

- It is accepted the soils contain soil carbon, and different soils can contain different levels of soil carbon. It is also accepted that some soils can be managed to have a buildup of carbon – i.e., sequester carbon. It is also accepted that soils can lose carbon through both farm management and natural events.
- What is less agreed is where do New Zealand soils sit on this spectrum and how can any changes in soil carbon be measured in a consistently accurate manner.
- There is research and smaller on-farm projects in different areas of New Zealand involved in this subject.
- Soil carbon has not been considered for this project – but is a "watch this space" subject.

Taking these BERG Report comments into consideration the following have been considered for this project:

- Firstly, the initial stock number and stock policy changes being considered by the farmers;

- Secondly, the use of low-methane genetics at a 5% level (representing BERG's lower 2030 position) and at a 15% level (representing BERG's lower 2050 position). This has been applied to the sheep and dairy stock. Any beef cattle sourced from dairy beef supply chain has this genetic reduction applied at 50%; and
- Thirdly, the use or either methane inhibitors or vaccines has been considered. Their impact has been considered at what BERG considered as lower end results of a 10% reduction by 2030 and 30% reduction by 2050.

13.4 Sequestration rates

Table 37: 16-year average and year 25 sequestration rates (Carbon Look-up Tables for Forestry in the Emissions Trading Scheme[4])

	All post-1989															Pre-1990		
	Indigenous Forest			**Pinus Radiata**			**Douglas-fir**			**Exotic soft-wood - Redwood**			**Exotic hard-wood**			**Indigenous Forest**		
	Carbon stock/ha	Rate /ha /year	Average Rate	Carbon stock/ha	Rate /ha /year	Average Rate	Carbon stock/ha	Rate /ha /year	Average Rate	Carbon stock/ha	Rate /ha /year	Average Rate	Carbon stock/ha	Rate /ha /year	Average Rate	Carbon stock/ha	Rate /ha /year	Average Rate
0	0.0	0		0.0	0		0.0	0		0.0	0		0.0	0			0	
1	0.6	1		0.4	0		0.1	0		0.2	0		0.1	0			0	
2	1.2	1		3.0	3		0.1	0		1.0	1		3.0	3			0	
3	2.5	1		7.0	4		0.5	0		3.0	2		13.0	10			0	
4	4.6	2		25.0	18		1.0	1		12.0	9		34.0	21			0	
5	7.8	3		50.0	25		2.0	1		26.0	14		63.0	29			0	
6	12.1	4		84.0	34		4.0	2		45.0	19		98.0	35			0	
7	17.5	5		111.0	27		7.0	3		63.0	18		137.0	39			0	
8	24.0	7	**6.8**	130.0	19	**22.1**	20.0	13	**12.1**	77.0	14	**11.3**	176.0	39	**27.2**		0	**1.8**
9	31.6	8		142.0	12		33.0	13		87.0	10		214.0	38		109.0	0	
10	40.2	9		163.0	21		50.0	17		95.0	8		251.0	37		107.0	-2	
11	49.8	10		188.0	25		69.0	19		106.0	11		286.0	35		108.0	1	
12	60.3	11		218.0	30		90.0	21		118.0	12		320.0	34		111.0	3	
13	71.5	11		249.0	31		113.0	23		132.0	14		351.0	31		115.0	4	
14	83.3	12		283.0	34		138.0	25		147.0	15		381.0	30		121.0	6	
15	95.5	12		318.0	35		165.0	27		163.0	16		409.0	28		129.0	8	
16	108.1	13		354.0	36		193.0	28		180.0	17		435.0	26		137.0	8	
16 Yr Ave.	**6.8**		108.1	**22.1**		354.0	**12.1**		193.0	**11.3**		180.0	**27.2**		435.0	**4.0**		28.0
Year 24	204.7			636.0			382.0			315.0			601.0			214.0		
Year 25	215.0	**10.3**		666.0	**30.0**		409.0	**27.0**		330.0	**15.0**		618.0	**17.0**		223.0	**9.0**	

[4] Ministry for Primary Industries, July 2017

KCRC King Country River Care
Supporting resilient and thriving rural communities

Ministry for Primary Industries
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