Whole systems impact of composting shelters in New Zealand

Prepared for

Our Land and Water Rural Professionals Fund 2021

Report prepared by

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5 August 2022

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Status:	Final	

Bibliographic reference for citation:
Durie, R., & Woodford, K. 2022. Whole systems impact of composting shelters in New Zealand. Report prepared by Perrin Ag Consultants for Our Land and Water Rural Professionals Fund. August 2022. 90 pages.

Acknowledgements

We acknowledge Our Land and Water for funding this project through their Rural Professional's Fund.

The authors thank all those who gave their time to this research. In particular, the farmers who gave their time to host the project team on farm and participate in farmer interviews. The insights from these interviews provided enormous value to the project findings.

Special mention must also be given to Kokako Pi Karere LP who provided their farm as the case study for this project. In addition, Kokako Pi Karere LP, as the Māori lead and rural entrepreneur, contributed their knowledge through participation in the field tours and farmer interviews, and shaped the way the research was approached.

Executive Summary

Composting shelters are attracting growing interest from farmers looking to operate more sustainable, resilient and profitable businesses. Limited knowledge within the New Zealand pastoral context, however, is available to support farmers and rural professionals in their evaluation of the system.

This project builds on the knowledge base of farmers and technical experts to provide a document that can be used as a starting point for those seeking to understand the potential impacts of composting shelters within their own situation.

Farmer interviews along with desktop modelling have been completed to consider the impact of composting shelters within a Māori-owned case study dairy farm. Consideration has been given to the impact of the shelters on the farm environment, farm system, financial performance, animal welfare and staff wellbeing. Evaluation of the system has been guided by four Te Taiao pou (whenua, wai, āhuarangi and koiora), recognising that the health of each of these pou is fundamental to the long-term success of agriculture.

The unanimous response from the six farmer interviews across New Zealand was that the investment in composting shelters has been beneficial. It was the intangible benefits (i.e., improved animal welfare, staff wellbeing and/or environmental performance) that were weighted most highly and were the key drivers for construction of the composting shelter, although most farmers interviewed also noted financial benefits. Of particular note, were the consistent advantages across farms regarding increased cow comfort and welfare, improved staff working conditions or improved labour efficiency, improved environmental performance, and reduced pasture damage. These improvements led to overall increased satisfaction, less stress, and increased pride in dairy farming as both a business and appropriate land-use.

It was evident from the interviews that more needs to be understood about the management of bedding and implications thereof for longevity of bedding, which varied between the farmers interviewed. It was apparent that specific infrastructure decisions affecting moisture evaporation, plus the choice of specific bedding materials, and the specific pattern of use of the shelters across the seasons, are all relevant to the outcomes achieved. Given that these farms are operating in a business environment rather than within a research environment, there was a lack of quantitative data to support the qualitative findings relating to key farm metrics such as pasture growth, animal health and operating profit.

Many of these metrics will be system and location dependent. The analysis and discussion provided in the case study modelling provides a starting point. It should be noted that the desktop modelling relies on experiential knowledge from farmers interviewed, supported by knowledge from the technical expert and rural professional, and guided by the case study farm. However, the composting shelter technologies and systems have not been incorporated to date within formal New Zealand research and development (R&D) programmes. Accordingly, there is a level of uncertainty around particular system parameters. Risk analyses have been utilised to provide guidance on the range of uncertainty for key system parameters including milk price, production and frequency of bedding replacement.

The case study farm (Kokako Tuarua), located in South Waikato, comprises 172.3 effective hectares of predominantly flat to rolling contour, with peak milking of 565 cows under a System 4 operation producing 410 kg MS/cow.

A base composting shelter model was created in which a hybrid indoor-outdoor farm system was analysed with cows spending part of each day inside the shelter. Design parameters were based on 8.5 m^2/cow of space within the shelter (7.4 m^2 compost per cow; 1.1 m^2 concrete per cow), and included two common shelter types. Scenario 1 models are based on a rigid roof structure comprising an inverted "V" shaped steel roof, with a ridge vent and cap running along the apex to extract warm out of the shelter. In contrast, Scenario 2 models are based on an industrial fabric tunnel roof structure. Note, the tunnel roof scenarios do not include a roof venting system which, if included, would add to the overall cost of the shelter. The specific requirement for a roof venting system will depend on the site location and should be considered in design planning. Each of the design scenarios include a high (S1H & S2H) and low (S1L & S2L) capital model. Capital pricing for each of the scenarios is specific to the case study farm system and location.

The high-capital cost scenarios are based on use of concrete for all feed infrastructure areas including the cow standing area, feed walls and tractor alleys, as well as for the compost retaining walls and turning aprons. In contrast, the low-capital cost scenarios substitute some of the concrete for timber and gravel surfaces, accepting higher repairs and maintenance costs. Capital costs were $2.6 million ($4,542/cow) and $2.3 million ($4,011/cow) for Scenario 1 high and low models, and $1.9 million ($3,324/cow) and $1.6 million for Scenario 2 ($2,820) high and low models, respectively. Overall, the physical shelter structures comprised 59% - 67% (Scenario 1 high and low) and 46% - 54% (Scenario 2 high and low) of the overall investment cost. It should be noted that some farmers are achieving lower capital cost builds, than those modelled here, by further reducing the level of concrete within the shelter.

Incorporation of composting shelters on farm resulted in estimated milk production increasing by 57 kg MS/cow and 186 kg MS/ha as a result of increased feed conversion efficiency, higher pasture growth and feed utilisation, and reduced heat stress over summer. As a result, cash operating surplus (EBITDA) increased by 17% to $4.19/kg MS for the high-capital models and by 16% to $4.16/kg MS for the low-capital models. Repairs and maintenance were the key variable impacting on cash operating surplus between the high and low models.

Incorporation of composting shelters on farm resulted in a 45% reduction in nitrogen leaching loss from 51 kg N/ha/yr to 28 kg N/ha/yr as modelled in OverseerFM. Of this, 87% was attributed to reduced urinary N deposition through the practice of duration-controlled grazing with cows spending an average over the year of 6.6 hours per day in the shelter.

Impacts on greenhouse gas emissions are currently difficult to evaluate given OverseerFM in its current state (v6.4.3) does not model the impact of the aerobic composting process on methane and nitrous oxide emissions. It can be hypothesised that the reduced urinary N deposition will lead to less overall nitrous oxide emissions from farming systems that incorporate composting shelters but the necessary research to demonstrate this has yet to be conducted.

Performance of the composting shelter investment was evaluated using discounted cash flow analysis on the pre-tax cash flows. Internal rate of return (IRR) was used to assess the whole business performance of the composting shelter scenarios along with the status quo scenario. The marginal returns from the individual composting shelter investments were then assessed by determining the change to the annual cash flows compared to the status quo ('marginal analysis'). The results were analysed using IRR and net present value (NPV).

All costs were estimated based on 2022 prices and milk was valued at $9.00/kg MS. Accordingly, by using constant value (2022) dollars, the estimated investment returns are in real terms independent of future inflation. In contrast, nominal returns in an inflationary environment could be expected to increase over time from those reported here.

Over a 50-year investment period, the expected lifespan of the structure, the resulting whole business return ranged from 6.8% (S1H) to 7.4% (S2L), depending on specific infrastructure decisions, and is above the 6.3% return achieved from the status quo system. The return on the composting shelter system investment itself, based on the new capital expenditure and consequent changes in net cash flows from the status quo, ranged from 8.4% (S1H) to 12.4% (S2L).

Net present value (NPV) analysis demonstrates that providing Kokako Tuarua's WACC is below 8%, overall business profitability is improved by investing in any of the composting shelter scenarios, regardless of shelter lifespan, investment period and salvage value. Assuming a 50-year lifespan and investment period, a positive NPV can also be generated from the lower capital scenarios at a 10% WACC.

Sensitivity analysis indicated that these IRRs for the investment project (i.e., the 'with versus without' comparison) were remarkably robust to changes in the milk price, with the investment IRR increasing by approximately 1.0% – 1.5%, depending on specific infrastructure costs, for each $1.00/kg MS increase in the milk price. Likewise, for every $1.00/kg MS decrease, the marginal IRR decreased by 1.0% - 1.5%. Similarly, the IRR of the investment was influenced in only a minor way by reducing the project life from 50 years to 25 years. Also, salvage values assigned at the end of the investment had only a minor effect on the project IRR. Accordingly, based on economic criteria, the investments were assessed as profitable.

Although the returns from the investment project itself were robust to changes in milk price, the returns from the whole farm business were highly dependent on the milk price, with this situation being the case for both the status quo and for the systems incorporating composting shelter investments. Accordingly, the financial risks to the whole farm business were largely independent of the investment decision relating to the composting situation.

Because the investment analyses are based on discounted cash flows for the life of the investment, and with all capital fully costed at the time it is incurred, it is not appropriate to include non-cash depreciation. That would lead to double counting. However, in any business there is a need for capital renewal. Accordingly, a capital renewal allowance of approximately $130,000 is included each year in the EBIT (earnings before interest and tax) cash flows for the whole-farm business appraisals, both status quo and for the composting shelter scenarios. Additional capital renewal has been included at the appropriate times for the composting investment options. This provides some further cash flow flexibility in years of low milk price, with ability to delay these items.

As noted above, all analyses were conducted pre-tax. This is considered appropriate for a generic project. Accordingly, when the findings of this report are applied to specific businesses other than the case study farm, these taxation issues would need to be considered. In that regard, it is noted here that the depreciation allowances become a tax benefit that can help cash flow management in the initial years.

Although there are differences in the economic returns from the two types of shelter modelled in this project, no recommendation is given here in relation to specific design. Those decisions should be made on a case-by-case basis, making judgements as to relative performance under farm-specific criteria. One of these criteria include the specific wind-loading of the site which will impact on structural design requirements.

Consideration also needs to be given to who will operate the farm system. Specific skills are needed to ensure a focus on management of the bedding and corrective action if intervention is needed. Similarly, consideration of the impact of the operator on financial performance should also be given. In order to understand the impacts of composting shelters on the whole farm business, this case study assumed a farm manager. Where farm management structure varies, i.e., under a 50/50 sharemilking structure, many of the financial benefits would be shared with the sharemilker. With capital costs typically paid for by the land owner, the net benefit to the owner would be reduced under a sharemilking structure.

One of the most challenging decisions of this project related to the necessary per cow area of compost for the specific case study location. This specific decision has a direct impact on the necessary infrastructure cost. In this project, the assumed area of 7.4 square metres of bedding per cow was at the upper end of the necessary estimate per cow, with another farm successfully operating a similar system and in a similar environment at a considerably lower allowance of approximately 5.5 square metres per cow. The higher figure chosen for this report reflects a conservative approach.

The overall conclusion of this report is that composting shelters have diverse benefits to the human environment, the biophysical environment and to animal welfare, and encapsulate enhancement of Te Taiao. The overall economics appear sound. However, significant capital expenditure is required and this needs to be budgeted with care. Also, it needs to be recognised that composting shelter developments in New Zealand agriculture are currently being farmer-led, without formal research and development programmes to guide the way. Farmers considering composting shelters should take care in ensuring sufficient personal research is undertaken before committing to a project, to make certain that the design will be fit for the specific location and purpose. Inevitably, there is much more to be learned.

CONTENTS

1 Background

This project, 'Whole systems impact of composting shelters in New Zealand', is funded through the Our Land and Water National Science Challenge under the Rural Professionals Fund 2021. The fund aims to test innovative ideas that could lead to significant improvements in food and fibre farming systems with the purpose of creating benefit for New Zealand farming communities.

The project is being delivered by Perrin Ag Consultants Ltd with Rachel Durie as the key rural professional, Keith Woodford from AgriFood Systems Ltd as the technical expert, and Kokako Pi Karere LP as the rural entrepreneur and Māori lead. The project objective is to understand the implications of incorporating composting shelters within a dairy farm system taking into consideration the environment, physical performance, financial performance and impacts to animal welfare and staff wellbeing. The project combines a Western science approach to research with Mātauranga Māori value systems and draws heavily on the experiential knowledge of existing composting shelter farmers to provide a holistic, whole-systems approach to the research.

Desktop modelling of the case study farm is used to test the project aims and is supported through the collaboration of farmers already using the composting shelter technology. Six farmer interviews and three field tours with the project team were completed to ground truth assumptions and findings, and to allow non-quantitative metrics to be assessed (e.g., animal welfare and staff wellbeing).

The project comprises three phases;

1. Phase One draws on current farmer knowledge of composting shelters using in-depth farmer interviews. A field tour of three composting shelters in Canterbury and Waikato was undertaken by members of the project team including the rural professional, technical expert and rural entrepreneur. Farmer interviews were completed at each composting shelter farm with a further three interviews conducted by phone. These field tours and interviews showcased the variation in which composting shelters are incorporated within dairy farm systems and assisted the development of the scenarios tested in Phase Two.

2. Phase Two utilised desktop modelling to evaluate the impact of composting shelters on the case study farm (Kokako Tuarua). A status quo farm system was created from which composting shelter scenarios were modelled and evaluated. Scenarios were analysed based on their impact to the environment, the physical farm system, including staff and animals, and on the farms financial performance. Evaluation of the scenarios was considered in the context of Te Taiao.

3. The final phase of the project (Phase Three) extends the project findings to the wider dairy sector through the creation of an additional online summary report and video output. These sit alongside the main project report and can be accessed from https://www.perrinag.net.nz/ and www.ourlandandwater.nz/compostingsheltersRPF

2 Introduction

Composting shelters are a unique animal housing structure that have the potential to become a transformational technology for the New Zealand dairy industry. The fundamental principle that differentiates composting shelters from other dairy housing structures is the composting process that occurs within the loafing area.

While widespread in the Northern Hemisphere, composting shelters are a relatively new concept in New Zealand and are utilised in a different manner to adapt to the country's pasture-based grazing system. The general concept is that cows spend a proportion of time under a roofed structure where they lie on a deep bedding comprising plant-based material (e.g., sawdust, wood shavings, wood chip or other material with a high lignin component). Aerobic composting, aided by daily tilling and ventilation, mixes the bedding with urine and dung creating *in situ* composting. The heat generated from composting (ideally 50-60ºc at 30 cm deep) keeps the bedding warm and dry, allowing it to remain in place for one year or more (depending on the system) before it is replaced. Once removed from the shelter, the composted material, which contains nutrients from the dung and urine, can be applied to farm paddocks as an organic form of fertiliser. Unlike other dairy housing facilities, the composting process can eliminate the need for a specific effluent capture system.

These composting structures are already in operation on some early-adopter farms. In most cases, the shelters are incorporated into the system year-round in a hybrid indoor-outdoor grazing system. In this system, cows will spend a portion of the day in the shelter and a portion outdoors on pasture. The proportion of time cows spend in the shelter will vary depending on the individual farm system and the desired outcomes. However, there is a general trend of utilising the shelter at nights during the cooler autumn and winter months, and using the shelter during the day in the warmer months. Alternatively, there are some farms using the shelter solely as an alternative wintering system to grazed crops. This is particularly the case in the South Island where winters can pose considerable environmental and animal welfare challenges.

Incorporation of composting shelters within New Zealand's pasture-based farming system has the potential to improve farm environmental performance, animal welfare and staff wellbeing while providing economic benefit. While there is extensive overseas literature pertaining to the system, there is a lack of documentation and evaluation within a whole-systems framework to quantify these claims in the New Zealand pastoral context. To date, knowledge on New Zealand use of composting shelters within farming systems has come from end-user innovation and experience.

This project reports on the knowledge and experience of farmers utilising the shelters within New Zealand, and quantifies potential impacts to farm systems using a South Waikato case study farm.

3 Method

This case study project was split into two phases. Phase One comprised field tour and farmer interviews which were designed to inform the second case study desktop modelling phase of the project (Phase Two).

The project combined a western science approach with Mātauranga Māori values and experiential knowledge from innovative farmers to provide a holistic, whole-systems approach to the research.

3.1 Phase One

Phase One comprised six farmer interviews of which three were completed as in-person field visits and a further three by phone. Selection of farmer interviewees was informed through the project team's professional networks and encompassed farms spanning five regions ensuring diversity in farm location and system operated.

Interviews were semi-structured and provided flexibility to explore aspects unique to the individual farm. The interviews enabled an in-depth insight to be gained on the motivators for incorporating composting shelters on farm, the challenges that exist and the different ways that the shelters have been integrated within farm systems. Interviews were structured to provide an understanding of the benefits from operating with a composting shelter system, along with the drawbacks, and to also identify what farmers may have done differently should they start the process again. The interviews also had a focus on understanding, from the farmer's perspective, the impacts of composting shelters on koiora (living communities; animal and staff welfare) which is difficult to obtain from published literature.

3.2 Phase Two

Phase Two comprised the case study desktop modelling. The case study farm, Kokako Tuarua, was provided by the rural entrepreneur (Kokako Pi Karere LP) and provided the basis for the evaluation of a composting shelter system against a status quo dairy farm without any housing infrastructure. The status quo system represents the forward projection of the current farm business based on current policy; essentially the counterfactual to the investment.

Financial and physical data from the current and preceding three seasons (2019-20 to 2021-22) were analysed to develop the representative status quo system. The farm financial and physical metrics were analysed through custom built financial models in Microsoft Office Excel, and environmental metrics modelled through OverseerFM v6.4.3. Financial inputs and expenditure were updated to current (2022) values to achieve consistency between the composting shelter system and the counterfactual.

Composting shelter scenarios were then developed for the case study farm supported by information gathered during Phase One. Scenarios varied by structure type and capital investment as well as the location of feeding.

The physical, financial and environmental performance of each of the scenarios modelled was evaluated and compared against the status quo, and included considerations for animal welfare and staff wellbeing as informed by Phase One.

Discounted cash flow analyses were used to assess performance of the investment at a pre-tax level and were completed on 25-year and 50-year timeframes. The 50-year timeframe is reflective of the long-term view of Māori-owned businesses as well as the expected lifespan of the composting shelter structures. Sensitivity analyses were then undertaken to understand the resilience of the investment to key input parameters.

A Te Taiao Framework (Primary Sector Council Working Group, 2020) was used to guide analysis of the research and evaluate the impacts of composting shelters against the four Te Taiao pou (see Section 4).

Full assumptions for the case study modelling are detailed in the appendices.

4 Te Taiao

Principles of the Te Taiao Framework were used through the course of the research and are referred to throughout the project report. A brief description of Te Taiao is provided.

Te Taiao is the natural environment that contains and surrounds humanity in an interconnected relationship of respect (Primary Sector Council Working Group, 2020). There are four pou (pillars) of Te Taiao:

- Āhuarangi (climate);
- Whenua (land and soil);
- Wai (all freshwater bodies and their connections);
- Koiora (all living communities: human, plant, animal).

Each of the Te Taiao pou are interconnected, and the wellbeing of the four pou are fundamental to the long-term success of agriculture. Farmers have a deep connection with the land, and responsibility to protect the land and surrounding environment for future generations. This project embraces Te Taiao and measures the impact of composting shelters on the health of the climate, land, water and living communities.

Te Taiao aligns with Kokako Trust as the owners and guardians of the case study farm and reflects their vision of "ko takapuhurihuri e whangai ngā tangata" ("the whenua as the ever-turning stomach, the food basket that sustains the people"). To implement this vision, all activities must be focused on enabling the land, animals and people to thrive. This in turn will ensure work opportunities, food supply and financial benefits for whānau and community now and into the future.

The Te Taiao framework is also useful for assessing the resilience of a farm business, and potential mitigations (including composting shelters), against incoming regulations. For instance, the Essential Freshwater package, including the National Policy Statement for Freshwater Management 2020 (NPS-FM), and National Environmental Standards for Freshwater (Freshwater NES), provides national direction on farming activities that have an impact on water. As part of these regulations, farm businesses will need to identify farming activities that cause adverse effects to freshwater and specify actions to avoid, remedy or mitigate. Many farmers are looking at composting shelters as one potential solution. Using a Te Taiao framework comprising of four pou (āhuarangi, whenua, wai, and koiora) ensures that in evaluating composting shelters as a mitigation option, the potential impact on the full interconnected living environment and farm system are also considered.

5 Phase One: Findings from the Field Tour and Farmer Interviews

5.1 Introduction

The aim of Phase One was to capture existing farmer knowledge of composting shelters and identify different methods of incorporation on farm to help guide scenario development and ground truth assumptions used in Phase Two (case study modelling) of the project. To achieve this, six interviews were completed with farmers who had existing composting shelters. Three farms were visited (two in the Waikato and one in Canterbury) and interviews conducted in person, while a further three farms located in Hawkes Bay, Otago and Southland were interviewed by phone. The farm system, cow numbers and experience with a composting shelter varied amongst the farms interviewed as displayed in Table 1.

A further aim of Phase One was to generate an understanding of the qualitative (non-quantitative) impacts from incorporating a composting shelter on farm, particularly the impacts on animal and staff welfare, which will help inform the koiora (living systems) aspect of Te Taiao. These intangibles are particularly important as they are often part of the key thinking behind building a composting shelter.

Results from Phase One are presented as a discussion of the findings from the interviews completed and have been summarised into five key sections:

- Key motivators for constructing a composting shelter
- How farmers have incorporated composting shelters on farm
- Key advantages and disadvantages
- Key lessons learnt and considerations
- Impacts to koiora (living systems)

Table 1: Details of farms interviewed.

	Location	Years with Composting Shelter	Cow Numbers	Shelter System
Farm 1	Canterbury	1	530	Winter & calving
Farm 2	Waikato	8	290	Year-round
Farm 3	Waikato	3	350	Year-round
Farm 4	Southland	1	120	Winter
Farm 5	Hawkes Bay	4	650	Year-round
Farm 6	Otago	2	350	Year-round

**Farm 4 is a corporate entity that have been able to create a small trial shelter to winter 120 out of their 900 cows.*

***Farm 6 milks 900 cows but utilises the shelter for just 350 autumn calving cows.*

Figure 1: Canterbury composting shelter (Farm 1).

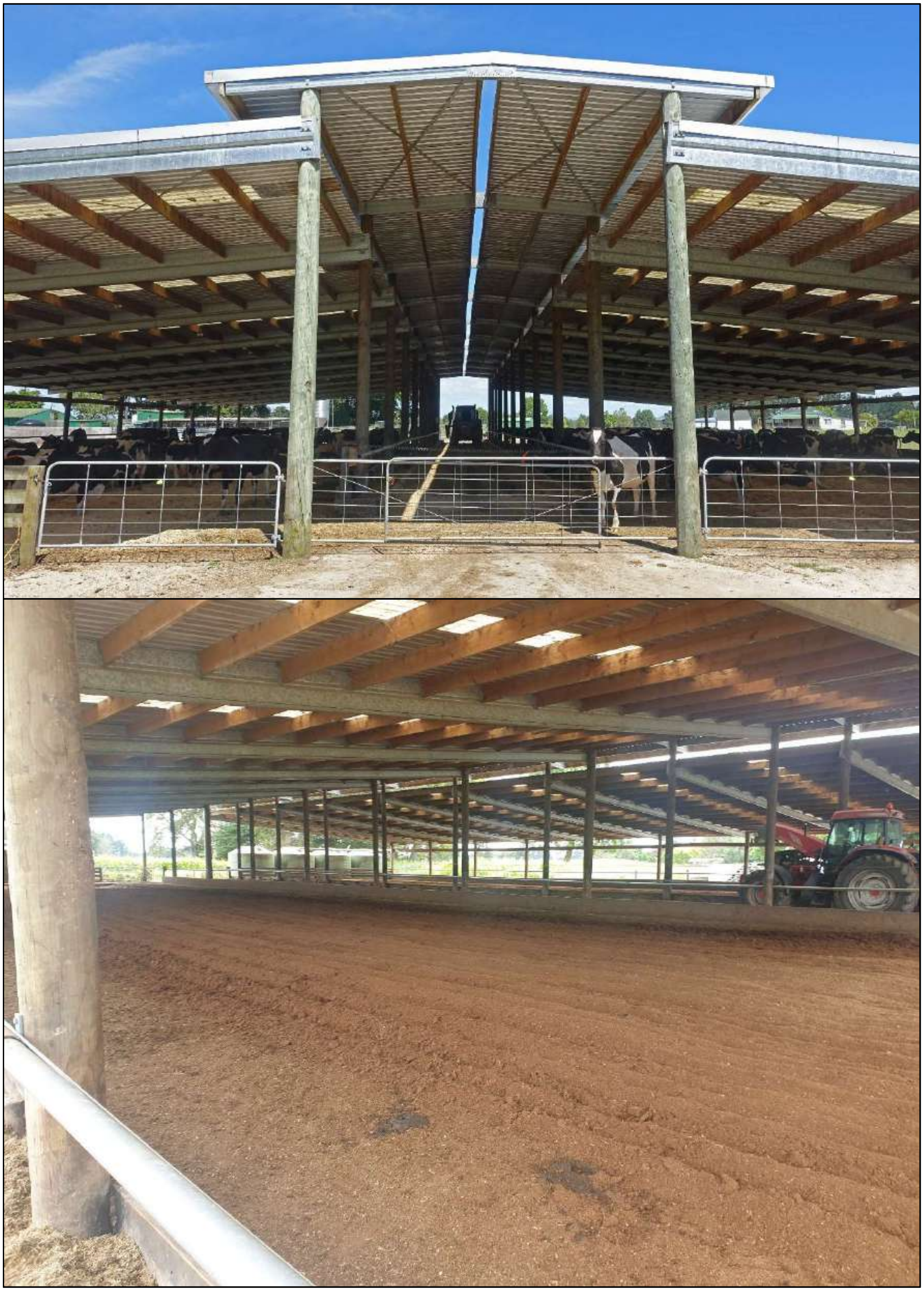

Figure 2: Waikato composting shelter (Farm 2). Note, this shelter was not originally designed for composting.

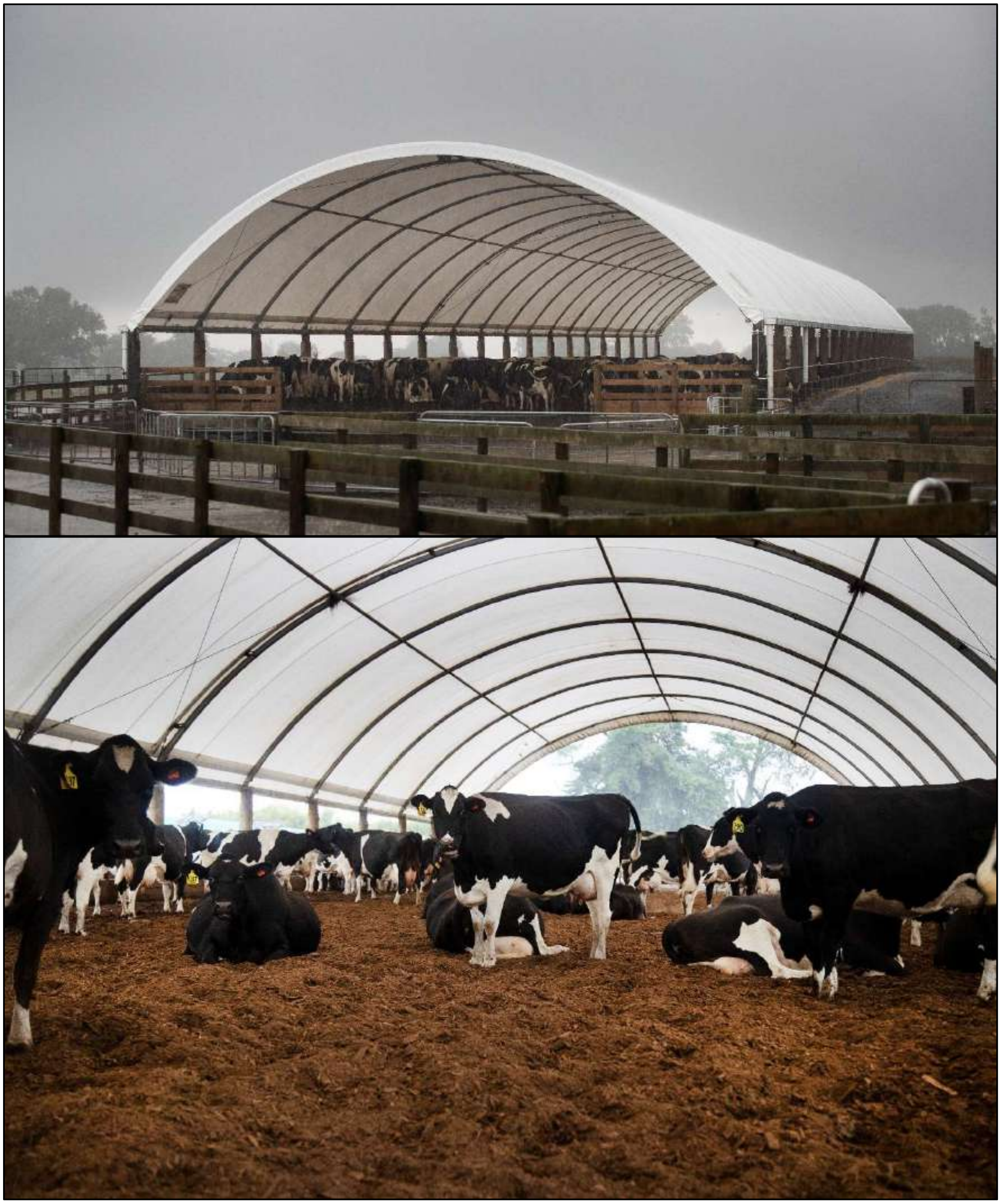

Figure 3: Waikato composting shelter (Farm 3).

5.2 Key motivators for constructing a composting shelter

There were a number of key drivers for building a composting shelter that came across from the interviews. For the majority of farms, these could be broadly categorised into wintering, environmental, staff and animal welfare reasons. These motivators however were not in isolation and in most cases it was a combination of these four drivers that led to the decision to build a composting shelter.

For all farms, the ability to winter cows either 24/7 inside the shelter or for a portion of each day was a key reason behind the initial decision to build. Most noted that wintering was a difficult and stressful time of the year and was "*hard on people, hard on cows and hard on the soils".* This sentiment came across particularly from the farms wintering on crop, but was also noted by farms wintering on pasture. For the latter, the damage done to pastures during inclement weather in winter was a key motivator along with the desire to provide stock with shelter. Wintering was also mentioned as an expensive process by at least three of the farms both in terms of the cost of cropping or grazing off and also the damage done to soils and races. Farm 4 noted the "*fact that cows could be fed much less was hugely inviting*" given the lower maintenance requirements of cows housed in the shelter over winter.

Environmentally, at least four of the farmers felt that their previous wintering systems were unsustainable in terms of the damage done to soils, was not a good look for the industry, and/or they wanted to do better or pave the way for other farmers. Many mentioned that the ability to get cows off pasture during inclement weather to avoid pugging and improve pasture management was also a key part of the decision-making process. For one of the farms, complying with nitrogen (N) loss restrictions was part of the reason to build a composting shelter as it provided a way to stand cows off pasture for long periods in a comfortable and sheltered environment thus reducing urinary N on pasture and therefore N leaching.

Animal welfare was a key motivator for all farms especially from a wintering context. This was because the farmers saw the shelters as a way to provide a warm and dry environment out of the cold and mud during winter and calving, and on a comfortable, non-concreted floor. Two of the farms noted high soil potassium (K) levels, and therefore the ability to calve in the shelters was also seen as an attraction. In addition, the ability to minimise heat stress during the summer was also a key factor for the North Island farms.

Staff welfare was mentioned as a key driver for at least one of the farms where having a labour-efficient and stress-free farm system was highly valued. Farm 1 stated;

> "*one of the ways to take the stress out of the system for the staff, is to take the stress out of the system for the animals*"

A composting shelter was seen as a key way to do this. The ability to have cows and winter feeding all in one place, sheltered and out of the rain was seen as a time-saver and a way of providing a better working environment compared to a winter cropping system. Furthermore, the ability to calve in the shelter was seen as a way not only to improve the environment for the cow, but also for staff completing night checks or when intervention is required.

Overall, it was the intangible or harder to quantify drivers that came across as the initial key reasons for building a shelter. Wintering was the primary motivator, even in milder winter climates, which in itself was driven by the associated environmental, animal and staff welfare challenges. While in many instances the farmers interviewed have noted financial savings or cost benefits from the shelters, it is clear also that farmers weight the intangible benefits highly and in most instances it is these motivators that have been the primary driver of construction as opposed to financial gain. These intangibles should therefore be considered when assessing the viability of composting shelters on farm.

Furthermore, while some of these motivators (e.g., animal and staff welfare) may be considered non-quantifiable there is likely to be indirect financial gain in areas such as improved animal health and staff retention. Farm 4 encapsulates this with the comment;

> "*it's not just about 'it costs this much and will save this much', the benefit is environmental and animal welfare*".

Over time, and between farms and locations, there are also likely to be changes in the key motivators for building. Wintering came through strongly in these interviews and is likely to continue to be a key motivator as climate change causes more extreme weather and a greater need to get cows off pasture for parts of the year, although there may also be areas where the winter climate becomes milder and less of a challenge. Managing drought and mitigating heat stress on the other hand, while mentioned by some farmers, were not emphasised as strongly. Going forward, however, it is likely that heat stress will become a larger factor in the decision-making process for new builds as summer droughts and hotter temperatures become more prevalent, and as industry puts greater focus on mitigating heat stress. This has already begun to occur through processor incentive schemes and greater provision of industry resources that focus on managing challenges related to animal welfare.

5.3 How farmers have incorporated composting shelters on farm

Across the six farms interviewed, there have been two approaches to incorporation of a composting shelter on farm:

- Hybrid, indoor-outdoor year-round grazing system
- 24/7 indoor wintering system

A hybrid indoor-outdoor grazing system is being operated by four of the six farmers interviewed. This system is based on cows spending a portion of each day inside the shelter and the remainder outdoors on pasture. The proportion of time cows spend in the shelter varied between the farms and feed systems operated. However, there was a general trend of bringing cows into the shelter at night during the cooler autumn and winter months and then during the warmer months bringing the cows inside during part of the day. This was to provide shelter to the cows during winter and then shade over summer – effectively mitigating the impact of seasonal climatic conditions (cold and heat stress) on cows and subsequent production levels.

Farms 2, 3 and 5 had trigger temperatures for bringing cows inside during the summer months. Depending on the farm, once temperatures reached 20-24ºC, cows were brought inside. In most instances this involved monitoring temperatures and then staff bringing cows in once the trigger level was met. The set up on Farm 6, however, enabled the cows to make this decision themselves. Automatic gates gave cows the choice to stay in the paddock or freely walk to the shelter between morning and afternoon milking. Since operating this system, Farm 6 observed that once temperatures reach between 20-25ºC the cows will freely walk themselves to the shelter, even when no feeding is occurring.

On some of the farms operating under this hybrid indoor-outdoor grazing model, there were also times of the year, mainly during mild weather conditions, where cows remained 24/7 outdoors on pasture.

The location of each of the farms interviewed has influenced the specific details of the system integrated. For instance, in comparison to the North Island farms, Farm 1 in the Canterbury region built and operates their structure on the premise of a wintering only system (although it has potential to be used at other times of the year). This farm has transitioned from a typical winter cropping system with a portion of cows wintered off-farm to a system where all cows are now wintered on-farm, along with replacement stock, inside the shelter 24/7 from approximately 15 May through to calving in August. Silage is utilised as the sole winter feed diet and is provided through access to adjoining feed pads. Access to the feed pads is essentially ad-lib, however the amount of silage offered is restricted to 8-9 kg DM/cow/day.

Farm 4 in Southland, which is trialling a composting shelter system, is also using the shelter for wintering only. This farm has previously wintered all 900 cows off-farm at grazing 3-4 hrs away. With incorporation of the trial shelter, the farm has shifted to initially wintering 120 cows in the composting structure (restricted by regional council consenting requirements) with the remainder still wintered off-farm. The farm is using a 24/7 indoor wintering approach, although with the ability to allow cows outdoors to graze during fine weather conditions. In contrast, Farm 6 which is located in Otago and also farms in a similarly challenging environment, has incorporated the shelter in a year-round system although this too is influenced by the high input feed system operated.

On all but Farm 4 (who were trialling the system), the composting shelter is used for calving. For those that use a hybrid indoor-outdoor system this typically meant having the cows in the shelter at night when most of the calves were born and providing restricted access to pasture for a portion of the day. For Farm 1, which operates a 24/7 wintering approach in the shelter, this extended through to calving after which point calved cows were shifted to a typical 24/7 outdoor grazing system. Partitioning gates within the shelter allowed for separation of springer and dry mobs at calving.

The volume of feed imported to the farm system after incorporation of the shelter varied across the farms interviewed with one farm increasing to a high input operation, while another reverted to a low input operation. The remaining farms made no changes to the feed system, although feed utilisation for those now feeding in the shelter (compared to on paddocks) improved, and the composition of the diet changed on some farms with increased ability to utilise cropping (e.g., maize silage) following construction of the shelter. This was a result of increased pasture utilisation, less feed required over winter following incorporation of the shelter and less overall grazing area required, thus freeing up area for cropping. The findings from the interview suggest that composting shelters are able to be successfully incorporated within any feed system, and the profitability of the system after incorporation of a shelter is not constrained to any particular feed system. On most of the farms, the shelters have provided a tool for larger farm system change whether that be in the context of feed, cropping, staffing or wider system change.

For instance, on Farm 5, the construction of the composting shelters allowed the farm system to be reviewed and resulted in a shift down in cow numbers from 900 to 650. The pasture stocking rate remained the same as more cropping was enabled following improvements in grazing management with the ability to manage time on pasture. Further system change was then enabled with additional irrigation area and effluent pond “tools” that allowed a transition to an autumn-calving system and winter-milking contract. These changes could not have been made without the composting shelter which provided both flexibility and control of the system, particularly in regards to grazing management and avoidance of pugging.

On the other hand, Farm 1 used the composting shelter as an opportunity to de-intensify the system and become almost fully self-contained. The farm previously wintered 710 cows with 150 wintered off-farm and the remainder wintered on-farm on crop. All replacement stock were also reared off-farm from weaning through to coming back as in-calf heifers. With incorporation of the shelter, the farm reduced cow numbers to 530 allowing for all cows to be wintered in the shelter along with replacement stock. For the rest of the year, cows and replacements are grazed on farm 24/7 on pasture. Wintering in the shelter has allowed winter feed requirements to be halved with silage cut from the farm as the sole winter feed diet. Costs of grazing stock off, winter cropping and purchasing feed for the transitionary diet are no longer incurred.

5.4 Key advantages and disadvantages

Farmer participants were asked what the key advantages and disadvantages were of operating with a composting shelter. All farms provided a long list of advantages of which many were shared between farms. Most farms had very few disadvantages, if any, and more probing was needed to bring these out. In general, there was only one drawback that was common between farms and that was the potential for bedding availability to become an issue if demand outstripped supply. When asked if the farmer would go back to farming without the composting shelter all said “no”, or that the costs of farming without the shelter (quantifiable and non-quantifiable) were greater than with the shelter.

A summary of the advantages and disadvantages are provided below, with the farm numbers provided in brackets to indicate the number of farms that shared the same or similar answer.

Note; the advantages/disadvantages listed below are based solely on opinions and experiences from the individual farmers interviewed and have not been quantified.

<u>Advantages:</u>

- Content, happy and more relaxed/calmer cows (all farms).
- Improved staff working conditions resulting from a less stressful system, particularly during winter and calving. Improved staff morale and reduced fatigue (all farms).
- Improved environmental performance related to:
  - Removal/reduction of winter cropping or 24/7 winter grazing (Farm 1, 2, 4, 5, 6).
  - Less time on pasture resulting in reduced urinary N leaching (Farm 4, 5).
- Ease of putting condition on cows (Farm 1, 2, 3, 4).
- Improved pastures, more pasture grown and/or lower weed burden resulting from:
  - Reduced/no pugging (Farm 1, 2, 3, 5, 6).
  - Reduced/no over-grazing (Farm 2, 3).
- Faster recovery after drought or winter wet conditions due to improved pasture management. No lag phase (Farm 3, 5, 6).

- Lower fertiliser bill from applying the bedding compost to crop and/or pasture paddocks (Farm 2, 4, 5, 6).
- Provides flexibility and reliability to the system (Farm 1, 2, 3, 5).
- Reduced climatic risk (Farm 1, 2, 3, 5).
- Lower winter feed requirement and reduced feed bill (Farm 1, 2, 4).
- Milk production gains from:
  - Mitigating heat stress during summer allowing peak production to be held for longer (Farm 2, 3, 5).
  - Ability to milk longer in autumn/keep empty and cull cows for longer with less pasture cover required to be taken through into winter and spring (Farm 1, 3).
- Lower calf mortality (Farm 1, 2, 5).
- Improved ability to manage animal (e.g., calving) and weather (e.g., storms) events and reduce the impact on the farm, staff and animals (Farm 2, 5).
- Improved utilisation of supplementary feed (Farm 2, 6).
- Lower deaths from improved cow comfort, less exhausted staff and ability to identify sick cows earlier, and/or reduced diet risks from winter cropping. (Farm 1, 6).
- Ability to become self-contained. Reduced biosecurity risk (Farm 1).
- Less mastitis (Farm 6).
- Ability to capture rain water from roof to use for stock water resulting in water and power saving (Farm 2).
- Faster crop turnover time resulting from reduced soil damage (Farm 5).

Disadvantages

- Potential for bedding supply to become an issue if demand outstrips supply – availability and cost (Farm 1, 2, 3, 5).
- If calving in the shelter, harder to match cows and calves so have to complete calving checks more often or DNA test. However, much nicer to check cows in a dry barn close to the shed than out in the paddock (Farm 2, 3).
- Need to buy a tilling implement and have someone available to till bedding each day, although much easier than winter cropping (Farm 4).
- Need to be able to cash flow the large lump sum bedding cost (Farm 5).
- Increased mastitis (Farm 2).

5.5 Key lessons learnt and considerations

All farms found the transition to a composting shelter system was relatively easy. Cows and staff took to the system well, although in most cases there was a period in the first 24 hours where cows were getting used to the new bedding material. This was often characterised by cows prancing around on the bedding, similar to when calves and heifers are let out on to new pasture. Farm 6 stated;

> "*cows went crazy when they first went in. Thought they were going to break legs. But within a day or two the change in behaviour was phenomenal. They adjusted so quickly*".

While on most farms, the transition was as simple as putting cows in the shelter, Farm 4 completed the transition to a 24/7 indoor wintering system over a two-week period with cows gradually spending longer in the shelter each day rather than putting all cows in at once. The aim of this was to ensure successful composting by slowly adding stock and associated dung and urine to the bedding, rather than 'flooding' it with urine before the bedding temperature could build up.

Management of bedding was the one new skill that had to be learnt by all farms following incorporation of the shelter. Successful composting is key to ensuring a clean, warm and dry environment in the shelter and relies on good management of the bedding and correct shelter design. In order for successful composting to occur, bedding temperature and moisture levels need to be maintained in the optimum range. This requires regularly assessing and aerating the bedding, and taking corrective action as needed. Assessment of the bedding varied between farms with some having a dedicated staff member that would frequently read the bedding temperature and take dry matter samples, others relied on temperature readings only, and in some cases visual assessment only was used.

Understanding the corrective action to take when bedding temperature or moisture levels deviate from the optimum was noted as a key part of successful bedding management. For most, this meant having top-up material on hand when temperature levels needed to be lifted or if bedding was getting too wet. Frequency of full replacement of bedding was again dependent on how often the shelter was being used, stocking rate, shelter design and management of the bedding. Farm 1, which utilises the shelter for wintering only, is planning on a three-year bedding turnover timeframe (although has only been through one winter to date), whereas Farm 2 changes the bedding each year prior to calving. This farm, however, utilises the shelter year-round and has a smaller bedding space per cow (5.5 m^2/cow). Farm 5 also changes over the bedding annually, while Farm 6 changes the bedding over every 18 months.

Tilling of the bedding to create aeration within the compost pack is a critical component to stimulate the aerobic bacteria required for successful composting. Frequency of tilling across the farms interviewed varied and tended to relate to frequency of shelter use, stocking rate (bedding space per cow), and the importance that the individual farmer placed on bedding management. For most, this generally meant tilling a minimum of once per day when the shelter is in use while some tilled twice a day. Tilling was generally noted as a 10-20 minute job and was completed when cows were out of the shelter either at milking, while on a feed pad or out on pasture. A specialised tilling implement appropriate for the type and depth of bedding was used by each farm. Farm 1 has trialled a range of implements and now selects the specific implement for the type of bedding, moisture level and depth they wish to aerate to.

The type of bedding material used varied between the farms and in some cases has changed over time with availability and cost, but also as knowledge has been gained on how various materials compost. Most of the farms interviewed are using a fine wood chip or wood chip/sawdust mix. One farm has also been using miscanthus (a C4 perennial grass) as a top up material and is trialling growing miscanthus on farm in shade and shelterbelt rows to eventually be used as the bedding material. Farm 2 trialled miscanthus but found that it composted very quickly and didn't last as long. Similarly, Farm 5 didn't recommend sawdust on its own due to its high carbon content, resulting in a fast compost and quicker replacement time. On the other hand, Farm 1 is using a straight sawdust bedding (with miscanthus or oat straw as a top up material).

Given the importance of bedding management for the overall success of the composting shelter, farmers considering or building a composting shelter should visit and learn from those farmers who have prior experience.

Along with bedding management, there were a number of other key lessons or considerations that the farmers interviewed have learnt through their own experiences or found from their own research before they built. These are described below.

<u>Lessons learnt</u>

- For cows wintered in the shelter there is a significant reduction in the winter feed requirement compared to a 24/7 outdoor system. Farm 1, 2 and 4 noted that feed requirements need to be well calculated as it is very easy otherwise for cows to gain too much condition in the shelter and become too fat for calving. One farm noted a 50% drop in the winter feed allocation relative to their winter cropping system, with 8-9 kg DM/cow eaten being a common figure noted by the farmers interviewed. This compares to a typical winter diet of 10-16 kg DM/cow depending on the winter climate and body condition gain required.

- The amount of pasture built up through autumn and taken through into winter was another lesson learnt by Farm 1, and was also mentioned by Farm 3. Previous to the composting shelter being built on Farm 1, a large part of the pastoral area was taken up with winter cropping. With cows now housed in the shelter over winter and fed on a silage diet, the cropping area was removed thereby increasing the available pasture area. With a self-contained system also run, and therefore lower milking cow numbers (as replacements are now reared at home), the spring stocking rate and feed demand was much lower than the previous system. As a result, there was a large pasture surplus in the first spring following wintering in the shelter and, as no grazing had occurred, pasture quality had declined resulting in suppressed milk production. Going into the second winter with the shelter, a focus is now being placed on farming for their "new normal" system and ensuring the right amount of pasture is taken through into spring to meet quality requirements for the lower stocking rate.

- Three of the farms interviewed (Farm 2, 3 and 5) mentioned that during design of the shelter they built an effluent capture system beneath the bedding that linked in with the farm's effluent system. The idea was that this would capture any effluent coming out of the bottom of the bedding and mitigate any leaching risk. However, in practice all three farms noted that this was a wasted expense as no effluent has ever come out.

In contrast, Farm 1 originally built the shelter with a sealed loafing area using stabilised pit shingle. There was no drain built in to allow any water or leachate to drain away, as the assumption was that there would not be any leakage from the bedding. However, in reality a large build-up of liquid in the loafing area did occur (approximately 100 mm) which was unable to be soaked up in the composting process through the subsequent winter and spring. By late spring, a drain leading to a witness hole was installed to deal with the liquid which could then be pumped out. There were two likely causes of this liquid build-up identified:

i. The first was through the initial introduction of sawdust in summer. The sawdust had been stored outside and was very wet when it was loaded into the shelter. In hindsight, the farmer believes this should have been dried out before the winter by full depth aeration of the bedding.

ii. The second cause of liquid build-up occurred when the remains of a tropical cyclone hit causing rain to enter the shelter through the open sides and resulting in liquid ponding on top of the sawdust bedding. This occurred before construction of the shelter was completed, which meant shade sails on the exposed side walls had not yet been installed. Initially, the aeration equipment used over winter was not able to aerate down to the full depth of the bedding which further impeded the drying process.

The key learning from this experience, was that if moisture and temperature is kept at optimum levels, then no leaching or build-up of liquid should occur. However, if the composting process is sub-optimal (whether driven by climatic or management factors) and the bedding becomes overloaded with moisture, then leaching will occur and this liquid will need to be dealt with.

<u>Considerations other farms should think about before building:</u>

- "*Do your homework. Visit farms already operating with a composting shelter. Find out what they would do differently. Don't take any shortcuts*."
- Consider how the shelter will fit into the farm system and ensure it is designed and built for purpose. Think about:
    - Feeding area – will there be a feeding area with the shelter and will this be within or outside the shelter?
    - When will the shelter be used – how will this affect bedding space per cow and size of shelter?
    - Location - how does the shelter flow with farm infrastructure? Think about ease of access and height above groundwater table.
    - Effluent requirements. How will any concrete areas be cleaned and what impact will the additional effluent catchment area have on storage abilities?

- Will the shelter be designed to hold all of the cows?
    - Will cow numbers change?
    - Will the shelter be used for calving? How will mobs be separated?
    - Design – rigid or non-rigid roof, steel or timber build, clear-span width, location of internal poles and impact on ease of tilling, location and positioning to maximise ventilation and minimise moisture, roof pitch, ease of loading and unloading bedding inside shelter.
    - Depth of bedding.
    - How will the compost be used? Does it need somewhere to be stored to complete composting before applying to land?
    - What additional equipment will be needed (e.g., tractor, tilling implement)?

- Consider impacts to cash flow, particularly managing the cost of purchasing bedding.

- Ensure someone is going to be focused on monitoring bedding temperature and moisture and be prepared if intervention is needed.

- Understand that when considering a composting shelter "*it's not just about it costs this much and will save this much – all the benefit is environmental and animal welfare*".

As the interviews have indicated and with any large scale build or system redesign, there will inevitably be an aspect of trial and error and design or system adjustments. Some lessons learnt will have minor ramifications (e.g., feed supply going into winter, amount of winter feed offered) that can easily be corrected, but others could have very costly implications particularly when it relates to design of the shelter and management of the bedding. It is these aspects in particular that farmers contemplating a composting shelter should spend the most time considering and researching before building. As one farm pointed out;

> "*do your homework and don't take any shortcuts*".

5.6 Qualitative metrics

Understanding the impact of composting shelters on qualitative aspects of farm performance, including animal and staff welfare, was a key objective of the farmer interviews given these cannot easily be quantified through case study modelling, and are key drivers for building a composting shelter. A summary of the impacts of the shelter on animal and staff welfare and pasture management is provided below.

Animal welfare

All farms interviewed noted improved animal welfare resulting from the provision of a dry and warm environment during winter, as well as through the provision of shade over summer for those that used the shelter year-round. Improved animal welfare from the farmers' perspective was in the context of animal behaviour and having calmer and more content cows. Farm 1 noted that after being in the shelter;

"*the cows and the yearlings just get so quiet. They are different animals and the yearlings they're in here and they're just inquisitive. They're just so incredibly friendly. I AB [artificial breeding] the heifers for 3 weeks each year and we've been doing that for five or six years and we've noticed when we did it this year how incredibly different those animals were. They just look at you and they come up and lick your arm and they're almost actually a nuisance. They don't want to move, they just want to be my friend. And the cows are like that. They'll be lying down there and you'll just walk right past her and she won't even move. It's a lot more pleasurable and satisfying for staff."*

Similarly, Farm 2 noted;

"they come in here and obviously they're so happy and secure, they're just bodies and they're flat out. Flat out on their sides comatose and they're snoring. You can walk between them and they don't even open their eyes. They've got to be happy when they're like that".

Farm 6 has also observed that *"cows have become exceptionally calm, can calve any cow in the middle of the barn".*

When asked specifically about the impacts to mastitis and lameness, varied responses were received. Farm 1, 3, 4 and 5 stated no changes to mastitis cases in the herd since operating with the shelter, while Farm 6 noted a reduction in mastitis cows possibly due to the removal of winter cropping. In contrast, Farm 2 noted significant challenges with *E. coli* and Klebsiella bacteria which became more evident after the first few years of operating with the shelter and when bedding temperature dropped below the optimum range. The farm is now investing in a brush system to clean teats prior to milking in an effort to reduce cell count and mastitis cases.

In terms of lameness, all farms mentioned there had been no changes, with the exception of Farm 3 who noted a reduction in lameness as a result of cows spending less time on concrete and being fed in the shelter standing on the woodchip bedding as opposed to the previous concrete feed pad.

Farm 1, 2 and 5 also noted a reduction in calf mortality since shifting to calving in the shelter. Before construction of the shelter, Farm 1 noted that;

"*calves were constantly wandering off and getting lost in gullies and drains whereas now we have netting around and so they can't go anywhere. They're 100% accountable. It's all dry, no mud and water. Calves are dry*".

Three of the farms also noted a reduction in cow deaths. On Farm 6 where the death rate had always been low, there was a further reduction in cow deaths after incorporating the shelter which the farmer put down to cow comfort and having less exhausted staff that were more proactive and able to identify sick cows earlier on.

<u>Staff welfare</u>

All farms noted that the working environment for staff after building the composting shelter was more pleasurable particularly over the winter and calving period.

Farm 1 stated that the staff refer to it as a "*hobby farm*". The sharemilker has had to change the roster as the labour requirements compared to the previous winter cropping system have reduced significantly;

> "*530 cows and 145 yearlings are in the shelter over winter. There is no other stock on the farm so this is where the action is for winter. It takes one person 3.5 hours in a split shift but that's it. And it can bucket down with rain, and it can be a flood outside and it's still one person 3.5 hours and that's it, no more. What do you do with all the other manpower that's floating around? And the calving in the spring time, normally one of the staff would do 2,000 or 2,500 km on their motorbike in the spring time. I think he did something like 250 km this spring because all of the action was located here. Just stuff like that. It makes enormous difference to the workload. Hence the term hobby farm. But I can tell you it's not like that when you're running multiple mobs of cows on crop and then it rains. It's all hands on deck and you're up to here in mud and cows are slopping through mud and you can't tell what model tractor you've got. It's horrible. The change is just dramatic*".

Farm 6 noted a similar change with reduced workload over winter;

> "*now it takes 40 minutes to feed the cows and turn the bedding. Before a lot longer than 40 minutes and that doesn't take account of all of the repairs and maintenance from damage done to races*".

In contrast, the labour requirement on Farm 3, 4 and 5 did not change and on Farm 2 it increased but this was largely due to adopting a higher input feed system. The working conditions on all farms did however improve considerably. Farm 2 stated that it was far more relaxed and less stressful;

> "*I used to wake up in the middle of the night and it would be pouring with rain and I've gone through my life going 'oh need to go shift those cows or it is going to be a mess in the morning' but now I go to bed and don't even worry about it*".

Farm 3 also noted that having the shelter was "*good for morale and reduced fatigue*". Night checks during calving were much easier and drier, and on three of the farms cameras had been installed which allowed staff to check on the cows remotely.

<u>Pasture management</u>

Another key benefit that was difficult to quantify but came across from most of the farms interviewed was the improvement to pastures in terms of quicker recovery after drought or storm events, faster crop turnover times and improved pasture growth all resulting from better grazing management and the ability to prevent pugging or over-grazing by bringing cows into the shelter. Farm 3 described the farm as being "*three weeks ahead of surrounding farms*" following incorporation of their composting shelter, while Farm 6 mentioned that they are now able to be;

> "*more aggressive in spring and take more risks. We always have a back-up plan now*".

Four of the farms noted that with the incorporation of the composting shelters on farm there was improved ability to utilise pasture or increase cropping areas. Farm 1 noted there was an ability to milk longer into autumn and reduce the amount of feed carried through to winter, Farm 2 and 3 have increased the area of summer cropping (maize and/or rape), while Farm 5 likened the shelter to be equivalent to 10 ha of land;

> "*if we have the shelters, we need 10 ha less land as result of reduced damage, no pugging and a reduced lag phase following drought events*".

5.7 Conclusion

It is evident from the farmers interviewed, that the shift to a composting shelter system has been a beneficial investment. While most farmers noted financial gain following incorporation of the shelters, it was the intangible benefits to animal wellbeing, working conditions and environmental performance that were weighted most highly, and were the primary drivers of construction. These intangibles should therefore be considered when assessing the viability of composting shelters on farm.

Going forward, there will be continued pressure from society and markets to improve the outcomes of on-farm activities. Regulations such as Essential Freshwater, the associated National Policy Statement for Freshwater Management (NPS-FM) and National Environmental Standards for Freshwater (Freshwater NES), are requiring farmers to further minimise the impacts on water quality from farming, particularly from winter grazing. In addition, proposed changes to the Dairy Cattle Code of Welfare are likely to result in a stronger focus on managing environmental conditions for enhanced animal welfare outcomes. These pressures combined are likely to stimulate further farmer interest in composting shelters.

There is, however, still much to learn regarding management and operation of composting shelter systems on farm, as indicated by the varying responses in the farmer interviews and learnings over time. In particular, management of the bedding for efficient composting and longevity of bedding material is important. The composting process is complex and impacted by bedding material type, stocking rate, shelter design, tilling management and use of the shelter. Understanding the key factors for successful composting and being able to implement a system that provides longevity in bedding material will be a driving factor for profitability. Availability of bedding material was mentioned as a potential key drawback of the composting shelter system if significant uptake of the system occurs. Sourcing or finding ways to grow alternative bedding materials will be of particular importance to the long-term viability of the system.

There is also a need to build on the experiential knowledge of early adopters and quantify the performance of composting shelter systems against current farming practices. Phase Two of this report acts as a starting point to help quantify the physical, environmental and financial performance of the system taking into consideration impacts to animal welfare and staff wellbeing. This will need to be supported by further industry research and science.

6 Phase Two: Case Study Modelling

6.1 Status quo farm system

Phase Two of the case study modelling involves creation of the status quo farm system operated on Kokako Tuarua, with this used as the current-state scenario against which multiple composting shelter scenarios are evaluated.

The representative status quo system has been created from the actual system operated on Tuarua with the corresponding environmental and financial performance modelled in OverseerFM v6.4.3 and Microsoft Office Excel. Despite the farm currently being operated by a 50:50 sharemilker, the financial performance of the system has been analysed in the context of the whole farm so that the full system impacts of incorporating a composting shelter can be analysed. Actual financial data from the sharemilking business and owner's business from the past three seasons (2019-20 to 2021-22) have been used to create this model. All financial figures were updated to current value (2022) to enable a fair comparison against the investment which is priced at current dollars (2022).

6.1.1 Status quo physical performance

Kokako Pi Karere LP's dairy farm, Kokako Tuarua, is located in Lichfield, South Waikato. The property is 172.3 ha effective with an additional 20.1 ha of forestry and 2.8 ha of native bush and scattered trees. The farm sits predominantly on pumice soils (74%) with areas of allophanic soil interspersed (26%). Both soil types are deep, well-drained loams with high soil water holding capacity. The majority of the farm is flat to rolling (150 ha), with the exception of 22 ha of steep contour along the road boundary.

The farm receives a mean annual rainfall of 1,527 mm, with an average temperature of 12.8ºc (OverseerFM, 2022). Winters tend to be mild, whereas the summer and early autumn periods have become drier and dictate performance for the second half of the season.

Over the last three seasons the farm has wintered 570 – 580 cows to peak milk 565 cows with production averaging 410 kg MS/cow (1,344 kg MS/ha). The farm is currently run as a system 4 operation with 26% of feed imported as supplement and off-farm winter grazing. Supplements largely consist of maize silage (580 t DM), grass silage (95 t DM) and palm kernel (130 t). Maize and grass silage is predominantly fed on the feed pad, while palm kernel is fed in trailers. Winter grazing typically consists of 200 – 250 cows wintered off-farm for 4-6 weeks depending on feed availability. Remaining winter cows are grazed at home on oats (3 ha), silage and pasture. Turnips (6 ha) are also grown to provide additional summer feed. Home-grown pasture and crop eaten averages 12 t DM/ha. A 21% replacement rate is operated with all young stock grazed on the lease block from approximately 1 January until they return as in-calf heifers at the start of June, approximately 17 months later.

The farm is run with three full-time labour equivalents, plus management labour assumed at 0.2 FTE. Infrastructure consists of a 40-bail rotary cowshed, 300-cow uncovered feed pad, effluent pond and solids separation.

The status quo farm system parameters are displayed in Table 2.

Table 2: Status quo farm system indicators.

Physical Indicators: Status Quo System		
Farm Details		
Effective area (ha)	172.3	
Total farm area (ha)	201.5	
Cows wintered	580 (230 off-farm for 4 wks)	
Peak cows milked	565	
Stocking rate (cows/ha)	3.3	
Cow liveweight (kg)	525	
Breed	Friesian	
Planned start of calving	10-Jul	
Mean calving date	24-Jul	
Dry-off date	10-May	
Labour (FTE)	3.2	
Feed	t DM/ha	t DM/cow
Total feed eaten	17.2	5.3
Total imported feed eaten	5.3	1.6
- Supplements eaten	*4.8*	*1.5*
- Winter grazing	*0.5*	*0.2*
Pasture and crop eaten	12.0	3.7
Summer crop	Turnips (6 ha)	
Winter crop	Oats (3 ha)	
Feed conversion efficiency (kg DM/kg MS)	12.8	
Nitrogen use (kg N/ha)	150.0	
Production		
Production (kg MS)	231,650	
kg MS/cow	410	
kg MS/ha	1,344	
kg MS/kg lwt	0.78	
Days in milk	273	

6.1.2 Status quo financial performance

The status quo financial analysis is based on the physical system, using historical annual accounts adjusted to current (2022) value. A milk price of $9.00/kg MS has been assumed with earnings on Fonterra shares of $0.25/share. Full financial assumptions are provided in Appendix 10.1, with a summary of the financial performance indicators provided in Table 3.

Cash operating surplus (earnings before interest, tax, depreciation and amortisation; EBITDA) was $12,928/ha ($9.62/kg MS), with net cash income of $8,104/ha ($6.03/kg MS) and farm working expenses of $4,823/ha ($3.59/kg MS).

Table 3: Status quo financial performance indicators.

Financial Indicators: Status Quo System		
	$ per ha	$ per kg MS
Net cash income	12,928	9.62
Farm cash working expenses	8,104	6.03
Cash operating surplus (EBITDA)	4,823	3.59

6.1.3 Status quo environmental performance

The status quo farm system operated on Kokako Tuarua has been modelled in OverseerFM v6.4.3, based on the physical farm system assumptions and using Best Practice Data Input Standards (Overseer, 2019).

Nitrogen (N) losses to water (largely via leaching of urinary N) are 51 kg N/ha/yr while phosphorus (P) losses (largely via runoff) are 2.8 kg P/ha/yr. Nitrogen loss efficiency is modelled at 22.4 kilograms milk solids per kilogram of N loss (kg MS/kg N).

Biological greenhouse gas (GHG) emissions (methane and nitrous oxide) are modelled at 11.3 tonnes of carbon dioxide equivalents per hectare per year (t CO_2 eq./ha/yr) with methane (CH_4) and nitrous oxide (N_2O) contributing 79% and 21% to total biological emissions, respectively.

Within the farm gate, methane is the largest contributor to greenhouse gas emissions and is directly related to dry matter intake (DMI), with higher intakes associated with higher CH_4 emissions (DMI x 21.6 g/kg DM eaten). Effluent management also has a small impact on methane emissions resulting from anaerobic storage. Nitrous oxide (N_2O), however, is driven by various factors including nitrogen excreted on pasture (largely by urine), nitrogen fertiliser use, and soil type with higher losses on heavier soils.

Table 4: Status quo farm environmental indicators (OverseerFM v6.4.3).

Environmental Indicators: Status Quo System	
Nitrogen (N)	
Total N loss (kg N/yr)	10,341
N loss per hectare (kg N/ha/yr)	51
N loss efficiency (kg MS/kg N)	22.4
N surplus (kg N/ha/yr)	220
Phosphorus (P)	
Total P loss (kg P/yr)	570
P loss per hectare (kg P/ha/yr)	2.8
Biological greenhouse gas emissions (bGHG)	
bGHG (t CO_2 eq./ha/yr)	11.3
Methane (t CO_2 eq./ha/yr)	8.9
Nitrous oxide (t CO_2 eq./ha/yr)	2.4
bGHG efficiency (kg CO_2 eq./kg MS)	9.8

6.2 Composting shelter scenario modelling

A summary of the scenario analysis used for the case study modelling is provided in Figure 4 and described below.

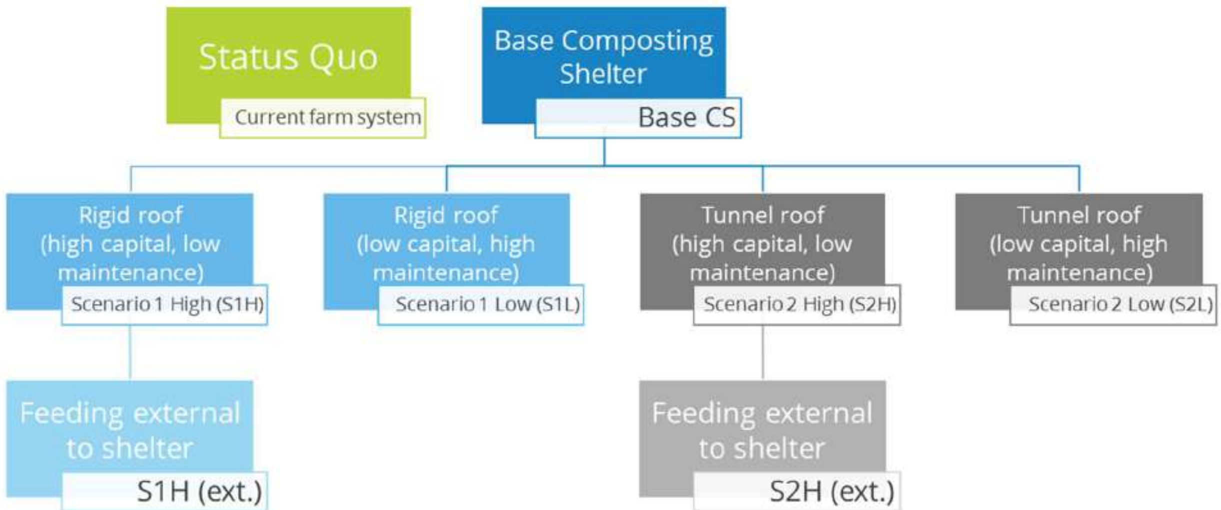

Figure 4: Scenario description.

The case study modelling analyses two core scenarios – the status quo farm system (current system) and the base composting shelter (CS) system which assumes in-shelter feeding.

The base composting shelter system is then varied based on the structural design (specifically roof type) and materials used as described below:

- Scenario 1H (S1H): Rigid roof structure, with in-shelter feeding and based on a high capital, low maintenance investment;
- Scenario 1L (S1L): Rigid roof structure, with in-shelter feeding and based on a low capital, high maintenance investment;
- Scenario 2H (S2H): Tunnel roof structure, with in-shelter feeding and based on a high capital, low maintenance investment;
- Scenario 2L (S2L): Tunnel roof structure, with in-shelter feeding and based on a low capital, high maintenance investment;

The high-capital cost scenarios are based on use of concrete for all feed infrastructure areas including the cow standing area, feed walls and tractor alleys, as well as for the compost retaining walls and turning aprons. In contrast, the low-capital cost scenarios substitute some of the concrete for timber and gravel surfaces, as described in Section 10.2.2 of the appendices.

Physical and environmental system assumptions remain the same between each of the composting shelter scenarios, however, there are changes to the financial assumptions for each.

In addition to these four models, a brief scenario analysis of utilising existing feed pad infrastructure as opposed to in-shelter feeding was also undertaken (S1H ext. & SIL ext.).

6.3 Base composting shelter farm system

6.3.1 Composting shelter physical performance

A full discussion on the assumptions used for the base composting shelter physical system modelling is provided in Section 10.2 of the appendices, with a summary provided in Table 6. Key physical performance indicators for the base composting shelter scenarios are displayed in Table 5.

Incorporation of composting shelters on farm was based on a hybrid year-round indoor-outdoor grazing system where cows spend part of each day in the shelter. Stocking rate remained the same as the status quo under the composting shelter system, however all cows were modelled to be wintered on-farm (as opposed to 230 cows wintered off-farm for four weeks) with 18 hours per day spent in the shelter over the non-lactating period.

Total feed imported (type and quantity) remained the same under both systems, however total feed (pasture and supplement) eaten increased by 6% under the composting shelter model. This was a result of an increase in feed utilisation (pasture and supplement) combined with a 5% increase in pasture growth from mitigating the impacts of over-grazing and winter pasture damage. Utilisation of supplements in the shelter was assumed at 95%. This compared to an average of 88% for the status quo with feed fed in the paddock and on the feed pad.

Along with increased feed eaten, the provision of composting shelters on farm allowed for improved body condition and an extended lactation period, reduced winter feed requirements and the mitigation of heat stress. These factors combined resulted in a 7% improvement in feed conversion efficiency from 12.8 kg DM/kg MS under the status quo to 12.0 kg DM/kg MS with the composting shelters. Similarly, production as a percentage of liveweight increased by 10% to 0.86 kg MS/kg liveweight.

Overall, milk production was modelled to increase by 14% with an additional 57 kg MS/cow (+186 kg MS/ha). The way in which an individual farmer alters the diet following incorporation of shelters on farm will be a key determinant of the impact to milk solids produced. For Kokako Tuarua, the type and quantity of feed imported was purposefully not changed to remove the confounding effects that feed inputs can have on the physical key performance indicators.

The 6% increase in feed conversion efficiency (the efficiency of converting dry matter into milk production) reflects the efficiencies that are modelled to be achieved from a composting shelter on this case study farm irrespective of feed inputs. Efficiencies able to be achieved may vary for other farm systems and regions. For instance, if a farm was shifting to a composting shelter and had no existing feeding infrastructure then the efficiency gains resulting from greater feed utilisation would be greater. The ability to feed in the shelter may then also result in the use of feeds that could otherwise not be used in a paddock situation. Similarly, some farms, particularly in the South Island, are likely to achieve greater feed efficiencies than the case study farm from housing cows over winter as compared to current intensive wintering cropping systems.

Table 5: Key physical performance indicators for the status quo and base composting shelter scenarios.

Physical Indicators	Status Quo		Base Composting Shelter Scenario	
Farm Details				
Effective area (ha)	172.3		172.3	
Total farm area (ha)	201.5		201.5	
Cows wintered	580 (230 off farm 4 wks)		580	
Peak cows milked	565		565	
Stocking rate (cows/ha)	3.3		3.3	
Cow liveweight (kg)	525		545	
Breed	Friesian		Friesian	
Planned start of calving	10-Jul		10-Jul	
Mean calving date	24-Jul		24-Jul	
Mean dry-off	10-May		4-Jun	
Labour (FTE)	3.0		3.0	
Feed	t DM/ha	t DM/cow	t DM/ha	t DM/cow
Total feed eaten	17.2	5.3	18.3	5.6
Total imported feed eaten	5.3	1.6	4.4	1.4
- *Supplements eaten*	*4.8*	*1.5*	*4.4*	*1.4*
- *Winter grazing*	*0.5*	*0.2*	*0.0*	*0.0*
Pasture and crop eaten	12.0	3.7	13.6	4.2
Summer crop	Turnips (6 ha)		none	
Winter crop	Oats (3 ha)		none	
Feed conversion efficiency (kg DM/kg MS)	12.8		12.0	
Nitrogen use (kg N/ha)	150		150	
Production				
Production (kg MS)	231,650		263,719	
kg MS/cow	410		467	
kg MS/ha	1,344		1,531	
kg MS/kg lwt	0.78		0.86	
Days in milk	273		292	

Table 6: Summary of physical system assumptions used for the composting shelter modelling.

Grouping	Assumption	Status quo	Composting Shelter Scenarios 1 & 2	Appendix
Overview	Feed system	• System 4	• System 4 (no change to quantity or type of supplements imported)	10.2
	Wintering	• 230 cows wintered off-farm for four weeks	• All cows wintered on farm	10.2.8

	Grazing system	• 24/7 pastoral grazing	• Year-round hybrid indoor-outdoor grazing system
			  • Spring (10 July – 31 Oct): 4 hours per day in shelter
			  • Late spring to early autumn (1 Nov – 31 Mar): 5 hours per day in shelter
			  • Late autumn (Apr – end lactation): 4 hours per day in shelter
			  • Non-lactating period: 18 hours per day in shelter
			• Annual average of 6.6 hours per cow per day in the shelter equivalent to 100 full 24-hour days (27% of the year).
				10.2.1

Shelter design	Space	• n/a	• Year-round use with 8.5 m^2/cow of space within shelter.	10.2.2
	Roofing	• n/a	• Scenario 1 (high and low) based on rigid roof design • Scenario 2 (high and low) based on fabric tunnel roof design • High cost models utilise concrete for surrounding areas • Low cost models utilise a combination of concrete, timber and gravel for surrounding areas	10.2.2
Pasture and cropping	Monthly pasture production	• Based on historical farm performance	• 5-10% increase in winter and early spring (Jun – Sep) growth rates from avoidance of pugging • 10-20% increase in late summer and early autumn growth rates from avoidance of over-grazing	10.2.4

	Annual pasture production	• 14.0 t DM/ha grown	• 5% increase in annual pasture production • 14.6 t DM/ha grown	10.2.4
	Cropping	• 6 ha summer turnips • 3 ha winter oats	• none	10.2.4
Cow condition	Cow liveweight and body condition	• 525 kg liveweight	• 545 kg liveweight • + 0.5 body condition score average	10.2.6
Lactation	Milk production	• 410 kg MS cow; 1,344 kg MS/ha	• 467 kg MS/cow; 1,531 kg MS/ha	10.2.11
	Lactation length	• Average days in milk per cow: 273 days • Maximum lactation length: 290 days	• Average days in milk per cow: 292 days • Maximum lactation length: 315 days	10.2.7
	Dry period	• 10 May dry off • 75 day average dry period, minimum 61 days dry	• Staggered dry off date based on calving date. • Mean dry off 4 June • 61 day average dry period, minimum 50 days dry	10.2.7
	Calving	• Planned start of calving: 10 July • Calving mid-point: 24 July	• Planned start of calving: 10 July • Calving mid-point: 24 July	10.2.7
Winter feed	Winter feed requirements	• Feed eaten: 9.3 kg DM/cow/day • Feed offered: 11.1 kg DM/cow/day	• Feed eaten: 8.1 kg DM/cow/day (-13%) • Feed offered: 8.9 kg DM/cow/day (-20%)	10.2.8
	Winter feed diet	• Maize silage and pasture	• Maize silage, grass silage and pasture	10.2.9
	Feed utilisation	• Supplements on feed pad: 90% • Pasture (winter): 80%	• Supplements in shelter: 95% • Pasture (winter): 85%	10.2.9
Heat stress	Days warm enough to reduce production	• 117 days	• 117 days • 6.76 kg MS/cow/yr increase from mitigating heat stress	10.2.10

6.3.2 Composting shelter environmental performance

A full discussion on the assumptions used for the composting shelter environmental modelling is provided in Section 10.4 of the appendices. The physical summary provided in Table 6 details these assumptions.

The key environmental performance indicators, as modelled in OverseerFM v6.4.3, for the base composting shelter system are displayed in Table 7.

The incorporation of composting shelters on farm under the described hybrid indoor-outdoor grazing system reduced nitrogen (N) leaching to 28 kg N/ha/yr, equivalent to a 45% reduction compared to the status quo model. Of the total reduction in N loss, 87% (20 kg N/ha/yr) was attributed to a reduction in urinary N leaching as result of housing cows off pasture for 27% of the year (6.6 hours per day on average). The remaining 13% (3 kg N/ha/yr) was attributed to the removal of 6 ha of summer cropping and 3 ha of winter cropping as represented by the change to other N leaching (Figure 5).

In addition, there is also the benefit of reduced urinary N leaching on the grazing block where 230 cows were previously wintered under the status quo system. This impact, however, is not accounted for in the farm-level modelling.

The efficiency of nitrogen use in the base composting shelter system improved significantly. Nitrogen loss efficiency, the amount of milk produced per kilogram of N leached, more than doubled while the farm's nitrogen surplus reduced by 36%.

Methane emissions are expected to increase under the composting shelter scenario with increased feed eaten and higher cow numbers on farm over winter, which effectively shifts methane emissions from off-farm to on-farm. The increase in methane emissions is estimated by OverseerFM at +15%. However, this does not take into account the improved feed conversion efficiency (kg DM/kg MS) from increased feed utilisation in the shelter, or the reduction in maintenance energy requirements from reducing environmental stressors which are ignored by OverseerFM (Wheeler, 2018).

Nitrous oxide emissions, on the other hand, have not been provided for the base composting shelter scenarios. This is because OverseerFM in its current form (v6.4.3) does not model the aerobic composting process within the shelter which is expected to have a large effect on nitrous oxide emissions. Although some nitrous oxide is likely to be released from the compost while it is in the shelter, this is likely to be more than compensated by a reduction in on-paddock release of nitrous oxide from deposited urine. However, research is required to quantify this.

Table 7: Key environmental performance indicators for the status quo and base composting shelter system.

Environmental Indicators	Status Quo	Base Composting Shelter
Nitrogen (N)		
Total N loss (kg N/yr)	10,341	5,714
N loss per hectare (kg N/ha/yr)	51	28
- Urinary N loss (kg N/ha/yr)	*40*	*20*
- Other N loss (kg N/ha/yr)	*11*	*8*
N loss efficiency (kg MS/kg N)	22	46
N surplus (kg N/ha/yr)	220	141
Phosphorus (P)		
Total P loss (kg P/yr)	570	576
P loss per hectare (kg P/ha/yr)	2.8	2.9
Biological greenhouse gas emissions (bGHG)		
bGHG (t CO_2 eq./ha/yr)	11.3	-
Methane (t CO_2 eq./ha/yr)	8.9	10.2
- methane efficiency (kg CO_2 eq./kg MS)	*7.7*	*7.8*
Nitrous oxide (t CO_2 eq./ha/yr)	2.4	-
- nitrous oxide efficiency (kg CO_2 eq./kg MS)	*2.1*	-
bGHG efficiency (kg CO_2 eq./kg MS)	9.8	-

**N_2O emissions have not been provided for the base composting shelter scenarios, given OverseerFM v6.4.3 does not model the composting process within the shelter.*

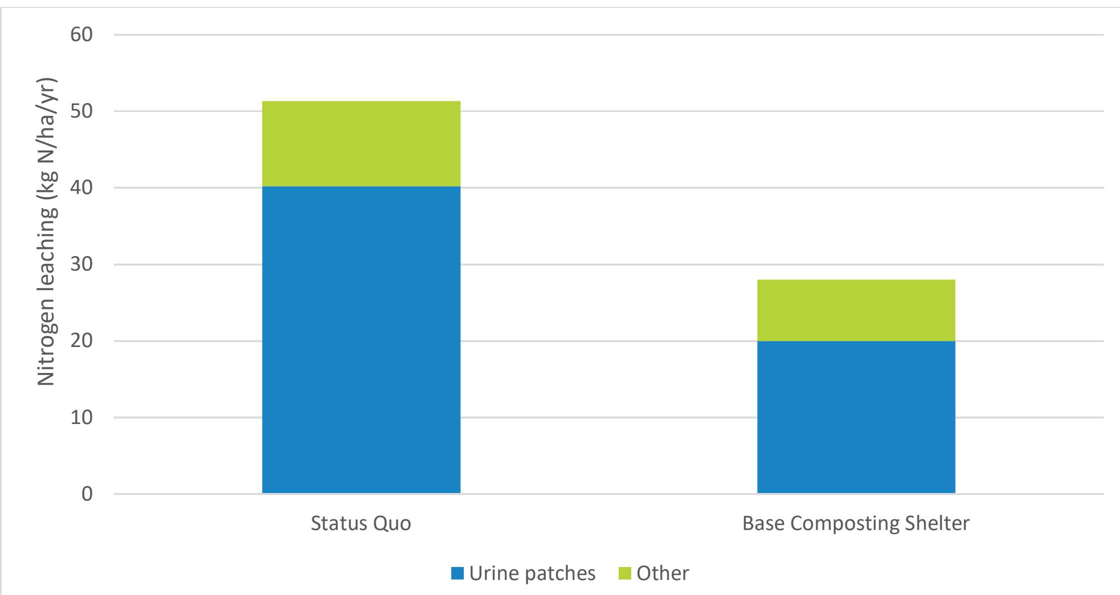

Figure 5: Urinary N loss and other N loss as a proportion of total N loss in the status quo and base composting shelter scenarios.

6.3.3 Composting shelter financial performance

A full discussion on the assumptions used for the composting shelter financial system modelling is provided in Section 10.3 of the appendices.

Key financial performance indicators are provided in Table 8 and are compared against the status quo. Adjustments to the composting shelter financial model were made in accordance with physical assumptions.

Financial metrics for the composting shelter high and low-capital scenarios (S1H & S2H; S1L & S2L) are similar with the key difference being the level of repairs and maintenance (R&M) expenditure. The low-capital models include an additional $7,000 of R&M per annum related to repairing timber boards within the shelter and re-metalling surrounding areas, as discussed in Section 10.3.8 of the appendices.

Net cash income for both high and low-capital models increased by 14% to $14,658/ha ($9.58/kg MS), largely as a result of increased production. The net change to farm working expenses under the high and low scenarios was a 3% increase totalling $8,246/ha ($5.39/kg MS) for the high-capital models, and $8,287 ($5.41/kg MS) for the low-capital models. The key changes to expenses included a reduction in off-farm winter grazing, however this was offset by the new bedding expense and increased R&M. Overall, total cash operating surplus (earnings before interest, tax, depreciation and amortisation; EBITDA) increased by 33% to $6,412/ha ($4.19/kg MS) and $6,371/ha ($4.16/kg MS) for the high and low-capital models, respectively. This cash is then available for debt servicing, tax, capital upgrades, reinvestment or distributions.

Table 8: Composting shelter financial performance indicators.

	Status Quo		Composting Shelter (S1H & S2H)		Composting Shelter (S1L & S2L)	
Financial Indicators	**$/ha**	**$/kg MS**	**$/ha**	**$/kg MS**	**$/ha**	**$/kg MS**
Net cash income	12,928	9.62	14,658	9.58	14,658	9.58
Farm cash working expenses	8,104	6.03	8,246	5.39	8,287	5.41
Cash operating surplus (EBITDA)	4,823	3.59	6,412	4.19	6,371	4.16

6.3.4 Composting shelter investment analysis

Discounted cash flow analyses have been created for the status quo farm system and each of the composting shelter scenarios (Figure 4):

- Scenario 1H (S1H): Rigid roof structure, with in-shelter feeding and based on a high capital, low maintenance investment;
- Scenario 1L (S1L): Rigid roof structure, with in-shelter feeding and based on a low capital, high maintenance investment;
- Scenario 2H (S2H) : Tunnel roof structure, with in-shelter feeding and based on a high capital, low maintenance investment;
- Scenario 2L (S2L): Tunnel roof structure, with in-shelter feeding and based on a low capital, high maintenance investment;
- Scenario 1H (ext.): Rigid roof structure with feeding on existing feed pads external to the shelter. Capital costs based on a high-capital, low maintenance investment.
- Scenario 2H (ext.): Tunnel roof structure with feeding on existing feed pads external to the shelter. Capital costs based on a high-capital, low maintenance investment.

Discounted cash flows are pre-interest and tax to allow comparisons with other farm businesses, which may have different capital structures and tax obligations. Two sets of cash flows based on alternative investment horizons have also been created. A shorter 25-year investment period reflects standard investment timeframes, while a 50-year investment period recognises a longer-term Māori view while also aligning with the expected lifespan of the composting shelter infrastructure.

The investment performance of the whole farm system under both the status quo and composting shelter scenarios have first been evaluated on a 'whole-farm' basis using a criterion of internal rate of return (IRR). The investment returns of the composting shelter investments have then been calculated, also using the IRR criterion, by determining the change to the cash flows in each year relative to the status quo (known as a 'marginal analysis'). Salvage values of the composting shelter structure at the end of the investment period have been varied to understand the impact of shelter lifespan to the performance of the investment.

Because the investment analyses are based on discounted cash flows for the life of the investment, and with all capital fully costed at the time it is incurred, it is not appropriate to include non-cash depreciation. That would lead to double counting. However, in any business there is a need for capital renewal. Accordingly, a capital renewal allowance of approximately $130,000 is included each year in the EBIT (earnings before interest and tax) cash flows for the whole-farm business appraisals, both status quo and for the composting shelter scenarios. Additional capital renewal has been included at the appropriate times for the composting investment options.

6.3.4.1 Base composting shelter cash flows

Results and interpretation of the investment analyses for the in-shelter feeding composting models are presented in Table 9 to Table 11. Examples of the full discounted cash flow analyses are provided in Appendix 10.7 for the status quo and a composting shelter scenario (S1H).

Table 9: Summary of whole business pre-tax performance of composting shelter scenarios (S1H, S1L, S2H, S2L) relative to the status quo (SQ) as measured by internal rate of return (IRR; %)

	Investment Period		
	50 years	25 years	
SQ	6.3%	6.4%	
Salvage value on investment	**0%**	**50%**	**0%**
S1H	6.8%	6.7%	6.5%
S1L	7.0%	6.9%	6.8%
S2H	7.2%	7.2%	7.0%
S2L	7.4%	7.4%	7.3%

Table 10: Summary of the pre-tax marginal return on investment for each of the composting shelter scenarios (S1H, S1L, S2H, S2L) as measured by internal rate of return (IRR; %).

	Investment Period		
	50 years	25 years	
Salvage value on investment	**0%**	**50%**	**0%**
S1H	8.5%	7.8%	7.0%
S1L	9.5%	8.9%	8.2%
S2H	11.0%	10.6%	10.1%
S2L	7.4%	7.4%	7.3%

Table 11: Summary of the pre-tax marginal net present value (NPV) for each of the composting shelter scenarios (S1H, S1L, S2H, S2L) at avrying disocunt rates.

Investment terms		Discount rate	S1H	S1L	S2H	S2L
50 years	0% salvage value on investment	4%	2,431,814	2,720,373	2,957,127	3,230,754
		6%	1,007,615	1,290,729	1,571,210	1,839,674
		8%	154,927	432,798	736,322	999,814
25 years	50% salvage value on investment	4%	1,426,908	1,659,180	1,887,853	2,108,106
		6%	559,176	807,329	1,075,781	1,311,093
		8%	-44,699	211,262	503,963	746,679
25 years	0% salvage value on investment	4%	958,873	1,247,432	1,549,983	1,823,610
		6%	268,463	551,577	865,918	1,134,382
		8%	-226,886	50,985	372,443	635,936

Net present value (NPV) is a metric used to determine the present value of all future cash flows generated by an investment at a specific discount rate over a specific lifespan, including the initial capital investment. Typically, an entities weighted average cost of capital (WACC) is used as the discount rate. If Kokako had a WACC of 6% (discount rate) then the S2H composting shelter scenario is worth a net value of $1,571,210 to the business today (Table 11). A negative NPV indicates that a business will make a net loss on the investment and therefore shouldn't proceed.

These results demonstrate that providing Kokako's WACC is below 8%, overall business profitability is improved by investing in any of the composting shelter scenarios regardless of shelter lifespan, investment period and salvage value (Table 11). Assuming a 50-year shelter lifespan and investment horizon, the NPV for the lower capital scenarios (S2H and S2L) is still positive at a 10% discount rate.

Comparison of the IRR in the 25-year and 50-year scenarios indicates that a composting shelter lifespan beyond 25 years is not essential to provide increased returns relative to the status quo. The difference between 50% and 0% salvage value at 25 years has a minimal impact on IRR (0.1% to 0.2%).

The successive increase in marginal IRR for each of the composting shelter scenarios reflects the same level of revenue between structure type and capital model, for little additional cost and investment (Table 10). For instance, while the lower capital models (S1L and S2L) have increased annual maintenance costs (+$7,000), this is insignificant given the much lower capital costs (i.e., -$300,100 for the rigid roof structure, and -$284,570 for the tunnel roof structure). Similarly, whilst the tunnel roof scenarios (S2H & S2L) include additional capex of $132,000 (16% of the overall structure cost) every 15 years for replacement of the roof, this additional capital investment is insufficient to outweigh the overall lower capital cost of the tunnel roof structure at the outset.

Of note, is the magnitude of change in the marginal IRR between the low and high-capital models (Table 10). For the rigid roof structures (S1), at a 50-year investment period, the difference in IRR is +1% in favour of the lower capital investment. This is expanded to +1.7% for the tunnel roof structures (S2), also in favour of the lower capital cost model. The key capital cost change between these models is the amount of concrete, which under these scenarios, has a large impact on return.

Some farmers opt to include concrete for large parts of the composting structure and surrounding area including tractor lanes, feed alleys and walls, cow stand areas, compost retaining walls, and connections to other farm infrastructure (i.e., the dairy yard). The high-capital models (S1H and S2H) reflect this scenario. In contrast, some farmers choose to limit concrete and may only include it for the cow stand area, compost retaining walls and turning apron, utilising other materials (i.e., timber, gravel or compacted rock) as a substitute. This is what the S1L and S2L scenarios reflect. Further still, some farmers may choose to limit concrete even further having no concrete within the shelter and very minimal concrete surrounding the structure. They may only have the base of the feed alley as concrete. Often, this decision is made on the basis of potential animal health implications (e.g., lameness), as well as minimising initial cost. This scenario has not been modelled but greater IRRs still could be expected, provided maintenance costs and bedding costs which may require more frequent top-ups (particularly around the feeding area) can be minimised.

There is no right or wrong when it comes to determining shelter type (i.e., rigid roof or tunnel roof) or extent of concrete. In many cases, the farm location and system specifics may refine the number of options available. However, it is worth understanding the impact capital costs can have on the level of returns so that informed decisions can be made.

The other key parameter that drives capital cost is the shelter itself. For the rigid roof scenarios, cost of the shelter is 59% and 66% of the overall capital investment for the high and low models, respectively. Similarly, for the tunnel roof scenarios, cost of the shelter is 46% to 54% of the overall capital investment for the high and low models, respectively. The shelter, and more specifically the roof, is therefore a key component of the overall capital cost, which itself is driven by the space per cow allocation within the shelter.

For this project, each of the scenarios are based on a design parameter of 8.5 m^2/cow. For the rigid roof scenarios (S1H and S1L), this results in a capital cost of \$315/m^2 for the shelter alone, and \$180/m^2 for the tunnel roof scenarios (S2H and S2L). In general terms, the overall cost of the shelter can be pro-rated based on square metres per cow. Therefore, shelters with smaller space allowances will be cheaper to build compared to those with greater space allowances. Annual running costs and frequency of replacement, however, is likely to be higher for shelters with lower space allowances.

The impact of shelter type and extent of capital investment at a whole business level is much less, compared to the marginal returns, with only an average 0.7% increase in business return from the lowest cost scenario (S2L) compared to the highest cost scenario (S1H). This being the case, business liquidity and the ability to cash flow the initial capital outlay may determine structure type and extent of expenditure as opposed to long-term return.

Overall, discounted cash flow analyses indicate that at a whole farm business level, a composting shelter system would be beneficial to Kokako Tuarua from a financial perspective, assuming a weighted average cost of capital of less than 8%. NPV returns can be positive at higher discount rates, but relies on lower capital costs whether this is achieved through structure design or extent of associated concrete works.

Where farm management structure varies, i.e., under a 50/50 sharemilking structure, many of the financial benefits would be shared with the sharemilker. With capital costs typically paid for by the land owner, the net benefit for Kokako would be reduced under a sharemilking structure.

6.3.4.2 Risk analysis

Sensitivity analyses have been completed for key system assumptions impacting on farm revenue and expenses to understand the impact to the marginal pre-tax returns at a 50-year investment period (Table 12 and Table 13). For these analyses, two composting shelter scenarios (S1H and S2H) have been selected to provide an example of the change in IRR to key parameters.

Risk analyses have not been completed on capital costs as this is essentially covered through the four main composting shelter scenario models (S1H, S1L, S2H, and S2L).

INCOME

Milk price and production are the two key drivers of farm revenue. Varying the level of production also encompasses risk analysis on the key production drivers including pasture growth and feed conversion efficiency.

Milk price has a significant impact on the performance of the composting shelter scenarios, with an average +/- 1.0% and 1.5% change to the marginal IRR for every $1.00/kg MS increase or decrease in the milk price for S1H and S2L, respectively (Table 12 and Table 13). However, given that the composting investment performs well at $9.00/kg MS (marginal IRR of 8.5% - 12.7%, depending on capital costs), milk price would need to drop to $7.00/kg MS and $5.00/kg MS for S1H and S2L, respectively, to equal the returns of the status quo system. Below these milk price levels, the returns from S1H and S2H would be lower than the status quo system.

While the investment itself is robust to changes in milk price, the returns from the whole farm business are highly dependent on the milk price, with this situation being the case for both the status quo and for the systems incorporating composting shelter investments. Accordingly, the financial risks to the whole farm business were largely independent of the investment decision relating to the composting situation.

The change to the additional production assumed above the status quo, for the composting shelter scenario has a lesser impact to the marginal return than milk price. For every 10% increase or decrease (equivalent to +/- 11 kg MS/cow from the assumed +57 kg MS/cow in the base composting shelter scenario), the IRR alters by 0.9% for S1H and 1.3% for S2L.

At a $9.00/kg MS milk price, the additional production required from the composting shelter system to breakeven with the status quo needs to be at least +31 kg MS/cow for the low-capital scenario (S2L) and at least +44 kg MS/cow for the high-capital scenario (S1H). This demonstrates the importance of increasing milk production for the case study farm. For farms where the cost structure can be significantly reduced following incorporation of shelters (i.e., systems where in-shelter wintering could replace intensive winter grazing on crops), the level of additional milk production needed to breakeven with the pre-barn system will likely be much less, and there may be some situations where no additional milk production is required.

Table 12: Impact of milk price and production on the marginal pre-tax internal rate of return (IRR) for Scenario 1H.

		Milk price ($/kg MS)		
		7.50	**9.00**	**10.50**
Additional production (kg MS)	**-50%** (+28 kg MS/cow)	2.5%	3.5%	4.4%
	-25% (+43 kg MS/cow)	4.8%	6.1%	7.3%
	0 (+57 kg MS/cow)	6.9%	8.5%	10.0%
	25% (+71 kg MS/cow)	8.8%	10.7%	12.5%
	50% (+85 kg MS/cow)	10.6%	12.8%	15.0%

Table 13: Impact of milk price and production on the marginal pre-tax internal rate of return (IRR) for Scenario 2L.

		Milk price ($/kg MS)		
		7.50	**9.00**	**10.50**
Additional production (kg MS)	**-50%** (+28 kg MS/cow)	4.4%	5.7%	6.9%
	-25% (+43 kg MS/cow)	7.6%	9.4%	11.0%
	0 (+57 kg MS/cow)	10.5%	12.7%	14.9%
	25% (+71 kg MS/cow)	13.2%	15.9%	18.5%
	50% (+85 kg MS/cow)	15.7%	19.0%	22.1%

EXPENSES

Bedding costs are a significant new expenditure item in the composting shelter scenarios that is directly related to bedding space per cow and depth allocations. Uncertainty exists with regard to the required bedding space per cow and depth parameters needed for efficient and successful composting. The assumed metrics of 7.4 m^2/cow and a depth of 800 mm, with full replacement every two years, is considered conservative.

Sensitivity analyses have been completed to understand the impact that frequency of bedding replacement and cost of replacement has to the marginal composting shelter returns (Table 14 and Table 15).

Overall, frequency of bedding replacement has a far greater impact on investment returns than the actual cost of replacement which includes supply, removal, spreading and install. Extending the use of the bedding from one year to the assumed two years, results in an average 1.9% and 2.8% increase to the marginal IRR for S1H and S2L, respectively. However, further increases in the lifespan of the bedding from two years to three years has a much lesser impact – increasing the IRR by an average of 0.6% and 1.0% for the high and low cost scenarios, respectively. This indicates that there is financial merit in providing sufficient bedding space per cow and bedding depth (which has higher capital costs) to allow two years of use from the bedding. Beyond two years, however, the benefit from achieving greater lifespan out of the bedding diminishes as the cost-saving becomes smaller.

There are also specific practicalities that need to be kept in mind when considering replacement of bedding. This includes timing of replacement, with a pre-winter change typically beneficial. This allows new dry bedding to be installed prior to the wet months which can create challenges for keeping moisture content within the compost low.

Table 14: Impact of frequency of bedding replacement and cost of replacing bedding on the marginal pre-tax internal rate of return (IRR) for Scenario 2H.

		Bedding replacement frequency (years)		
		1	2	3
Cost of replacing bedding	20%	5.8%	8.1%	8.9%
	10%	6.2%	8.3%	9.0%
	0	6.6%	8.5%	9.1%
	-10%	7.0%	8.7%	9.2%
	-20%	7.4%	8.9%	9.4%

Table 15: Impact of frequency of bedding replacement and cost of replacing bedding on the marginal pre-tax internal rate of return (IRR) for Scenario 2L.

		Bedding replacement frequency (years)		
		1	2	3
Cost of replacing bedding	20%	8.8%	12.1%	13.3%
	10%	9.3%	12.4%	13.5%
	0	9.9%	12.7%	13.7%
	-10%	10.4%	13.0%	13.9%
	-20%	11.0%	13.3%	14.1%

6.3.4.3 Analysis of external feeding scenarios

Many farms, like Kokako Tuarua, will have existing feeding infrastructure which they may choose to utilise as opposed to adding feed and tractor lanes to the shelter. In that scenario, the composting shelters act purely as shelters and are provided with access to external feed pads. Scenario 1H (ext.) and Scenario 2H (ext.) analyse the change to the composting shelter system from using existing feed pads.

Changes to the base composting shelter assumptions for S1H (ext.) and S2H (ext.) compared to the base composting shelter models are summarised below:

- Shelter design based on Scenario 1H and 2H (high-capital, low maintenance), but adjusted to exclude tractor lanes, the concreted cow standing area and feed walls. Size of the shelter therefore reduced to 77 m by 18 m for the rigid roof scenario (S1H ext.) and 70 m by 20 m for the tunnel roof scenario (S2H ext.). A concrete turning apron and connection to the feed pad at the front of the shelters is still included however the length is reduced to 8 m.

- Compost area was assumed to remain the same at 7.4 m^2/cow. There is potential for the bedding area to be further reduced with external feeding given much of the urination and defecation will occur while feeding outside of the shelters.

- External feed pads are uncovered with feed utilisation of 90%.

- Time in shelter per cow reduces by two hours per day for feeding on the feed pad, however total time off pasture remains the same.

The associated impacts to the physical farm system, compared to the base composting shelter models, are:

- Feed eaten reduced by 0.1 t DM/cow to 5.5 t DM/cow due to a reduction in feed utilisation.

- Production subsequently reduced by 5,650 kg MS to 258,069 kg MS (457 kg MS/cow; 1,498 kg MS/ha).

The associated impacts to farm financial performance, compared to Scenario 1H and 2H, are:

- Net cash income reduced by $51,924 to $2,473,677 ($14,357/ha; $9.59/kg MS). As no change to farm working expenses was assumed, cash operating surplus reduced by the same amount to $1,052.867 ($6,111/ha; $4.08/kg MS).

Discounted cash flow analyses were then created for scenarios S1H (ext.) and S2H (ext.), based on the expected cash operating surplus and capital outlay, to understand the impacts of feeding cows external to the shelter on existing uncovered feed pad infrastructure, as opposed to within shelter (Table 16 and Table 17).

Table 16: Comparison of whole business pre-tax IRR of the external feeding composting shelter scenarios (S1H ext. & S2H ext.) relative to the corresponding internal feeding scenarios (S1H & S2H).

	Investment Period		
	50 years	25 years	
Salvage value on investment	0%	50%	0%
S1H	6.8%	6.7%	6.5%
S1H (ext.)	6.9%	6.8%	6.7%
S2H	7.2%	7.2%	7.0%
S2H (ext.)	7.2%	7.2%	7.1%

Table 17: Comparison of the marginal pre-tax IRR of the external feeding composting shelter scenarios (S1H ext. & S2H ext.) relative to the corresponding internal feeding scenarios (S1H & S2H).

	Investment Period		
	50 years	25 years	
Salvage value on investment	0%	50%	0%
S1H	8.5%	7.8%	7.0%
S1H (ext.)	9.4%	8.8%	8.2%
S2H	11.0%	10.6%	10.1%
S2H (ext.)	12.8%	12.4%	12.1%

The key difference in cash flows between the internal (S1H and S2H) and external (S1H ext. and S2H ext.) scenarios is the milk income and initial capital outlay. Milk production for the uncovered external feed pads is assumed to be 2% less (-10 kg MS/cow) than for the in-shelter feeding scenarios as a result of reduced feed utilisation from having uncovered feeding areas and less time to eat (90% compared to 95%).

Capital outlay reduced under the external feeding scenarios relative to feeding in the shelter with all concrete for feed alleys, walls and tractor feeding lanes no longer required. As the feed pads already existed, there was no capital associated with this aspect. For S1H (ext.), the reduction in capital outlay compared to internal feeding (S1H) is -32% (-$788,630), and for S2H (ext.), the reduction in capital outlay compared to internal feeding (S2H) -37% (-$670,288).

This reduction in capital outlay provided increased performance from the composting shelter investment at +0.9% for the rigid roof structures, and +1.8% for the tunnel roof structure over a 50-year period. Comparison of the marginal IRR at the 25-year scenarios showed little impact to the investment performance.

Overall, the change to whole business IRRs from shifting the location of feeding to the existing feed pads were minor (less than -0.2% for both scenarios). This suggests that where farms have existing feed pad infrastructure suitable to provide good feed utilisation (i.e., concreted pads), the choice of whether to continue feeding on the feed pad or shift to feeding inside the shelter is unlikely to have a large influence on whole business returns. Therefore, the ability to cash flow the initial capital outlay of in-shelter feeding infrastructure, specifically concrete, should have a larger influence on decision-making than long-term returns.

Where the quality of feed pad is sub-standard, resulting in either poor feed utilisation or animal health issues, greater outcomes will likely be possible by shifting feeding within the shelter.

7 Evaluation of Composting Shelter System

7.1.1 Te Taiao evaluation

Evaluation of the composting shelter model has been completed through a Te Taiao lens and demonstrates the ability of composting shelters to provide an environment in which the land, animals and people can thrive (Figure 6).

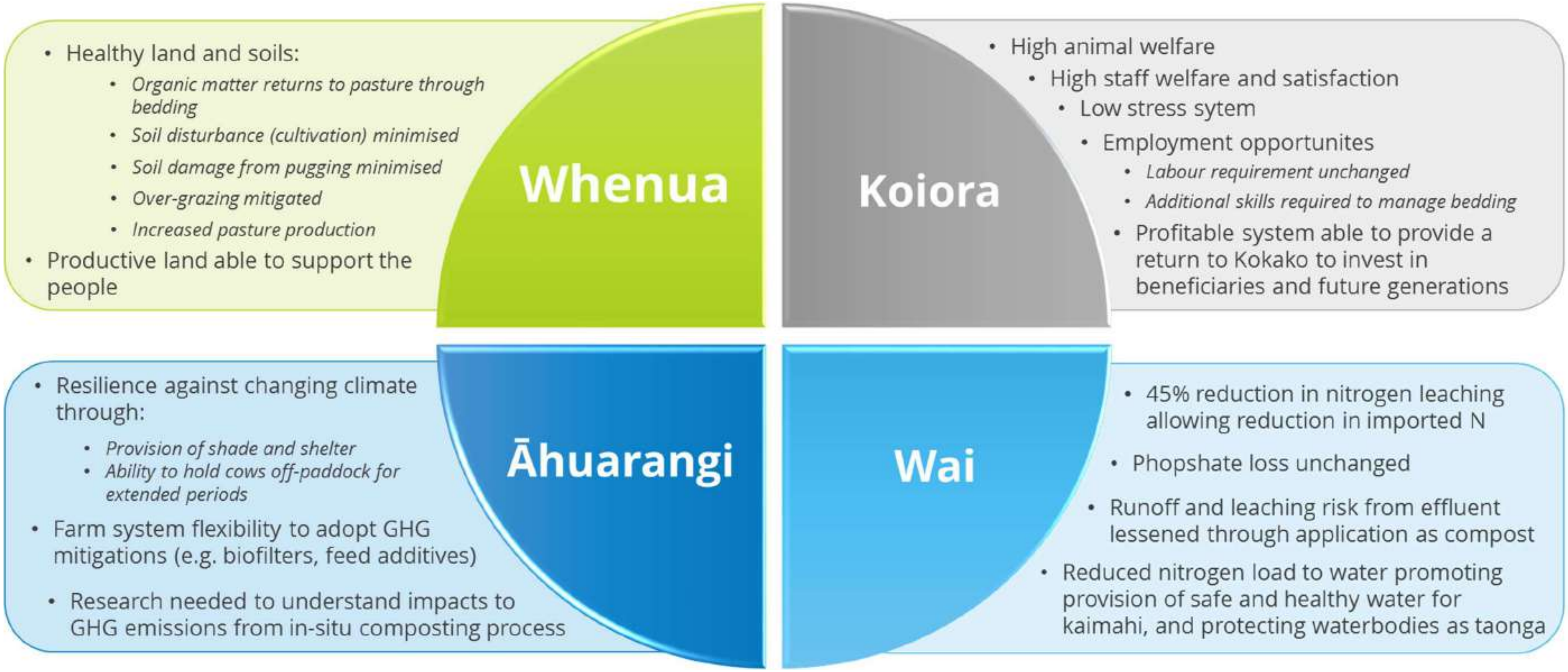

Figure 6: Evaluation of the composting shelter system within a Te Taiao framework.

7.1.2 Evaluation of animal welfare

Evaluation of animal welfare performance of the composting shelter scenarios on the case study farm has been considered in the context of animal health, behaviour and comfort, and supported by literature (where available) and farmer responses during Phase One of the project.

7.1.2.1 Animal health

The two key animal health issues impacting dairy cows in New Zealand are mastitis and lameness.

Mastitis is the inflammation of the mammary gland in response to an infection by a mastitis-causing agent. It is a multi-factorial and complex disease that is a result of interactions between cows, microorganisms and the environment (Petrovski, 2007; Watts, 1988). Several causative pathogens have been linked to mastitis with the most common pathogens in New Zealand usually Gram-positive bacteria including Streptococcus uberis (environmental mastitis) and Staphylococcus aureus (contagious mastitis) (Lacy-Hulbert et al., 2002; McDougall, 1998). While these pathogens can be problematic overseas it is commonly Gram-negative bacteria such as Escherichia coli and Klebsiella species that are associated with mastitis (Lacy-Hulbert et al., 2002) in the Northen Hemisphere. The differences in mastitis-causing pathogens between countries is typically due to a combination of nutritional and environmental factors. Herds in the Northern Hemisphere typically utilise a total mixed ration (TMR) diet with cows housed 24/7.

In contrast, composting shelter systems operated in New Zealand and modelled in this case study are based on a duration-controlled grazing system where cows spend a portion of each day in the shelter, and a portion outdoors on pasture. Farmers interviewed in Phase One reported varying impacts to mastitis levels after incorporation of composting shelters on-farm:

- Four farms reported no changes
- One farm noted an increase (*E. coli*)
- One farm noted a decrease

In a well-designed and managed shelter that promotes correct ventilation and aerobic composting, bedding material stays clean and dry. Under these circumstances, and supported by comments from the majority of farmers interviewed, the impacts to mastitis from operating a composting shelter is expected to be minimal. However, if the bedding becomes wet and sticky, either from over-stocking, poor management or design, then the risk of infection will increase.

The same principles of cow and environmental hygiene within the shelters applies to pastoral grazing systems. Herds required to walk or lie in muddy areas (e.g. paddocks, farm races) will likely show higher incidence of mastitis, as will herds where milking hygiene is not well-practiced. Overall, the incorporation of composting shelters on the case study farm is not expected to result in an increase to mastitis levels, nor is it expected to decrease the incidence of mastitis.

As with mastitis, lameness is also a multifactorial disease caused from interactions between the environment, nutrition and management (Hedges et al., 2001). In New Zealand pastoral systems, white-line disease, sole injury and foot-rot are the most common forms of lameness (Chesterton et al., 2008). None of the farmers interviewed in Phase One noted changes to lameness following incorporation of composting shelters except for one farmer who reported a decrease. This was attributed to the replacement of concrete feed pads with the composting shelters.

As with pasture, composting structures provide a soft, comfortable surface to stand and lie on which reduces the force impact on the knees and hooves (Dumelow, 1995). Given the case study farm currently uses a concrete feed pad, impacts to lameness may decrease from spending less time on concrete. However, as this is generally limited to 1-2 hours per day and the incidence of lameness is low, this impact is expected to be minor.

Responses from farmer interviews also indicated benefits of composting shelters to cow and calf health, particularly around calving. Calving cows in the shelter allows calves to be born into a dry, warm environment out of any mud, and the enclosed area prevents calves from wandering off. Having cows in a comfortable environment also has the potential to reduce mortality and makes it easier for staff to identify sick cows earlier on.

7.1.2.2 Animal behaviour and comfort

Comments from farmer interviews in Phase One indicated composting shelters provided a high welfare environment whereby cows were calm and content. This was often described in the context of cows stretched out on the bedding, in a deep sleep and not easily disturbed.

This reflects overseas research which found the open resting areas characteristic of composting shelters maintained cow health and welfare (Klaas et al., 2010), and allowed expression of natural behaviours (Endres & Barberg, 2007). One of these key behaviours is lying down which is considered a high-priority activity (Metz, 1985). Deprivation of lying, which can occur when cows are subjected to uncomfortable or dirty environments (e.g., concrete, muddy paddocks), causes abnormal behaviours indicative of frustration and stress (Krohn & Munksgaard, 1993). Studies in America have shown that composting shelters do not restrict the lying or lunging area for cows, provided appropriate stocking density, and allow cows to exhibit all the natural lying positions without disturbance or obstruction (Endres & Barberg, 2007).

It is therefore assumed that animal behaviour is unlikely to be negatively affected for the case study farm with the incorporation of composting shelters. For farms where winter grazing on crops is common practice, the use of composting shelters over winter may improve lying conditions and the overall welfare of the cow.

Furthermore, the provision of a comfortable lying surface sheltered from the impacts of the environment (wind, rain, snow, sun) is likely to result in improved animal comfort. For the case study farm, there are on average 117 days per year where the thermal-humidity index (THI) threshold for heat stress is exceeded. On these days, cows will reduce their feed intake and seek shade to minimise heat load. Under the status quo system, the main source of shade is trees. However, like many farms in New Zealand, the number and location of trees on farm is not sufficient to provide shade to all cows at all times. On particularly hot days, grazing location may be determined based on shade available in a paddock as opposed to the paddock most suited for grazing. The impact of composting shelters is therefore likely to improve cow comfort during summer through provision of shade and a space that creates wind flow and a cooling effect. This is reflected in the farmer interviews in which one farm noted cows preferentially chose to enter the shelters when temperatures reached 20-25^{o}c. The shelters also mitigate the need to walk cows to the milking shed during the heat of the day, which can further exacerbate heat stress.

Over the wetter and cooler months, the provision of shelter is also expected to increase cow comfort levels. This would be particularly the case for farms in cooler, southern regions. While cows can tolerate colder temperatures than people, the combination of wind and/or rain can lift the lower critical temperature for cold stress up to 7.5^{o}C (Bryant et al., 2010), which can be experienced throughout New Zealand, albeit less often in northern locations.

7.1.3 Evaluation of staff and farmer wellbeing

Evaluation of staff and farmer wellbeing following incorporation of the composting shelter on the case study farm is informed by responses from Phase One of the project.

For the case study farm, the requirement for farm labour was assumed to remain static. However, with the change from a 24/7 pasture-based grazing system to a duration-controlled pasture-based grazing system, there are expected to be a changes to the farm working environment. These changes are summarised below.

- Central location and provision of shelter
  - Providing shelter to the cow whether from wind, rain, sun or snow not only improves cow welfare, but improves working conditions for the farmer and staff.
  - As the shelters are centrally located within the farm this provides ease of access to the cows whether that be for feeding out, or completing calving checks.
  - For farms where the transition to composting shelters results in the removal of winter cropping, the shelters reduce time requirements on staff associated with setting up breaks, shifting cows and taking feed to paddocks.
- Calving
  - Calving is a stressful time of year for both animals and staff, and is often compounded by wet and/or cold weather.
  - Calving cows in the shelter creates a much more pleasurable environment for staff out of the rain, mud and cold. This makes night checks and intervention easier, enables staff to identify cows requiring assistance earlier, and makes picking calves up easier.
  - Cameras can be installed in the shelter allowing staff to easily check cows without having to physically go to the shelter each time.
- Reduced stress
  - The ability to put cows in the shelter during adverse weather or at calving times reduces stress on the farmer. For instance, during heavy rain events cows are sheltered and pastures aren't being damaged which provides peace of mind for the farmer (less sleepless nights).
  - Farmers enjoy seeing animals well looked after. The ability to minimise the effects of adverse weather (e.g. heat stress, wet weather) on stock and see cows content within the shelter is also expected to improve farmer satisfaction.

Many of the improvements to staff wellbeing and working environment are an indirect result of improving the environment for the cow. This is summarised well by the quote from Farm 1;

> "*one of the ways to take the stress out of the system for the staff, is to take the stress out of the system for the animals*".

8 Conclusion

- Responses from farmer interviews gave a clear consensus that the incorporation of composting shelters on farm provided significant animal welfare, farmer wellbeing and environmental improvements. This was often in the context of improved cow comfort and welfare from reduced exposure to environmental stressors (heat and cold), improved labour efficiency and/or working conditions, and reduced damage to pasture and soils.

- Environmental modelling of the case study farm both with and without a composting shelter indicated significant improvements to nitrogen loss, as measured by a 45% reduction in N leaching. This was a direct result of duration-controlled grazing which was made possible by incorporation of the composting shelters on-farm.

- Greenhouse gas emissions were more challenging to quantify given OverseerFM (v6.4.3) does not currently model the aerobic composting process within the shelters which is expected to have a large impact on nitrous oxide emissions, and methane emissions to a lesser extent. It can be hypothesised that the reduced urinary N deposition will lead to less overall nitrous oxide emissions from farming systems that incorporate composting shelters but the necessary research to demonstrate this has yet to be conducted.

- Incorporation of composting shelters on the case study farm resulted in milk production increasing by an estimated 57 kg MS/cow (186 kg MS/ha) as a result of increased feed conversion efficiency, higher pasture growth and feed utilisation, and reduced heat stress over summer. Cash operating surplus subsequently increased by 33% per hectare and 16% per kilogram of milk solids.

- Analysis of the relative performance of the composting shelter investment on Kokako Tuarua indicated a profitable investment with pre-tax IRR over a 50-year investment period ranging from 8.5% to 12.7%, depending on specific infrastructure decisions. At the whole business level, this provided returns of 6.8% to 7.4% (IRR) and were greater than the status quo IRR of 6.3%. The impact of investment period and salvage values had a minor impact on the IRR of the investment.

- Overall, desktop modelling indicated that incorporation of composting shelters on the case study farm can provide an environment in which the land, animals, people and business can thrive. The overall economics appear sound. However, significant capital expenditure is required and this needs to be budgeted with care, particularly with regard to the cost of capital.

- In addition, further research is required to reduce uncertainty in some of the modelling assumptions which have relied heavily on experiential knowledge from farmers and rural professionals. This includes research into the specific bedding space requirements and factors that impact on replacement frequency, and the impact of the composting process to nutrient composition and greenhouse gas emissions.

- For farmers considering composting shelters, care needs to be taken to ensure sufficient personal research is undertaken before committing to a project, to make certain that the design will be fit for the specific location and purpose. Consideration also needs to be given to who will operate the farm system. Specific skills are needed to ensure a focus on management of the bedding and corrective action if intervention is required.

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10 Appendices

10.1 Financial assumptions for status quo

Input expense data and product pricing were based on the case study farm's historical accounts and adjusted to current (2022) values. This allowed for the capital costs of the composting shelter investment to be assessed against current value farm profitability.

Key assumptions are detailed below with the full status quo financial model and dairy assets displayed in Table 18 and Table 19, respectively.

- Milk price: $9.00/kg MS
- Milk levy: $0.036/kg MS DairyNZ; $0.024/kg MS biosecurity
- Fonterra dividend: $0.25/share
- Labour:
    - Wages: Three full-time equivalents (FTEs) based on a manager, assistant manager and farm assistant
    - Management: assumed at 20% of an FTE reflecting activities involved with farm administration and management. For Kokako Tuarua, this role is currently covered by a farm consultant, however is reflective of the cost for other farm businesses where a manager or sharemilker is employed.
- Purchased feed:
    - Maize silage: $0.45/kg DM delivered and stacked
    - Grass silage: $0.42/kg DM delivered and stacked
    - Palm kernel: $400/t delivered
- Grazing:
    - Rising one-year heifers: $8.00/head/week
    - Rising two-year heifers: $11.00/head/week
    - Winter cows: $35.00/head/week

Table 18: Status quo financial model.

	Total $	$/ha	$/cow	$/kg MS
NET CASH INCOME (NCI)				
Net Milk Proceeds	2,070,951	12,019	3,665	8.94
Dividend	57,913	336	103	0.25
Net Dairy Trading Proceeds	98,580	572	174	0.43
Value of Change in Livestock	-	-	-	-
Other Farm Income	-	-	-	-
TOTAL NET CASH INCOME (NCI)	**2,227,443**	**12,928**	**3,942**	**9.62**
FARM WORKING EXPENSES				
Labour				
Wages	235,820	1,369	417	1.02
Management	18,000	104	32	0.08
Total Labour Expenses	253,820	1,473	449	1.10
Stock Expenses				
Animal Health	75,000	435	133	0.32
Breeding & Herd Improvement	45,600	265	81	0.20
Bedding	-	-	-	-
Farm Dairy	18,000	104	32	0.08
Electricity (Farm Dairy, Water Supply)	32,000	186	57	0.14
Total Stock Expenses	170,600	990	302	0.74
Feed Expenses				
Supplement Expenses				
Purchased	352,900	2,048	625	1.52
Cropping	12,600	73	22	0.05
Calf Feed	15,000	87	27	0.06
Total Supplement Expenses	380,500	2,208	673	1.64
Grazing & Run Off Expenses				
Young & Dry Stock Grazing	95,073	552	168	0.41
Winter Cow Grazing	35,650	207	63	0.15
Support Block Lease	-	-	-	-
Total Grazing & Support Block Expenses	130,723	759	231	0.56
Total Feed Expenses	511,223	2,967	905	2.21
Other Working Expenses				
Fertiliser	83,295	483	147	0.36
Nitrogen	81,725	474	145	0.35
Regrassing/undersowing	18,150	105	32	0.08
Weed & Pest	9,000	52	16	0.04
Vehicles & fuel	60,000	348	106	0.26
R & M - Land & Buildings	78,877	458	140	0.34
R & M - Plant and equipment	31,139	181	55	0.13
Freight and General	14,030	81	25	0.06
Total Other Working Expenses	376,215	2,183	666	1.62
Overheads				
Administration	42,601	247	75	0.18
Insurance	24,973	145	44	0.11
Rates	16,925	98	30	0.07
Total Overheads	213,992	1,242	379	0.92
TOTAL FARM WORKING EXPENSES	**1,396,358**	**8,104**	**2,471**	**6.03**
CASH OPERATING SURPLUS (EBITDA)	**831,086**	**4,823**	**1,471**	**3.59**

Table 19: Status quo dairy farm assets.

Dairy Assets: Status Quo			
Land	**ha**	**$/ha**	**Total $**
Flat/rolling	149.9	45,000	6,745,500
Steep	22.4	15,000	336,000
	172	**41,100**	**7,081,500**
Livestock	**no.**	**$/hd**	**Total $**
MA cows	460	2,086	959,560
R2 hfrs	120	1,892	227,040
R1 hfrs	130	1,232	160,160
			1,346,760
Shares	**no.**	**$/share**	**Total $**
	231,650	2.75	**637,038**
Machinery			**Total $**
Tractor			80,000
Silage wagon			20,000
Farm vehicle			25,000
Farm bikes			18,000
Other			18,000
			161,000
Total assets			**9,226,298**

10.2 Physical assumptions for base composting shelter system

The base composting shelter scenario has been designed using a hybrid indoor-outdoor grazing system in which the shelter is used for part of the day year-round, and in winter all cows are wintered on farm (as opposed to 230 being wintered off under the current system).

This system reflects the primary method of incorporation of shelters on farm from the farmer interviews conducted in Phase One, and also represents the fact that winters in South Waikato are milder than that experienced on the two farms where the shelters were used for wintering only.

The feed system operated (System 4) is assumed to remain the same in the composting shelter scenarios with no change to quantity or type of feed imported. This is to ensure a fair comparison between the systems, and avoid confounding effects on production from changing feed inputs.

Assumptions for the base composting shelter system are outlined below.

10.2.1 Time in shelter

Time spent by cows in the shelter varies throughout the year according to the stage of the milking season and climatic conditions (Table 20). From the commencement of milking (10 July) to October, cows spend four hours per day in the shelter. This is split into two hours prior to morning milking and two hours prior to afternoon milking for the primary reason of feeding cows.

From November through to March, time in the shelter increases to five hours per day as day time temperatures increase. Cows spend an hour in the shelter prior to morning milking for feeding, and then spend a further four hours in the shelter from 10.30 am until afternoon milking. After the evening milking, cows return to pasture until the following morning. The increased time in the shelter is largely to provide shade to the cows during the day and manage pasture residuals, as well as to allow feeding to occur.

April is typically characterised by cooler day time temperatures and increased pasture growth. Time in the shelter is assumed to reduce to four hours per day as per the start of the milking season.

At dry off, time in the shelter increases to 18 hours per day for dry cows. The winter diet is provided in the shelter and limited access to pasture is provided for the remainder of the day with the assumption that cows leave the shelter at approximately 10 am before returning to the shelter at 4 pm. If weather is unfavourable (i.e. wet and cold) then cows remain in the shelter. The main objective for housing cows for this time is to reduce maintenance energy requirements and allow all cows to be wintered on farm by feeding the majority of the winter diet in the shelter. Springer cows are transitioned to 24 hours per day in the shelter to restrict feed intake and avoid shifting cows. As soon as cows have calved, time in the shelter returns to four hours per day.

Table 20: Shelter usage for base composting system.

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Days	31	31	30	31	30	31	31	28	31	30	31	30	365
Cow numbers	580	575	570	565	565	563	561	560	510	460	580	580	-
Hours in shelter per day*	14	7	4	4	5	5	5	5	5	4	6	15	-
Total hours in shelter per month	442	205	130	124	150	155	155	140	155	120	188	442	2,405
Total cow days in shelter per month	18.4	8.5	5.4	5.2	6.3	6.5	6.5	5.8	6.5	5.0	7.8	18.4	100

**hours in shelter are based on the weighted average of milking cow and dry cow hours.*

Under this base scenario, cows spend an annual average of 6.6 hours per day in the shelter or 100 full [24-hour] days (27% of the year). At a bedding space of 7.4 m^2/cow and depth of 800 mm, this provides 13.5 cow days per square metre and 34 cow days per cubic metre. These are key metrics which inform the relative efficiency of bedding use, with higher cow days indicative of greater efficiency. The cow days per square metres figure is relevant to the evaporative capacity of the bedding, while the cow days per cubic metre relates to the ability to absorb nitrogen within the bedding, and maintain an optimum carbon to nitrogen ratio. The figures used in this project are considered conservative based on insights from farmer interviews.

10.2.2 Shelter design

Two shelter concepts (Aztech and SmartShelter) were designed and priced for Kokako Tuarua, based on the same design parameters, and reflect some of the variation in shelter designs available on the market. It should be noted that other design options are also commercially available and the options provided in this report are an example of just two concepts. No recommendation in relation to specific shelter design is given in this report. Those decisions should be made on a case-by-case basis, making judgements as to relative performance under farm-specific criteria.

The key difference between the two structures modelled for the case study farm is the roof. The Aztech design (referred to as "rigid roof" [Scenario 1] hereafter) is essentially an inverted "V" shape steel roof, with a ridge vent and cap running along the apex to extract warm air out of the shelter (Appendix 10.6.1; Figure 8). In comparison, the SmartShelter design (referred to as "tunnel roof" [Scenario 2] hereafter) comprises a tunnel-like structure with a curved industrial fabric roof to promote airflow (Appendix 10.6.2; Figure 9). Note, the tunnel roof design does not include a roof venting system. The specific requirement for a vent, to improve evaporative capacity, should be considered in relation to the specific site location and farm system.

Each design comprises three composting structures to enable shorter, squatter structures as opposed to long, narrow shelters. The idea behind shorter structures is to optimise cow flow and management as well as bedding efficiency. Longer structures may also be suitable, but consideration would need to be given to side entry and exit points to minimise compaction and concentration of effluent deposition at each end. The area between shelters has been designed on 7 m to enable side ventilation, and accommodate two feed tables and a tractor lane (see Figure 9).

Both designs are based around the same intended year-round use with space of 8.5 m^2/cow provided for. Once concrete within the shelter is accounted for (described below), total compost area available for the cows loafing area is 7.4 m^2/cow. Actual bedding requirements will vary based on the farming system and hours of use. For the farmers interviewed, bedding per cow ranged from approximately 5.5 m^2/cow to 8 m^2/cow. Where cows are housed for longer periods particularly over winter, then greater bedding space is needed to accommodate increased effluent loading.

For the base composting shelter system it was assumed that supplementary feeding would occur "in-shelter" using dedicated feed lanes on either side of the shelter. Feed face ranged between designs based on the roof clear-span width. The most economical option for the rigid roof design was an 18 m clear-span, whereas the most economical option for the tunnel roof design was a 20 m width. To enable the 8.5 m^2/cow parameter to be met, this resulted in each of the three rigid roof structures being 89 m in length, while the tunnel structures were 80 m in length. This created a feed face of 900 mm/cow and 800 mm/cow (which allows for impact of structural poles in feed space) for the rigid and tunnel roof structures, respectively.

The feeding area was designed to include a concreted standing area for the cow (1.2 m width sufficient for front feet). This is to ensure the cow stands at the correct level in relation to the feed table and feed rail height, and mitigates the impact either a build-up or compaction of bedding has on the cow's height relative to the feeding area (DairyNZ, 2019). It should be noted, that many farmers, however, are choosing to have no concrete with cows standing on the bedding while feeding and instead manage the compost height through tilling and bedding top-ups.

For the high-capital scenarios, concrete feed barriers are included to separate the cow standing area from the feed trough and tractor lane. The feed trough area and tractor lanes are assumed to be concreted with exterior lanes 5 m in width, and interior lanes 7 m in width. Concrete turning aprons at 12 m wide are also assumed at both ends of the shelters.

In comparison, the low-capital scenarios assume timber feed troughs, although the base remains concreted, and metalled tractor lanes. The turning apron at one end of the shelter where no cow access is allowed is also assumed to be metalled.

10.2.3 Bedding replacement and composition

The operation of composting shelters results in the creation of a composted by-product containing the original bedding material mixed with urine and dung. The composted material accumulated within the shelter is typically applied back to pasture or cropping blocks as an organic fertiliser. Longevity of bedding within the shelter is driven by moisture content, which in turn is impacted by shelter design and management, with factors such as ventilation efficiency, tilling management, stocking rate and time in shelter affecting the replacement rate of bedding.

For farmers interviewed in Phase One, frequency of replacement of bedding ranged from 1-3 years and, in some cases, bedding top-ups also occurred during the year. However, as five of the six farmers interviewed had been operating with their shelters for four years or less, the knowledge on successful composting and "normal" frequency of bedding replacement is still being accumulated. Longevity of bedding can have a large impact on profitability, given that bedding has its own capital cost as well as costs involved with removing it from the shelter and applying to land.

In the absence of a normalised turnover of bedding rate, and given the variability that occurs within existing systems and designs, the replacement of bedding for the case study farm was assumed to occur every two years. This was deemed appropriate given the reasonable space per cow and bedding depth allowed. If stocking rate was higher or bedding depth shallower, then a more frequent replacement rate may be required.

Based on a compost area of 7.4 m^2/cow at a composting depth of 800 mm, total compost volume to be replaced every two years is 3,345 m^3. Assuming a bulk density of 675 kg/m^3 measured in a trial of a loose-housed Redpath barn used predominantly for wintering in Southland (Chrystal et al., 2016), total wet weight removed from the shelter every second year is assumed at 2,258 t .

Composition of nutrient within the bedding as a percentage of wet weight is assumed at 0.6% nitrogen (N), 0.2% phosphorus (P), 0.9% potassium (K) and 15.5% carbon (Ca) based on reported results in the study by Chrystal et al. (2016). These concentrations are similar to laboratory testing results of composted bedding from a Waikato composting shelter farm.

The carbon to nitrogen ratio (C:N) is an important metric to check when applying compost to land. Microorganisms require nitrogen to breakdown organic matter. If insufficient nitrogen is available in the compost (i.e. C:N ratio greater than 20-30:1), microbes will utilise N from the soil causing immobilisation and the temporary depletion of soil N. In contrast, a C:N ratio lower than 20-30:1 will result in mineralisation and release of N into the soil. Where compost has a high C:N ratio, storing the compost to allow further decomposition may be beneficial to avoid immobilisation of soil N needed for plant growth.

10.2.4 Pasture grown

Total annual pasture production and seasonal distribution for the status quo and base composting shelter farm is displayed in Figure 7. Excel based feed budgeting was used to model the status quo system using data representative of the current system operated and summarised in Table 2. Annual pasture grown and monthly growth rates were back calculated from feed demand, supplementary feed inputs and estimated wastage. Annual pasture production for the status quo system is estimated at 14.0 t DM/ha including nitrogen grown pasture. This is considered representative of the South Waikato district.

With the incorporation of the shelters on farm and duration-controlled grazing year-round, improvements to grazing management and pasture production compared to the status quo is expected. Over the winter period, dry cows spend six hours per day on pasture but over the bulk of the milking season this is extended to up to 16 hours per day (assuming an individual cow spends three hours off pasture for milking related activities), with only five hours during the day in the shelter.

The ability to remove stock from pasture and provide cows with a comfortable resting space for long periods of time means grazing management can be optimised and pastures protected so as to reduce the negatives impacts from pugging and over-grazing. While farmers interviewed in Phase One could not quantify the increase to pasture production following the incorporation of shelters on farm (as feed eaten was largely estimated), farmers that used the shelters year-round noted faster pasture recovery times after drought or winter wet conditions, and/or the ability to incorporate forage crops (e.g. maize silage) within the milking platform after finding less grazeable area was needed due to improved pasture performance.

Impacts to pasture production from standing cows off pasture from industry research and literature is varied. For instance, DairyNZ uses an assumption of an increase in pasture production of 1-5% depending on soil drainage status with stand-off practices providing greater benefit on poorly-drained soils (DairyNZ, n.d.). The actual stand-off practice behind these assumptions was not defined. Similarly, a case study of a high performing Waikato farm found a 10% increase in pasture harvested after incorporating herd homes year-round, largely as a result of optimising pre and post grazing residuals and mitigating over-grazing through summer (Ministry for Primary Industries (MPI), 2016).

In contrast to the above studies, research by Christensen et al. (2019) looked at the impacts of duration-controlled grazing in Manawatu over three years in which cows were restricted to only eight hours grazing per day in two four-hour grazing bouts. Results from this study found a reduction in pasture growth in the second and third season of 9% and 20%, respectively, and was attributed to a reduction in nutrient deposited to pasture from urine and dung.

Compared to the study by Christensen et al. (2019), the restriction on grazing time in the case study farm was much less with cows still able to graze for 16 hours per day throughout the milking season, and is just three hours per day less than in the status quo system (allowing five hours per day for milking and feeding on the pad). Cows are therefore stood off pasture for just three hours more during the milking season under the composting shelter system, and therefore the reduction in nutrient deposited to pasture via urine and dung will be significantly less than that measured in the study by Christensen et al. (2019). Furthermore, cows show a diurnal excretion pattern that results in the greatest urination volumes occurring at sunrise and sunset. Under the composting shelter system, cows are stood off during the day only and therefore it is expected that the majority of nutrient deposition will still occur on pasture.

Over winter however, the reduction in grazing time is much larger with cows given access to pasture for just six hours per day compared to 22 hours per day under the status quo model. The reduction in nutrient deposition to pasture over this time compared to the status quo system is therefore likely to be much larger.

Under the status quo system, wintering from May to July generally occurs at a relatively high stocking rate with cows break fed on a small area (i.e. 30 m^2/cow). This results in a high concentration of nutrients via dung and urine being deposited to land. With an average 75 day dry period, the area grazed over winter at this high density is 108 ha, equivalent to 63% of the farm. In contrast, the base composting shelter model requires only 50 ha (29% of the farm) to meet the pastoral demand which also allows for the additional cows now wintered on farm. One third of the farm will therefore miss out on receiving nutrient from excreta over winter. The key nutrient likely to be impacted will be potassium (K), but this is unlikely to reduce winter production levels given clover production over winter is minimal. It may however require greater potassium applications in the spring to offset any potential K loading reductions from reduced winter grazing. This could be achieved through targeted effluent applications and compost applications to these areas to help mitigate any reductions in soil K levels.

For Kokako Tuarua, the overall impact to pasture production has been assumed at +5%. This assumption reflects the ability to mitigate pugging in winter, but particularly over-grazing during summer (Table 21). Under the current system, over-grazing is common during the summer months increasing the time for which it takes pastures to recover and often requiring under-sowing to renew damaged pastures. As Waikato summers are becoming increasingly dry and for extended periods, managing over-grazing is becoming a greater challenge.

For the status quo system, annual pasture growth was assumed at 14.0 t DM/ha including nitrogen grown pasture (150 kg N/ha). In comparison, pasture growth under the base composting shelter system was assumed at 14.6 t DM/ha (+5%), with higher growth rates assumed through winter and early spring (June – September), and through late summer and autumn (Feb – May) following rain (Table 21). Given the higher growths rates combined with the ability to winter in the shelter, cropping of 3 ha winter oats and 6 ha summer turnips was also removed under the base composting shelter system.

The pasture growth curve for each of the modelled systems is displayed in Figure 7. Given the farm is located in the South Waikato district on free-draining soils, the main impact of composting shelters will be the improved growth over the summer due to reduced over-grazing during dry periods which can cause critically low pasture covers. This is shown in Table 21 and Figure 7 from February through to early May. In other areas, with less free-draining soils the improvements to pasture production may be more significant over the June to September period.

Table 21: Average monthly pasture growth rates for the status quo and base composting shelter (CS) system.

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Status Quo	18	17	27	52	65	67	55	36	23	29	38	29
Base CS	19	18	30	55	65	67	55	36	26	36	43	29
% change	8%	10%	10%	8%	0%	0%	0%	0%	10%	20%	13%	3%

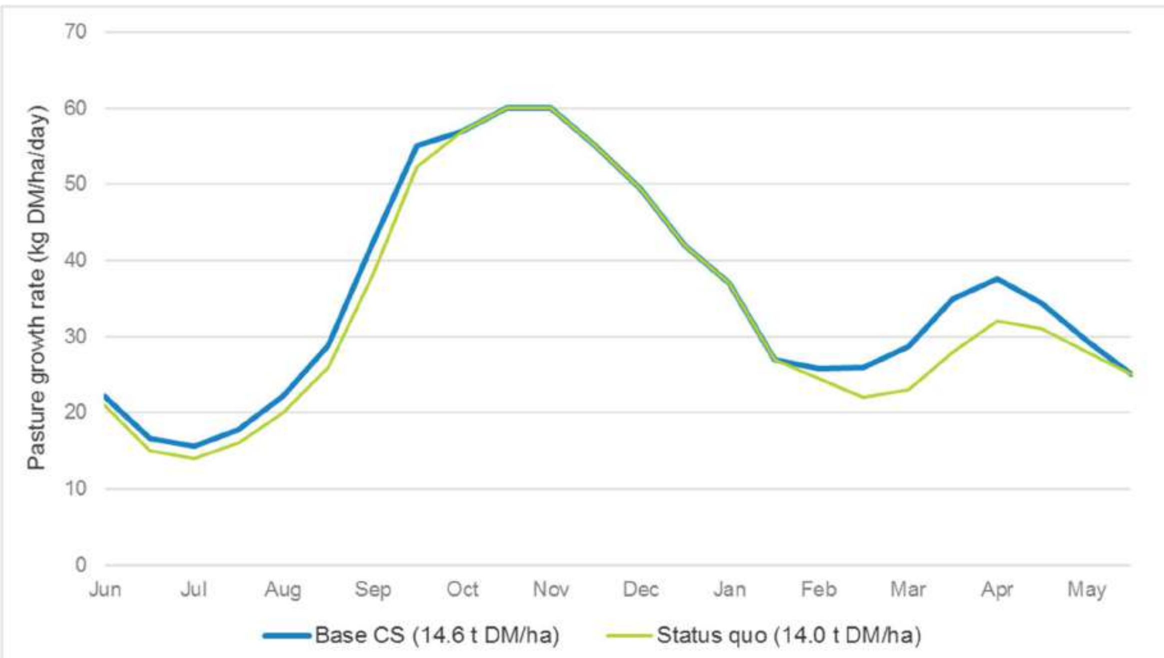


Figure 7: Comparison of seasonal pasture production between the status quo and base composting shelter system.

10.2.5 Nitrogen and fertiliser use

The incorporation of shelters will impact nutrient cycling around the farm. Total nutrient inputs are expected to remain the same in the composting shelter system given feed inputs and stock numbers are unchanged. However, there is expected to be a change to nutrient outputs (both through losses and milk exported) in the base composting shelter system which will affect the level of fertiliser input needed.

For nitrogen, the practice of duration-controlled grazing with cows spending a portion of each day in the shelter is expected to reduce urinary nitrogen leaching losses. The overall reduction to nitrogen leaching modelled in OverseerFM was 22 kg N/ha/yr. Of this, 19 kg N/ha/yr was attributed to reduced urinary N leaching. The balance (3 kg N/ha/yr) resulted from removal of cropping. With less nitrogen lost from the system, it is reasonable to expect that nitrogen applied as fertiliser could be reduced under the composting shelter system. The reduction in nitrogen fertiliser has been assumed at 15 kg N/ha/yr (80% of the reduction in urinary N loss), recognising that nitrogen reapplied to pasture in the form of compost will be in organic form and therefore be slower release limiting the time of year when it can be applied. Remodelling of the composting shelter system following removal of 15 kg nitrogen fertiliser per hectare, resulted in an additional reduction to nitrogen leaching of 1 kg N/ha/yr, bringing the total farm N loss to 28 kg N/ha/yr.

In regards to fertiliser, the impact form reduced grazing time on the return of nutrients and thus soil fertility, via direct deposition of urine and dung to pasture, is assumed negligible as discussed in Section 10.2.4. However, with greater pasture growth (+0.6 t DM/ha) assumed in the base composting shelter system, and the subsequent increase in milk production there is expected to be a greater volume of nutrient going out the farm as product.

An increase in maintenance fertiliser applications has therefore been assumed to offset this loss based on average maintenance requirements per kilogram of milk solids produced (Fertiliser Association of New Zealand, 2017). Additional milk solids produced under the base composting shelter system is 32,069 kg MS (see Section 10.2.11). Of this, 3,820 kg MS is attributed to the reduction in heat stress (See Section 10.2.10) and approximately 1,600 kg MS is attributed to lower feed requirements over winter. As such, additional milk solids from increased pasture eaten is approximately 26,649 kg MS (155 kg MS/ha).

Assuming 0.6 kg/ha of 20% potassic superphosphate or equivalent for every 1 kg/ha increase in milk solids produced (Fertiliser Association of New Zealand, 2017), total annual maintenance fertiliser requirements increase by 7 kg P/ha, 9 kg K/ha, and 8 kg S/ha.

In farm systems where feed inputs increase following incorporation of composting shelters there may not be a need for increased maintenance fertiliser given the additional nutrient imported into the farm via feed.

10.2.6 Cow liveweight and body condition score

Having cows in the shelter for a portion of the day year-round is expected to result in an improvement in cow condition. This has been assumed at half a condition score, which is approximately equivalent to +20 kg. Cows in the base composting shelter system are therefore expected to weigh 545 kg on average.

10.2.7 Days in milk and dry off date

It is assumed that the milking season under the base composting shelter system can be extended given the increase in body condition score, pasture grown and utilisation of imported feed.

Currently, dry off date under the status quo system is 10 May with a mid-point of calving of 24 July. This provides for a maximum lactation period of 290 days and an average dry period of 75 days. Total average days in milk per cow accounting for timing of culls and deaths is 273.

Under the base composting shelter analysis, a minimum 50 day dry period has been assumed with a staggered dry off date based on early, mid and late calvers. This provides an average 61 day dry period. Timing and number of culls and deaths are assumed to remain the same between systems, resulting in an average 292 days in milk per cow (6% increase from the status quo).

10.2.8 Winter feed requirements

With the incorporation of the composting shelters on farm, it is assumed that for the base system all cows will be wintered on farm in the shelters with duration-controlled access to pasture. Given pastures continue to grow over winter on the case study farm, with typical growth rates of 15 – 20 kg DM/ha/day, restricted grazing through the dry period provides an opportunity to manage pasture covers and feed quality for spring. In some regions (e.g., Southland, Canterbury) where winter growth is minimal (i.e. <10 kg DM/ha/day) and environmental conditions are more conducive to cold stress, housing cows 24/7 over the dry period is likely to provide greater benefit than providing restricted pastoral grazing.

Several of the farms interviewed during Phase One of the project noted reduced winter feed requirements following incorporation of the shelters on farm and a much greater ease of putting condition on cows over the winter. This was particularly significant for the South Island farms where the wintering system changed from an in-situ winter crop grazing system to a 24/7 in-shelter wintering system. Anecdotal evidence from the farmer interviews put this reduction at 31-50% based on a pre-shelter feed allocation of 13 - 16 kg DM/cow/day to a post-shelter allocation of 8 kg DM/cow/day. Some of this saving was a result of a substantial reduction in wastage, but there is also likely to be a reduction in maintenance energy requirements from being housed in a warm environment out of the weather.

Cows have a thermoneutral zone in which no additional energy above maintenance is needed in order to maintain body temperature. However, below the lower limit of the thermoneutral zone, known as the lower critical temperature (LCT), the animal experiences cold stress (Lee et al., 2012). If the ambient temperature falls below the LCT, additional energy is required to regulate body temperature (Bryant et al., 2010). Housing cows in composting shelters during the winter period when the occurrence of cold stress is most common, is therefore expected to reduce total maintenance requirements, in line with anecdotal evidence from the farmers interviewed.

The occurrence of cold stress in dairy cows in New Zealand will vary between seasons and farms. Modelling work by Bryant et al. (2010) suggests that the LCT for a non-lactating cow fed to requirements in New Zealand would be -13^{o}c under calm, dry conditions. The LCT will however increase significantly when there is rain (0^{o}c), strong wind but no rain (4^{o}c) or both wind and rain (7.5^{o}c). The increase in energy intake required to lift body temperature will depend on the actual conditions and the individual cow. Factors that impact on the degree of cold stress experienced include body condition score, body surface area, intake, coat length, wind speed, temperature and rainfall (Bryant et al., 2010).

Given the case study farm is located in the Waikato region where winter conditions tend to be mild, the impact of providing shelter to cows is expected to be less than the colder South Island climates. In the absence of literature and data to quantify the potential reduction in maintenance energy requirements from housing cows over winter, a winter feed diet of 8.1 kg DM/cow/day was assumed in line with anecdotal evidence of winter dry matter requirements from farmer interviews. This compares to 9.3 kg DM/cow/day under the status quo system and represents a 13% reduction in daily dry matter eaten (Table 22). This is comprised of a reduction in energy required for liveweight gain given the higher BCS at dry-off, as well as a 20% reduction in maintenance energy.

Table 22: Comparison of daily metabolisable energy (ME) requirements for dry cows.

	Status Quo	Base CS scenario
Assumptions		
Days dry	75	50
Feed (MJ ME/kg DM)	11	11
Avg. feed utilisation of diet	84%	91%
Liveweight (kg)	525	545
Liveweight change (kg/day)	0.4	0.2
Required BCS increase	0.8	0.3
km walked/day	1	1
Calf birth weight (kg)	35	35
Metabolisable energy requirements (MJ ME/day)		
Maintenance	60	62
benefit of shelter	-	*-12*
Milksolids	0	0
Walking	2	2
Pregnancy	23	29
Liveweight	18	9
Total ME required	102.8	89.3
Feed intake (kg DM)	9.3	8.1
Feed offered (kg DM)	11.1	8.9

**note, the higher energy requirement for pregnancy in the Base CS scenario is a result of the higher average daily requirement for the last 50 days of pregnancy that cows are dry, compared to the last 75 days of pregnancy that cows are dry in the status quo system.*

10.2.9 Winter feed diet

Under the status quo system, winter feed requirements are met with a diet of maize silage, pasture and oats, with maize silage fed on the feed pad (Table 23). In addition, 230 cows are grazed off farm for four weeks.

With the incorporation of composting shelters, time inside over winter is based on the described 18 hours per day, with opportunity for this to be altered dependent on weather conditions (i.e., longer if conditions are poor). For this scenario, it is assumed that cows receive the majority of their daily dry matter requirements in the shelter as a ration of maize and grass silage, with the balance made up from pasture (Table 24).

Feed utilisation is expected to increase under the composting shelter scenario to 95% for maize and grass silage. Utilisation of pasture is also expected to increase from 80% to 85% as a result of limited time on pasture and therefore reduced soiling and treading damage. Overall, this results in a 20% reduction in daily winter feed offered.

Table 23: Daily winter dry cow diet for the status quo system.

Status Quo			
	Feed eaten (kg DM)	Utilisation	Feed offered (kg DM)
Maize silage	4.0	90%	4.4
Pasture/oats	5.3	80%	6.7
Total	9.3	84%	11.1

Table 24: Daily winter dry cow diet for the base composting shelter scenario.

Base CS System			
	Feed eaten (kg DM)	Utilisation	Feed offered (kg DM)
Maize silage	3.0	95%	3.2
Grass silage	2.0	95%	2.1
Pasture	3.1	85%	3.7
Total	8.1	91%	8.9

Total winter feed requirements under the base composting shelter scenario reduce by 145 t DM (Table 25). While it is assumed that all dry cows are now wintered on farm in the shelter, as opposed to 230 being grazed off-farm for four weeks, the combination of reduced maintenance requirements, increased utilisation of feed and a shorter dry period result in an overall reduction in winter feed of 36%.

Total supplements (maize and grass silage) fed over the dry period however remain fairly static under the base composting system with a greater proportion of the diet fed in the shelter. As a result, supplements as a per cent of the total diet over winter increases to 62% (up from 43%), while total pasture eaten over winter reduces by 137 t DM (56%). With less pasture needed over the winter period, the farm has the ability to reduce the 1 June target cover levels, currently at 2,200 kg DM/ha, to take through into winter. Alternatively, and as modelled for the base system, less supplement is fed to the milkers through the spring period, making use of pasture and reducing the pressure on spring covers that existed in the status quo system.

Table 25: Comparison of feed volumes required for the winter period between the status quo and base composting shelter (CS) system.

	Status quo	Base CS system
Daily feed intake (kg DM/cow)	9.3	8.1
Avg. utilisation	84%	91%
Feed offered (kg DM/cow)	11.1	8.9
Dry period (days)	75	50
Cows wintered	580	580
Cows wintered off-farm	230	0
Days cows wintered off-farm	31	0
Winter cow days (on-farm)	36,370	29,000
Feed required (t DM)	404	259
- Supplements (t DM)	162	153
- Pasture (t DM)	243	106

10.2.10 Heat stress and production

Heat stress in dairy cows is becoming an increasing challenge and focus in the New Zealand pastoral context, with hot conditions shown to affect dairy breeds throughout New Zealand. In a study by Bryant et al. (2007) reductions of over 10 g of milk solids per day per unit increase in the temperature-humidity index (THI), a measure of 'hotness' based on combining temperature and humidity measurements, occurred in Holstein-Friesian (HF), HF and New Zealand Jersey (NZJ) cross, and NZJ cows when the THI reached 68, 69 and 75, respectively. A THI of 68 and 75 is approximately equivalent to 21ºc and 25.5ºc, respectively, at 75% relative humidity. Note, mean relative humidity recorded by NIWA from 1981-2010 has averaged 80-82% in the Hamilton and Rotorua area (NIWA, 2022), which are the most representative climate points for the case study farm.

In response to heat stress, cows reduce their feed intake and consequently milk production. This was noted on several of the farms interviewed during Phase One of the project (Section 5.4). The incorporation of composting shelters on Kokako Tuarua and the associated provision of shade during the summer months is therefore expected to increase milk production that is otherwise lost as a result of heat stress.

Climate data recorded over the period from 2018 – 2022 at a nearby weather station (3.5 km from the farm) was used to determine the numbers of days when the three-day average THI reached 68 or above (assuming relative humidity of 80%). From 2018 – 2022, the average number of days exceeding the THI threshold for heat stress was 117, equivalent to 32% of the year, and occurred between approximately 20 October and 15 April. With a minimum reduction of 10 g milk solids per day per unit increase in the three-day average THI threshold (68 for Friesian cows), total milk solids lost to heat stress each year is equivalent to 6.76 kg MS/cow (Table 26). This is similar to figures quoted by DairyNZ in the Waikato region (DairyNZ, 2022).

Table 26: Impact of mitigating heat stress on production at Kokako Tuarua.

	Kokako Tuarua
Days warm enough to reduce milk production*	117
Average milk solids reduction (kg MS/cow)	6.76
Peak cows	565
Total milk solids saved by providing shelter	3,820

*based on a 3-day rolling average THI (as per calculation in Bryant et al., 2007) using local climate data.

10.2.11 Milk production

Total season milk production was back calculated from feed budgeting using the assumptions described in this section. The combination of reduced winter feed requirements and increased feed utilisation enabled more feed to be made available through lactation which could then be converted to milk production. Opening and closing pasture covers were assumed to remain the same for the composting shelter system at 2,200 kg DM/ha. To ensure a feasible system, a pasture cover parameter was set with covers to remain between 1,850 kg DM/ha and 2,400 kg DM/ha throughout the season. Feed intake (kg DM/cow) was then adjusted in line with these pasture cover parameters and total supplement available.

Total feed eaten amounted to 5.6 t DM/cow allowing 460 kg MS/cow to be produced (DairyNZ, 2021). This does not include the effects of heat stress mitigation which were considered additive, and thus total milk produced for the composting shelter system was assumed at 263,719 kg MS (467 kg MS/cow; 1,531 kg MS/ha).

10.3 Financial assumptions for base composting shelter system

Financial modelling for the composting shelter scenarios have been completed in accordance with the physical assumptions described in Appendix 10.2.

Assumptions are detailed below with the full financial models provided in Section 10.3.16.

10.3.1 Capital cost

Four main composting shelter designs have been modelled for Kokako Tuarua. These include:

- Scenario 1H (S1H): Rigid roof structure, with in-shelter feeding and based on a high capital, low maintenance investment;
- Scenario 1L (S1L): Rigid roof structure, with in-shelter feeding and based on a low capital, high maintenance investment;
- Scenario 2H (S2H): Tunnel roof structure, with in-shelter feeding and based on a high capital, low maintenance investment;
- Scenario 2L (S2L): Tunnel roof structure, with in-shelter feeding and based on a low capital, high maintenance investment;

Capital pricing for each of the composting shelter scenarios are provided in Table 27 and Table 28. Figures provided are based on the case study farm and are indicative only. Actual pricing will depend on individual farm set-up, system requirements and farmer preferences. Capital pricing for the case study farm does not include any upgrades to existing effluent systems or feed storage, which were deemed appropriate for the system change. If additional effluent storage or new solids separation is required to allow the incorporation of composting shelters on farm then this should be factored into capital pricing.

Capital costs range from $2,820/cow under S2L to $4,542/cow under S1H. This reflects the impact of roof design and construction materials on the capital costs. Scenario 1 models average $686,000 ($1,220/cow) higher than for the Scenario 2 models and largely reflect the difference in roof pricing. Note, Scenario 2 models do not include a roof venting system which would be expected to add to the overall cost of the shelter by approximately $105,000 ($35,000 per shelter). The specific requirement for a roof venting system will depend on the site location and should be considered in design planning. Small differences in concrete pricing also exist between Scenario 1 and 2 models due to slight variation in dimensions between the shelter types.

The low-capital cost models provide an approximate $290,000 upfront saving by reducing the volume of concrete used and replacing with timber for feed troughs, and gravel for tractor lanes.

Additional machinery costs of $76,695 for each of the models has been assumed based on purchasing an extra tractor and ripper for aerating the bedding.

In addition to the upfront capital costs, the tunnel roof scenarios also have an additional cost of replacing the roof over time. This has been assumed at 16% of the whole structure cost every 15 years and equates to $137,216 (B. Cottle, personal communication, July 15, 2022). This cost has been included as a capital upgrade in the discounted cash flow analysis.

Table 27: Capital costs for Scenario 1 high and low models.

	Scenario 1H		Scenario 1L	
Structure	**Total $**	**$/cow**	**Total $**	**$/cow**
Composting shelter	1,516,130	2,683	1,516,130	2,683
Concrete and feed rails	773,035	1,368	472,934	837
Earthworks	86,892	154	86,892	154
Liner	49,982	88	49,982	88
Water troughs	8,367	15	8,367	15
Stormwater	30,000	53	30,000	53
Floodwash tank and pipes	25,000	44	25,000	44
Consents	6,000	11	6,000	11
Structure Sub-Total	**2,495,406**	**4,406**	**2,195,305**	**3,875**
Machinery				
100 HP tractor	70,000	124	70,000	124
Deep ripper	6,695	12	6,695	12
Machinery Sub-Total	**76,695**	**136**	**76,695**	**136**
Total	**2,572,101**	**4,542**	**2,272,000**	**4,011**

Table 28: Capital costs for Scenario 2 high and low models.

	Scenario 2H		Scenario 2L	
Structure	**Total $**	**$/cow**	**Total $**	**$/cow**
Composting shelter	857,600	1,518	857,600	1,518
Concrete and feed rails	743,722	1,316	459,150	813
Earthworks	86,037	152	86,037	152
Liner	50,688	90	50,688	90
Water troughs	8,367	15	8,367	15
Stormwater	30,000	53	30,000	53
Floodwash tank and pipes	25,000	44	25,000	44
Consents	6,000	11	6,000	11
Structure Sub-Total	**1,801,413**	**3,188**	**1,516,841**	**2,685**
Machinery				
100 HP tractor	70,000	124	70,000	124
Deep ripper	6,695	12	6,695	12
Machinery Sub-Total	**76,695**	**136**	**76,695**	**136**
Total	**1,878,108**	**3,324**	**1,593,536**	**2,820**

A further two sub-scenarios based on feeding on external feed pads, where this infrastructure already exists, has also been modelled:

- Scenario 1H (ext.): Rigid roof structure with feeding on existing feed pads external to the shelter. Capital costs based on a high-capital, low maintenance investment.

- Scenario 2H (ext.): Tunnel roof structure with feeding on existing feed pads external to the shelter. Capital costs based on a high-capital, low maintenance investment.

Capital costs for these scenarios are displayed in Table 29.

Table 29: Capital costs for external feeding scenarios - S1H (ext.) and S2H (ext.).

	Scenario 1H (ext.)		Scenario 2H (ext.)	
	Total $	**$/cow**	**Total $**	**$/cow**
Composting shelter	1,311,708	2,322	750,400	1,328
Concrete and feed rails	217,121	384	207,374	367
Earthworks	65,789	116	66,689	118
Liner	49,896	88	50,400	89
Water troughs	8,367	15	8,367	15
Stormwater	26,100	46	26,100	46
Floodwash tank and pipes	21,795	39	21,795	39
Consents	6,000	11	6,000	11
Sub-Total	**1,706,776**	**3,010**	**1,131,125**	**2,002**
Additional				
100 HP tractor	70,000	124	70,000	124
Deep ripper	6,695	12	6,695	12
Sub-Total	**76,695**	**136**	**76,695**	**136**
Total	**1,783,471**	**3,146**	**1,207,820**	**2,138**

10.3.2 Bedding

In line with the bedding space (7.4 m^2/cow) and depth (800 mm) parameters described in Section 10.2.3, bedding replacement is assumed to occur every two years. At $25/$m^3$ to supply and deliver, total bedding replacement cost is assumed at $83,625.

Spreading costs have been informed by farmer experience, and is assumed to cost $9,000 based on an hourly rate of $200 and a spreading rate of 75 m^3/hour at 22 m^3/ha.

In addition, the cost of removing the bedding and refilling is assumed at an hourly rate of $200. Assuming 24 hours to remove and install new bedding, in line with farmer experience, this is an additional cost of $4,800.

For the purpose of inclusion within the annual financial model, total bedding costs have been annualised at $48,713.

10.3.3 Labour

No changes to labour are expected with the integration of composting shelters on farm. While cow numbers over winter increase, the change to housing cows and feeding out in the shelter (close to feed stores) is expected to negate any labour increase. This is in line with comments from the farmer interviews, in which labour increased where the intensity of the feed system increased (i.e., Farm 2), or decreased when there was a change in the wintering system from winter grazing on crop to 24/7 in the shelter (i.e., Farm 1).

It should however be noted that a high level of management capability is required to manage the bedding and composting process within the shelter. For the status quo farm, production levels assumed a high level of management capability on the basis that production is currently being achieved by a 50:50 sharemilker. This high level of operator was carried through into the composting shelter scenarios.

Farms currently operating with lower skilled managers may need to allow for greater labour expenditure, or a shift in operating structure, to attract higher skilled operators.

10.3.4 Animal health and breeding

It is assumed that there are no changes to animal health and breeding costs with the integration of composting shelters on farm.

Comments from farmers on the impacts to mastitis were varied from the farmer interviews. One farm noted an increase in mastitis, while another noted a decrease and the remainder noted no changes. Similarly, no changes to lameness were reported except for one farm which attributed lower lameness cases to less time on concrete compared to the previous system that utilised concrete feed pads.

Overseas studies report improved animal health from composting shelter systems, however this is generally in the context of compost barns versus other housing facilities (Barberg et al., 2007; Lobeck et al., 2011). Whereas a study by Journeaux (2013) in the New Zealand context, noted changes to animal health costs were insignificant between pasture and pasture plus housing systems, although composting shelters were not included in this analysis. There is one caveat to this statement, in that if bedding within the composting shelter is not properly managed so as to enable aerobic composting, and the bedding becomes wet and smelly, then there is potential for increased mastitis.

There is literature to suggest that fertility can be improved though improved cow condition in barns (Journeaux, 2013) and thus breeding costs reduced in hybrid systems, however there is no clear evidence on the magnitude of cost reduction. Similarly, there was no evidence gathered from farmer interviews that suggested changes to breeding costs. As such, no changes have been assumed in this study.

10.3.5 Shed and electricity Costs

An increase to shed and electricity costs were assumed on the basis of increased days in milk, with costs increased proportionally on a per kilogram of milk solids basis. As a result, farm dairy and electricity costs increased by $2,492 and $4,430, respectively.

10.3.6 Nitrogen and fertiliser

The reduction in nitrogen fertiliser requirements of 15 kg N/ha/yr results in a saving in nitrogen fertiliser of $7,678 at $2.90/kg N and $32/t cartage.

This saving is offset by the increase in annual maintenance fertiliser assumed at 7 kg P/ha, 9 kg K/ha, and 8 kg S/ha. At $670/t for 20% potassic superphosphate and including cartage at $32/t this is equivalent to an increase in fertiliser costs of $11,232.

In addition, the removal of cropping from the base composting shelter system creates a larger area for pastoral fertiliser to be applied to further increasing fertiliser and nitrogen costs by $1,369.

10.3.7 Vehicles and fuel

With total feed inputs modelled to remain the same between the status quo and base composting shelter system, and feeding to occur in the same central location, no changes to fuel and maintenance of the tractor are expected from feeding out.

There is however expected to be an increase in tractor costs from daily tilling of the bedding. The activity is assumed to take 30 minutes per day, and over a full year this equates to 183 hours. Additional operating costs are assumed at $13,670 using the below assumptions:

- Fuel: 20 litres per hour at $2.90/litre ($10,614)
- R&M:
    - Oils and filter: 15% of fuel costs ($1,592)
    - Tractor repairs and maintenance: $8.00 per hour ($1,464)

10.3.8 Repairs and maintenance

Compared to other dairy housing facilities such as free-stalls, composting shelters have a much simpler fit-out. The structures are essentially an open-sided shed with a roof. Gates and feed infrastructure may also be included. A conservative increase of $5,000 for R&M relating to the shelter structure has been included for the high-capital cost scenarios.

The low-capital cost models are expected to have higher R&M expenses related to replacement of timber boards or sections of new metal. An additional $7,000 of R&M compared to the high-capital models has been assumed for an additional total of $12,000 per annum.

10.3.9 Rates and insurance

An increase of $2,000 for insurance premiums has been assumed for the base composting shelter farm. No changes to rates were assumed.

10.3.10 Milk production

Increase in milk production under the composting shelter system occurs as a result of an increase in feed conversion efficiency (FCE), days in milk and pasture grown, as well as from the mitigation of heat stress.

The increase in milk production from improved FCE, days in milk and pasture grown is assumed at 50 kg MS/cow (+28,250 kg MS), while the increase in production from provision of shelter (Table 30) is assumed at 6.76 kg MS/cow (+3,820 kg MS). Overall, this provides additional income of $286,700 net of dairy levies.

Table 30: Impact of mitigating heat stress on milk production for the base composting shelter scenario.

	Base composting shelter
Days warm enough to reduce milk production*	117
Average milk solids reduction (kg MS/cow)	6.76
Peak cows	565
Total milk solids saved by providing shelter	3,820
Milk price ($/kg MS)	9.00
Increased milk income from provision of shelter ($)	34,376

**based on a 3-day rolling average THI (as per calculation in Bryant et al., 2007) using local climate data.*

10.3.11 Dividend

Additional Fonterra shares in line with the extra milk production (32,069 kg MS) are assumed to be purchased under the base composting shelter system. Earnings on shares is assumed at $0.25/share providing an additional $8,017 of income.

10.3.12 Dairy cow sales

With no changes to animal health or replacement rate assumed, number of empty and cull cows sold remains the same under the base composting shelter system. However, the increase in cow liveweight is expected to result in increased stock sales valued at $3,440 (Table 31).

Table 31: Value of stock sales between the status quo and base composting shelter system.

	Status Quo	Base Composting Shelter
Liveweight (kg)	525	545
Liveweight at slaughter (kg)	473	491
Dressing out %	0.42	0.42
Carcass weight (kg cwt)	221	229
Price ($/kg cwt)	$3.90	$3.90
Price per head ($/cow)	860	893
Cows sold	105	105
Total stock sales ($)	$90,295	$93,735

10.3.13 Cropping

Removal of summer (6 ha turnips) and winter (3 ha oats) cropping results in a saving of $12,600 based on $1,600/ha for turnips and 1,000/ha for oats.

10.3.14 Wintering off and freight

Housing all cows over winter results in the removal of winter grazing costs for the 230 cows previously grazed off-farm for four weeks under the status quo. At a cost of $35 per head per week for grazing and freight of $25 per head, total cost saved from not wintering cows in the shelter is $41,400.

10.3.15 Regrassing and under-sowing

The avoidance of over-grazing pastures in summer is expected to result in a reduction in the amount of area required to be under-sown. Under the status quo, 30 ha is under-sown annually at a cost of $185/ha. Area to be under-sown in the base composting shelter system is assumed to be halved resulting in a saving of $2,775.

Regrassing in the status quo system had occurred as part of the cropping regime. While no cropping occurs in the base composting shelter system, the same allowance for regrassing has been assumed.

10.3.16 Financial models

Full financial models for the high and low composting shelter scenarios are displayed in Table 32 and Table 33, with repairs and maintenance the key differences between each of the models.

Table 32: Scenario 1H and 2H annual financial model.

	Total $	$/ha	$/cow	$/kg MS
NET CASH INCOME (NCI)				
Net Milk Proceeds	**2,357,651**	13,683	4,173	8.94
Dividend	**65,930**	383	117	0.25
Net Dairy Trading Proceeds	**102,020**	592	181	0.39
Value of Change in Livestock	-	-	-	-
Other Farm Income	-	-	-	-
TOTAL NET CASH INCOME (NCI)	**2,525,601**	**14,658**	**4,470**	**9.58**
FARM WORKING EXPENSES				
Labour				
Wages	235,820	1,369	417	0.89
Management	18,000	104	32	0.07
Total Labour Expenses	253,820	1,473	449	0.96
Stock Expenses				
Animal Health	75,000	435	133	0.28
Breeding & Herd Improvement	45,600	265	81	0.17
Bedding	**48,713**	283	86	0.18
Farm Dairy	**20,492**	119	36	**0.08**
Electricity (Farm Dairy, Water Supply)	**36,430**	211	64	**0.14**
Total Stock Expenses	226,234	1,313.03	400.41	0.86
Feed Expenses				
Supplement Expenses				
Purchased	352,900	2,048	625	1.34
Cropping	-	-	-	-
Calf Feed	15,000	87	27	0.06
Total Supplement Expenses	367,900	2,135	651	1.40
Grazing & Run Off Expenses				
Young & Dry Stock Grazing	95,073	552	168	0.36
Winter Cow Grazing	-	-	-	-
Support Block Lease	-	-	-	-
Total Grazing & Support Block Expenses	95,073	552	168	0.36
Total Feed Expenses	462,973	2,687	819	1.76
Other Working Expenses				
Fertiliser	**95,896**	557	170	0.36
Nitrogen	**74,047**	430	131	0.28
Regrassing/undersowing	**15,375**	89	27	0.06
Weed & Pest	9,000	52	16	0.03
Vehicles & fuel	**73,670**	428	130	0.28
R & M - Land & Buildings	**83,877**	487	148	0.32
R & M - Plant and equipment	31,139	181	55	0.12
Freight and General	**8,280**	48	15	0.03
Total Other Working Expenses	391,284	2,271	693	1.48
Overheads				
Administration	42,601	247	75	0.16
Insurance	**26,973**	157	48	0.10
Rates	16,925	98	30	0.06
Total Overheads	275,870	1,601	488	1.05
TOTAL FARM WORKING EXPENSES	**1,420,811**	**8,246**	**2,515**	**5.39**
CASH OPERATING SURPLUS (EBITDA)	**1,104,790**	**6,412**	**1,955**	**4.19**

Table 33: Scenario 1L and 2L annual financial model.

	Total	$/ha	$/cow	$/kg MS
NET CASH INCOME (NCI)				
Net Milk Proceeds	2,357,651	13,683	4,173	8.94
Dividend	65,930	383	117	0.25
Net Dairy Trading Proceeds	102,020	592	181	0.39
Value of Change in Livestock	-	-	-	-
Other Farm Income	-	-	-	-
TOTAL NET CASH INCOME (NCI)	**2,525,601**	**14,658**	**4,470**	**9.58**
FARM WORKING EXPENSES				
Labour				
Wages	235,820	1,369	417	0.89
Management	18,000	104	32	0.07
Total Labour Expenses	253,820	1,473	449	0.96
Stock Expenses				
Animal Health	75,000	435	133	0.28
Breeding & Herd Improvement	45,600	265	81	0.17
Bedding	**48,713**	283	86	0.18
Farm Dairy	**20,492**	119	36	**0.08**
Electricity (Farm Dairy, Water Supply)	**36,430**	211	64	**0.14**
Total Stock Expenses	226,234	1,313	400	0.86
Feed Expenses				
Supplement Expenses				
Purchased	352,900	2,048	625	1.34
Cropping	-	-	-	-
Calf Feed	15,000	87	27	0.06
Total Supplement Expenses	367,900	2,135	651	1.40
Grazing & Run Off Expenses				
Young & Dry Stock Grazing	95,073	552	168	0.36
Winter Cow Grazing	-	-	-	-
Support Block Lease	-	-	-	-
Total Grazing & Support Block Expenses	95,073	552	168	0.36
Total Feed Expenses	462,973	2,687	819	1.76
Other Working Expenses				
Fertiliser	**95,896**	557	170	0.36
Nitrogen	74,047	430	131	0.28
Regrassing/undersowing	**15,375**	89	27	0.06
Weed & Pest	9,000	52	16	0.03
Vehicles & fuel	73,670	428	130	0.28
R & M - Land & Buildings	90,877	527	161	0.34
R & M - Plant and equipment	31,139	181	55	0.12
Freight and General	**8,280**	48	15	0.03
Total Other Working Expenses	398,284	2,312	705	1.51
Overheads				
Administration	42,601	247	75	0.16
Insurance	26,973	157	48	0.10
Rates	16,925	98	30	0.06
Total Overheads	262,366	1,523	464	0.99
TOTAL FARM WORKING EXPENSES	**1,427,811**	**8,287**	**2,527**	**5.41**
CASH OPERATING SURPLUS (EBITDA)	**1,097,790**	**6,371**	**1,943**	**4.16**

10.4 Environmental assumptions for base composting shelter system

Environmental modelling was completed in OverseerFM v6.4.3 using best practice data input standards (Overseer, 2019). Adjustments to the base composting shelter model were made in accordance with the physical system assumptions (Section 10.1).

10.4.1 Composting shelter modelling assumptions

The method of modelling the composting shelters is described in Table 34. Guidance from Overseer was sought to model the composting shelter structure which is currently not well encapsulated within the model, in particular the composting process and management of effluent.

The shelter is modelled as a covered wintering pad with a carbon rich bunker, reflecting the covered structure with bedding base. Twenty-four months between adding animals and cleaning the bunker represents the longevity of bedding in the shelter. The liquids drained away option is left unchecked which results in the model combining the liquid effluent with the solids as occurs through the *in situ* composting process. It is assumed that the concrete standing area (feed apron) is scraped with no additional water used. Use of the shelter is modelled as per Section 10.2.1 - Time in Shelter.

All effluent (liquid and solid) is modelled as exported, as opposed to being managed through the farm effluent system which is not the case for the composted material. In a composting shelter, all liquid and solid effluent is composted *in situ*. In a well-managed shelter there is no effluent to manage, instead the bedding material is cleaned out (in this case every two years) and applied back to the farm as a compost. Exporting the effluent and then reimporting as a compost product provides the closest representation of this system.

Table 34: Composting shelter modelling assumptions used in OverseerFM v6.4.3.

Item	Assumption
Pad type	Covered wintering pad
Bunker management	Carbon rich (sawdust, bark, woodchips)
Time between adding animals and cleaning bunker (months)	24
Liquids drained away (added to liquid effluent)?	No
Concrete feeding apron present and used	Yes
Manure removal method	scraping (no water)
Time on apron (hours)	2
Feeding regime	Winter pad and grazing hours
Percent of animals on shelter and hours spent on shelter per day	100% of animals
	hours per day based on weighted average as per Section 10.2.1
Effluent management system	Exported
Solids management	Other (exported)
Solids storage method	No storage

10.5 Investment analysis assumptions

Discounted cash flow analysis was used to evaluate the performance of the status quo system and compare against each of the of the composting shelter scenarios. Key assumptions used for the analysis include:

- Cash flow analysis was evaluated at a cash operating surplus (EBITDA) level and therefore excluded the impacts of interest and tax. This allows the performance of the investment to be compared irrespective of capital structure and tax obligations, and regardless of how an individual entity might finance the investment.

- Cash flows were created exclusive of inflation using current value (2022) figures. This enables a fair comparison of the status quo and composting shelter scenarios by using the same financial parameters.

- Internal rate of return (IRR) was used to assess the whole business performance of the composting shelter scenarios relative to the status quo. Returns from the individual composting shelter investments were then assessed using IRR and net present value (NPV) by determining the change to the cash flows in each year compared to the status quo ('marginal analysis').

- No rental was assumed on the land, and therefore the investment in the land was assumed as a capital investment.

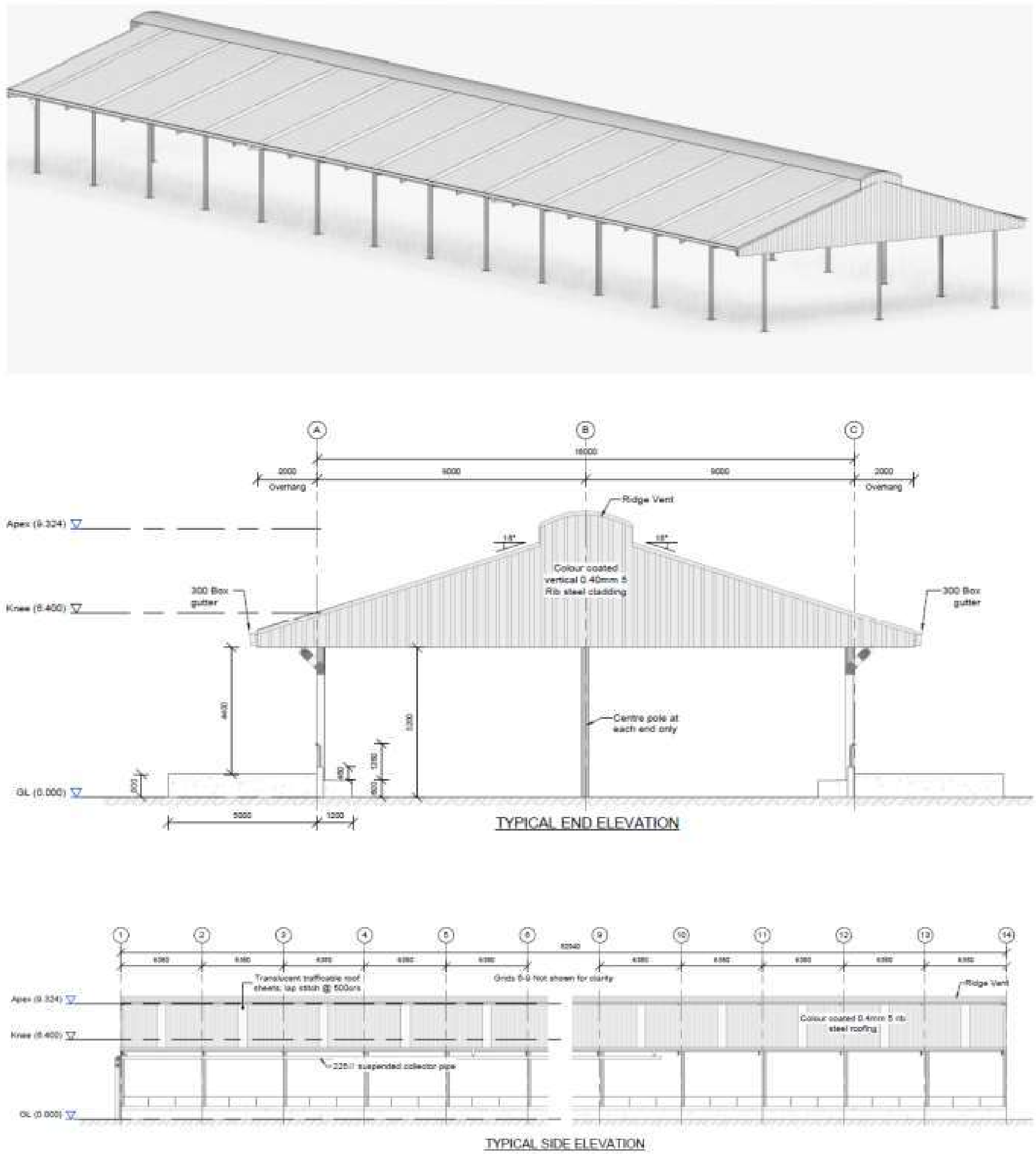
- Salvage values on status quo assets (land and buildings, machinery, shares and livestock) were assumed at 100% and therefore annual capital expenditure to upgrade assets was included.

- Salvage values on the composting shelter infrastructure were varied at 0% and 50%, to understand the implications to investment returns, and as such no capital upgrades were included. Capital renewal for new machinery related to the composting shelter scenarios was however provisioned at the time it is incurred. For the tractor, this was every ten years, and for the roof in the tunnel-roof scenarios this was every 15 years.

- Estimated production levels for the composting shelter scenarios was assumed to be achieved over a four-year transition period.

10.6 Shelter Designs

10.6.1 Rigid Roof



Aztech BUILDINGS

Figure 8: Rigid roof (S1) concept plan including end and side elevation view. All three shelters to be built as identical design. Concept plan provided by Aztech Buildings.

10.6.2 Tunnel Roof

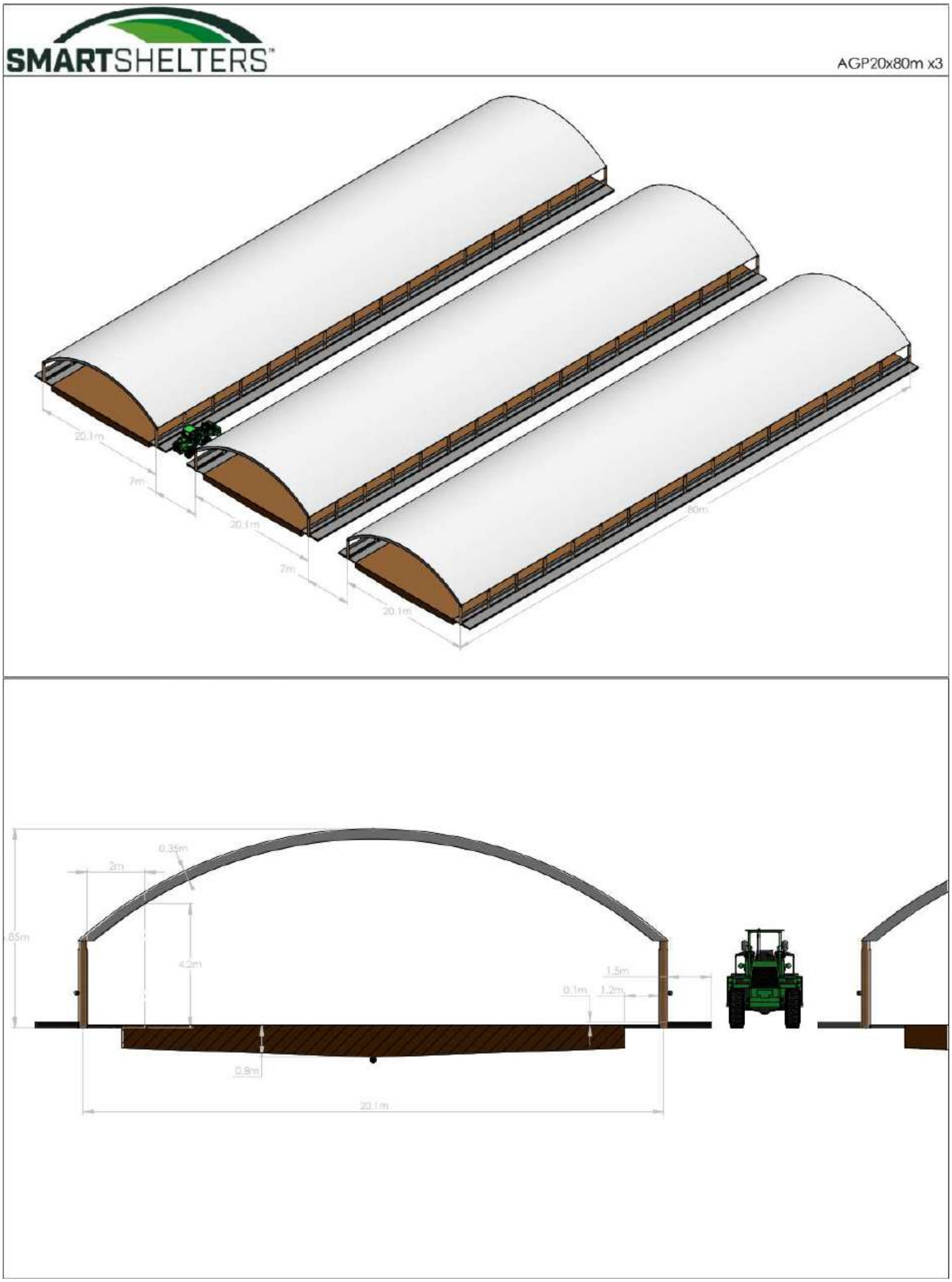


Figure 9: Tunnel roof (S2) concept plan including top and end elevation view. Concept plan provided by SmartShelters.

10.7 Discounted cash flow models

Examples of the discounted cash flow models for the status quo and one of the composting shelter scenarios (S1H) are displayed in Table 35 and Table 36. Additional discounted cash flows are held by the author.

Table 35: Discounted cash flow for the status quo at 25 and 50 year investment periods. Note, the spreadsheet has been compacted for ease of reading.

	Status Quo														
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 10	Yr 22	Yr 23	Yr 24	Yr 25	Yr 47	Yr 48	Yr 49	Yr 50
	Milk Revenue	$2,070,951	$2,070,951	$2,070,951	$2,070,951	$2,070,951	$2,070,951	$2,070,951	$2,070,951	$2,070,951	$2,070,951	$2,070,951	$2,070,951	$2,070,951	$2,070,951
	Fonterra Dividend	$57,913	$57,913	$57,913	$57,913	$57,913	$57,913	$57,913	$57,913	$57,913	$57,913	$57,913	$57,913	$57,913	$57,913
	Livestock Sales (Net)	$98,580	$98,580	$98,580	$98,580	$98,580	$98,580	$98,580	$98,580	$98,580	$98,580	$98,580	$98,580	$98,580	$98,580
	Operating Expenses	-$1,396,358	-$1,396,358	-$1,396,358	-$1,396,358	-$1,396,358	-$1,396,358	-$1,396,358	-$1,396,358	-$1,396,358	-$1,396,358	-$1,396,358	-$1,396,358	-$1,396,358	-$1,396,358
	EBITDAR	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593
	Rental	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	EBITDA	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593	$674,593
	Depreciation/Annual Capex Upgrades	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492
50yrs	Capital Investment														
	Fonterra Shares	-$637,038													$637,038
	Livestock	-$1,346,760													$1,346,760
	Machinery	-$161,000													$161,000
	Land & Buildings	-$7,081,500													$7,081,500
	Infrastructure Upgrades														$0
50yrs	Net Movement	-$8,681,197	$545,101	$545,101	$545,101	$545,101	$545,101	$545,101	$545,101	$545,101	$545,101	$545,101	$545,101	$545,101	$9,771,398
25yrs	Capital Investment														
	Fonterra Shares	-$637,038									$637,038				
	Livestock	-$1,346,760									$1,346,760				
	Machinery	-$161,000									$161,000				
	Land & Buildings	-$7,081,500									$7,081,500				
	Infrastructure Upgrades	$0									$0				
25yrs	Net Movement	-$8,681,197	$545,101	$545,101	$545,101	$545,101	$545,101	$545,101	$545,101	$545,101	$9,771,398				

Whole business 50yrs

IRR	6.3%

Discount rate	NPV
2%	$11,511,474
4%	$4,136,776
6%	$388,631
8%	-$1,677,668
10%	-$2,904,374

Whole business 25yrs

IRR	6.4%

Discount rate	NPV
2%	$7,220,578
4%	$3,105,110
6%	$413,880
8%	-$1,376,833
10%	-$2,588,090

Table 36: Discounted cash flow example for S1H at 25 and 50 year investment periods, and varying salvage values. Note, the spreadsheet has been compacted for ease of reading.

	Composting Shelter: Rigid (High)												
	Production	231,650	237,347	250,533	263,719	263,719	263,719	263,719	263,719	263,719	263,719	263,719	263,719
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 25	Yr 50
	Milk Revenue	$2,070,951	$2,121,886	$2,239,769	$2,357,651	$2,357,651	$2,357,651	$2,357,651	$2,357,651	$2,357,651	$2,357,651	$2,357,651	$2,357,651
	Fonterra Dividend	$65,930	$65,930	$65,930	$65,930	$65,930	$65,930	$65,930	$65,930	$65,930	$65,930	$65,930	$65,930
	Livestock Sales (Net)	$102,020	$102,020	$102,020	$102,020	$102,020	$102,020	$102,020	$102,020	$102,020	$102,020	$102,020	$102,020
	Operating Expenses	-$1,420,811	-$1,420,811	-$1,420,811	-$1,420,811	-$1,420,811	-$1,420,811	-$1,420,811	-$1,420,811	-$1,420,811	-$1,420,811	-$1,420,811	-$1,420,811
	EBITDAR	$650,140	$701,076	$818,958	$936,841	$936,841	$936,841	$936,841	$936,841	$936,841	$936,841	$936,841	$936,841
	Rental	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	EBITDA	$650,140	$701,076	$818,958	$936,841	$936,841	$936,841	$936,841	$936,841	$936,841	$936,841	$936,841	$936,841
	Annual Capex Upgrades	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492	-$129,492
	Capex on New Machinery	$0	$0	$0	$0	$0	$0	$0	$0	$0	-$38,348	$0	-$38,348
50yrs	Capital Investment												
	Fonterra Shares	-$725,228											$725,228
	Livestock	-$1,346,760											$1,346,760
	Machinery	-$237,695											$237,695
	Land & Buildings	-$7,081,500											$7,081,500
	Infrastructure Upgrades	-$2,495,406											$0
50yrs	Net Movement	-$11,365,941	$571,583	$689,466	$807,348	$807,348	$807,348	$807,348	$807,348	$807,348	$769,001	$807,348	$10,160,184
50 yrs	**MARGINAL CASHFLOW**	**-$2,684,745**	**$26,482**	**$144,365**	**$262,247**	**$262,247**	**$262,247**	**$262,247**	**$262,247**	**$262,247**	**$223,900**	**$262,247**	**$388,786**
25yrs	Capital Investment												
	Fonterra Shares	-$725,228										$725,228	
	Livestock	-$1,346,760										$1,346,760	
	Machinery	-$237,695										$237,695	
	Land & Buildings	-$7,081,500										$7,081,500	
	Infrastructure Upgrades	-$2,495,406										$1,247,703	
25yrs	Net Movement	-$11,365,941	$571,583	$689,466	$807,348	$807,348	$807,348	$807,348	$807,348	$807,348	$769,001	$11,446,235	
25 yrs	**MARGINAL CASHFLOW**	**-$2,684,745**	**$26,482**	**$144,365**	**$262,247**	**$262,247**	**$262,247**	**$262,247**	**$262,247**	**$262,247**	**$223,900**	**$1,674,836**	
25yrs 0%	Capital Investment												
	Fonterra Shares	-$725,228										$725,228	
	Livestock	-$1,346,760										$1,346,760	
	Machinery	-$237,695										$237,695	
	Land & Buildings	-$7,081,500										$7,081,500	
	Infrastructure Upgrades	-$2,495,406										$0	
25yrs 0%	Net Movement	-$11,365,941	$571,583	$689,466	$807,348	$807,348	$807,348	$807,348	$807,348	$807,348	$769,001	$10,198,532	
25 yrs 0%	**MARGINAL CASHFLOW**	**-$2,684,745**	**$26,482**	**$144,365**	**$262,247**	**$262,247**	**$262,247**	**$262,247**	**$262,247**	**$262,247**	**$223,900**	**$427,133**	

Marginal analysis (50yrs) - 0% salvage value

IRR	**8.5%**
Discount rate	NPV
2%	$4,965,069
4%	$2,431,814
6%	$1,007,615
8%	$154,927
10%	-$384,815

Marginal analysis (25yrs) - 50% salvage value

IRR	**7.8%**
Discount rate	NPV
2%	$2,696,827
4%	$1,426,908
6%	$559,176
8%	-$44,699
10%	-$472,175

Marginal analysis (25yrs) - 0% salvage value

IRR	**7.0%**
Discount rate	NPV
2%	$1,936,314
4%	$958,873
6%	$268,463
8%	-$226,886
10%	-$587,333

Whole business (50yrs) - 0% salvage value

IRR	**6.8%**
Discount rate	NPV
2%	$16,476,544
4%	$6,568,590
6%	$1,396,246
8%	-$1,522,741
10%	-$3,289,188

Whole business (25yrs) - 50% Salvage value

IRR	**6.7%**
Discount rate	NPV
2%	$9,917,405
4%	$4,532,018
6%	$973,056
8%	-$1,421,532
10%	-$3,060,265

Whole business (25yrs) - 0% Salvage value

IRR	**6.5%**
Discount rate	NPV
2%	$9,156,892
4%	$4,063,983
6%	$682,343
8%	-$1,603,719
10%	-$3,175,423