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Protein Extraction from Pasture

Cost-Benefit Analysis: A feasibility study evaluation of both investment and economic implications

June 2009

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Protein extraction from pasture

Cost-Benefit Analysis: A feasibility study evaluation of both investment and economic implications

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Stephen Sinclair and Rachael MacManus

Preamble

This report comprises three major sections (parts) written by the authors, in addition to co-joint and edited introduction, discussion and recommendations.

Part A : Results of pastoral farming system integration within a protein extraction bio-process system. (Stephen Sinclair). Overviews the feasibility of ex-farm raw material (green forage) supply to a bio-process facility from current modelled New Zealand pastoral farming systems.

Part B : A preliminary feasibility assessment regarding a proposed centralised bio-processing plant, incorporating the extraction of protein from green forages (Rachael MacManus). Overviews the feasibility of a bio-process plant establishment (capital cost) and operational management components (mass balance, operating cost and revenue) over a 'whole of life' plant cost cycle of 20 years.

Part C : Results of system dynamic financial modelling and risk assessment of an integrated protein extraction system. (Stephen Sinclair). Briefly overviews the feasibility of an integrated protein extraction system using system dynamics methodology and tools, deriving data input from Sections Part A and Part B.

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1. Executive Summary

This cost-benefit analysis (CBA) report completes the overall feasibility study investigation into the viability of an integrated protein extraction system, based on a feasibility scope of New Zealand pastoral farming systems providing raw green forage material (lucerne and temperate pasture) to a green crop fraction bio-process. Product outputs of leaf protein concentrate (LPC), with by-products deproteinised juice (DPJ) and residual protein extracted crop fibre (extracted fibre) provide the system revenue stream. The initial literature reviews and information compilation by Sinclair (2009a,b) have provided the overview for the bio-process and technical feasibility, and the conceptual frameworks for the supply of green forage, the operational management and environmental benefits on-farm with the system, and ultimate market development and strategic marketing issues important for revenue generation and system sustainability. In view of the complexity of bio-physical systems, the CBA has been completed in three parts to accommodate the dynamics involved.

PART A – Integrated pastoral farm systems within a 'protein extraction' system

New Zealand pastoral farming systems were evaluated for their operational and economic feasibility in supplying green forage to a centrally located bio-process facility. Lucerne green forage was modelled as supply from both North Island (NI) and South Island (SI) sheep and beef systems with lucerne crop area for grazing only, or 50% grazing and 50% dedicated protein extraction (PE) system crop (viz. PE lucerne). Temperate pasture supply (viz. PE Pasture) derived from NI and SI pastoral dairy systems providing surplus forage either in spring only, or combined spring and autumn harvested from 20%, or 20 and 10% of the farming area respectively. The farm systems were modelled (using accepted industry standard decision support software tools) using existing 'industry based regional farm templates' and utilising realistic current commercial information and expert opinion.

The sheep and beef systems were able to accommodate PE lucerne supply through manipulation of livestock enterprises (modification of feed budgeting and livestock classes) as grazing area was reduced. The sheep and beef PE systems conceivably supplied 1300 to 1800 t DM per farm, however gross farm revenue with the PE systems were lower than current systems. Sensitivity analysis evaluation of the PE system with control farms, using *ceteris paribus*[1] break-even 'margin' comparison, suggests that

[1] Other things being equal

around 18 c/kg DM for PE lucerne for both NI and SI farm comparisons would be required to equate to Control (current) farm system gross farm returns (GFR). However whilst operationally feasible, economic evaluation suggests that for PE lucerne production, farm gate pricing at 25 c/kg DM ($250 per t DM) appears reasonable for improved GFR (over current system returns) to enable consideration for an enterprise change. This pricing also has an imputed 'premium' or incentive value. Note that there was no bio-process product return as purchased supplement feed of protein extract fibre (PEF) and DPJ; this occurred with the dairy farm PE systems however.

Dairy farm systems were also seen to be operationally feasible in PE pasture supply, but predominantly for spring pasture surplus only, with minor and constraining autumn surplus availability from NI systems only. The NI dairy systems suggested input feed cost values for PEF + DPJ to obtain GFR comparable to current system, was in the range of $150 to $220 per t DM, and conversely output PE Pasture pricing was $265 to $310 per t DM. The SI dairy PE system required $170 and $295 per t DM respectively for feed input cost (PEF + DPJ) and PE Pasture sale price. If we assume say a 15% premium for PE pasture pricing to entice farmer system innovation to the PE system, PE pasture pricing around $330 per t DM may be indicative, based on this studies farm modelling, to induce an enterprise modification consideration. The use of assumed dairy system winter feed management and effluent disposal practices combined with PEF and DPJ feeding within an integrated PE system provided tangible economic benefits via estimated nitrogen trading market value allowances. Sensitivity analysis for inclusion of environmental benefit allowances showed dairy PE systems could obtain, by proxy, GFR values in excess of the current system similar to gains in reduced bio-process feed by-product input costs or increased forage sale revenue.

PART B – The bio-process

The processing plant basis of this "Protein from Pasture" project assessment was a centralised bio-process facility accommodating the supply of 288,000 tonne per annum of green forages (lucerne and pasture). The process generates four main marketable products, the main product being leaf protein concentrate (LPC), and the other three by-products are deproteinised juice (DPJ), fibre pellets and silage/baleage.

A mass balance was performed for the proposed process; however due to insufficient information being available several assumptions were made. It is recommended that pilot-scale work be carried out to specifically address these assumptions to confirm the mass balance.

The cost of the main plant items was estimated. Lang factors were applied to cover the indirect and direct cost associated with the building of the processing facility. The total estimated capital cost was $94.4 million. Operating costs were estimated at $33.3 million for the project; feed-stock and associated costs such as transport and harvesting accounts for 78% of this. The sale of the four products generated $38.4 million; nearly 60% is from the sale of LPC when sold at $1650 per tonne dry matter (DM).

A whole of life cost analysis model was developed for a 20 year term as a tool to assess economic feasibility. At the end of the 20 years the project had a cumulative Net Present Value (NPV; standard methodology for financial appraisal of long-term projects) of -$51.7million at a 10% discount rate. A sensitivity analysis was carried out that highlighted which areas which could improve the outlook of the project. When the operating costs were reduced by 50% the project broke-even in year 12, hence it is suggested the cost associated with the feedstock be investigated. The project would also break-even more rapidly if more revenue was generated; when the market price for LPC was increased by two times the break-even occurred in year 9. It is recommended that other higher-value markets (non-animal based) be looked into for LPC.

PART C – System dynamic financial modelling and risk assessment

The existing base investment model, under further multivariate and multiple Monte-Carlo simulation to increase quantitative risk assessment power, has confirmed the cumulative negative NPV values and rejection of the investment proposal on this criterion. The multivariate sensitivity simulations (MVSS) performed, in terms of NPV cash flow, have elucidated the current issue of raw material input cost ranges, and LPC market price probabilities, being unprofitable for the bio-process within the current integrated PE system analysis and appraisal. The sensitivity simulations have nevertheless added to information available for the decision making process, but suggest that alternative PE system criteria (such as vertically integrated raw material supply) and options (higher value LPC markets) be considered. Profitable investment scenarios appear unrealistic in the current cost and pricing regimes.

Overall feasibility study summary and recommendations

The following recommendations are made within the constraints and context of the body or work completed in Parts A, B and C; and also reflecting further the underlying integrated PE system knowledge, rationales and discussion outlined previously by Sinclair (2009a,b).

On the basis of the CBA investment appraisal and analysis, including accountability for intangibles, the current proposed 'integrated protein extraction system' is <u>considered not viable</u> for proceeding to the business planning phase or implementation, based on the feasibility study scope and information currently at hand.

The feasibility study has highlighted areas for further consideration and possibilities for optimising the bio-process in the future based on current knowledge. These are now addressed briefly.

Raw material (green forage) costing and supply

From a bio-processing facility perspective, the high proportion of operating expenditure allocated to raw material costs (green forage and associated harvest costs, up to 70%) necessitates consideration for optimised purchasing value. However analysis has suggested, within recognised farmer decision making to change or modify an enterprise, that current farm gate revenue expectations from the pastoral farming system exceed the purchasing cost ranges for a viable bio-processing venture. The options for the bio-process plant to lease land and control the forage supply process through vertical integration and dedicated technical input forage cropping may have logistical and costing advantages that are worthy of future investigation. This option would negate the compromise that exists with combined livestock and forage supply enterprises, and the competitive but realistic opportunity costing that exists for forage supply under this regime.

The innovative conceptual role for an integrated PE system within greenhouse gas environmental management and mitigation options for pastoral based dairy farm systems in particular is encouraging. Whilst unlikely as a major bio-process plant supply, surplus dairy pasture harvest may be regionally attractive and compatible to other green forage supply options (dedicated forage cropping land use).

Extract fibre (silage/baleage) and DPJ pricing

The ruminant livestock fodder market in New Zealand is highly competitive and with inherent pricing volatility. In this regard the scope to enhance revenue streams from the bio-process co-products appears constrained. The environmental benefits from extract fibre and DPJ return on farm within an integrated PE system are noted; however on-farm delivery pricing constraints and farmer alternative technologies suggest careful case by case assessment of the net benefit. The net benefit is greatly improved where nutrient discharge allowance market trading is likely to be, or is currently, occurring.

LPC pricing

The financial and product attribute value of xanthophylls pigment levels in LPC, particularly as a poultry feed ingredient, have been reviewed and discussed previously (see Sinclair, 2009b), and price premiums conjectured in previous crop fractionation economic analyses and assumptions (refer Heath et al., 1981; McDonald et al., 1981). The LPC price used in this feasibility study as a 'base', at $1650 per tonne DM, appears broadly relative to high value pricing evidenced in the US (refer Sinclair 2009b), and certainly could be surmised to have a premium value inclusion given domestic and some export market development options where pricing was estimated to be below $1,000 per tonne to be attractive as a valued feed ingredient (Sinclair, 2009b). In addition, the market development reality of proposed LPC product placement (as a new or novel product; Sinclair, 2009b) within high value animal feed ingredient segments suggests that imputed higher marketing costs in initial years may also need to be cost factored, putting further pressure on net LPC sales revenue projections.

Clearly the CBA analysis has shown that LPC revenues need to increase largely though price capture, through attention to higher value markets other than animal based (e.g. potential product markets could include cosmetics, personal care, human food ingredients, medical and pharmaceutical inputs).

Where to from here?

Further research and development is suggested in the areas of;

- Market segments and pricing for LPC, particularly higher value product options.
- Increased efficiencies in the bio-process engineering, in particular pilot study work to update and enhance product yields of each press and the moisture requirements of each press, recycling of DPJ and confirmed mass balance flows and component streams.
- Modification of the green forage supply systems to exclude livestock enterprise complexities, with the exception of intensive dairy systems in environmentally sensitive catchments, where complementation strategies could be examined further.

2. Acknowledgements

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Stephen Sinclair (AgResearch Limited)-Chair
Tom Pow (Farming interests and Herd Homes® Systems Ltd.)
Mark Aspin (PGgRc)
Duncan MacLeod (Farming interests and BNZ Agribusiness)
Angie Fisher (DairyNZ)
Rod McDonald (Contract scientist-engineer)

3. Introduction

A feasibility study has been funded into the analysis of the viability for a commercial scale plant fractionation bio-process in New Zealand, whereby green forage supply from existing pastoral faming systems is utilised as a source of leaf protein concentrate (LPC), with by-products being deproteinised juice (DPJ) and residual protein extracted crop fibre (extracted fibre or presscake[2]). Whilst initial pilot R&D[3] and small-scale commercial application of the protein fractionation system (bio-process) within New Zealand have been investigated previously in the 1970's and 1980's, ultimately both the R&D initiatives, and subsequent commercial application, were discontinued (refer Sinclair, 2009a, 2009b). However, recent market and socio-political influences on pastoral farming via greenhouse gas emissions and nutrient management have suggested that an integrated farming system and green crop protein extraction process may now be both economically and environmentally amenable to the New Zealand agribusiness sector.

The plant fractionation bio-process and its conceptual adaptability to farming systems has already been reviewed and discussed previously, including description of this feasibility study rationale and scope (refer Sinclair, 2009a). The scope of the project has encompassed: (i) consensus for static, centrally located, economies of scale plants to be considered for viability in the first instance, using intermediate to high protein extraction technologies; (ii) green crop raw material to be both lucerne (*Medicago sativa*) as a 'crop' derived from sheep and beef pastoral and cropping systems, and a temperate pasture mix comprising nominally perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) derived from pastoral dairy systems; and (iii) major products to market from the extraction plant being LPC and Presscake (extracted fibre) derivatives, namely silage and dehydrated lucerne, with DPJ concentrate re-incorporation into silage/dehydrated fibre products. These end-products constitute animal nutrition feed ingredients (ruminant feed products and higher value monogastric and aquaculture feed products) within the current scope for this project. Further, market development issues and product attributes and pricing have also been addressed to date within this project feasibility assessment (Sinclair 2009b). This report then documents an economic and financial appraisal of the project proposal, including an overall succinct feasibility study summary, and recommendations arising from the cost benefit analysis (CBA). The assumption that a conceptualised integrated protein extraction system exists (viz. an integrated PE system;

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[2] For the purposes of this report, both protein extracted lucerne fibre (PELF) and protein extracted pasture fibre will be commonly expressed as 'extract fibre' unless otherwise specified.
[3] Research and Development

refer Figure 11, pg. 35, Sinclair 2009b) assumes, especially for dairy systems, the bio-physical and cost imputed return of extract fibre and DPJ to farm forage suppliers.

Previous economic analyses of a green crop (leaf protein) fractionation or extraction process in both the UK and New Zealand have elucidated key cost and pricing variables within the scope of farm gate purchased green forage and fractionation process products used for animal feed inclusion (refer Wilkins et al., 1977; Heath et al., 1981; McDonald et al., 1981). Whilst recent modifications and cost structures in regard to the bio-process system require updating, this economic evaluation also considers a broader investment risk analysis, and the attributes of environmental benefits with an integrated PE system at the farm level. Accepted agribusiness investment appraisal and analysis tools are available within the agricultural based management and marketing paradigm that exists for this project proposal (refer Malcolm et al., 2005; Shadbolt and Gardner, 2005; Gardner et al., 2005), including cost benefit analysis[4] (CBA; refer Anon. 2005a; Malcolm et al., 2005). These have been utilised within the modelling framework and bio-process cost benefit estimation used in interpreting the viability of an integrated PE system in New Zealand.

Finally, this report, and the project proposal encompassed within, represents a feasibility study *and not* a business plan. There is sometimes confusion in this regard (see Hofstrand and Holz-Clause, 2006), where the feasibility study outlines and analyses scenarios, determines business venture viability and defines a scope for proceeding if a positive analysis results in the decision to proceed further with the project. The business plan proceeds only after an affirmative feasibility study, and includes more focussed direction, singular system design and planning, and project implementation strategies. Importantly, if the current feasibility study finds the project not viable in the current context, recommendations for further evaluation to assess other alternatives, or specifically address new costing or pricing options, or a decision not to proceed any further, can then be made (Hofstrand and Holz-Clause, 2006).

Objectives of this Cost-Benefit Analysis (CBA)

This preliminary study is to provide information on the likely cost structures and returns (i.e. the economic and financial merit) for an integrated protein extraction and farming system enterprise, using accepted methodology and tools, such as CBA. Specifically, this study seeks to;

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[4] Cost benefit analysis is an economic assessment tool, where costs and benefits in monetary terms, and discounting, enable determination of the net benefits (or costs) of a project proposal in today's dollars, and accounts for the discounting of future net cash flows to their equivalent present value.

- Quantify the tangible economic and financial factors in incorporating an integrated PE system with current pastoral farm systems.
- Quantify the tangible economic and financial factors in regard to a forage protein fractionation bio-process facility sourcing raw material from the pastoral farming systems.
- Evaluate the integrated PE system within a stochastic[5] model framework using a system dynamics model.
- Assess decision-making implications and discuss recommendations with regard to the viability of an integrated PE system by including both quantitative tangible factors, but also identified factors that are intangible (essentially qualitative) factors.

3.1 Limitations and constraints of the economic analysis

There are cost benefit and investment analysis criteria that represent significant determinates of the decision-making outcome of any financial and economic analysis, and some key limiting and constraining criteria with respect to this study are;

- *Identifying and quantifying the value of costs and benefits*. Identifying and valuing the costs and benefits of project proposals has major impacts on discounted and net cash flow analysis, where errors can exceed ranking criteria differences and diffuse decision making (refer Makeham and Malcolm, 1993; Anon. 2005a). In view of the paucity of publically available current protein extraction process data, reliance on conceptual system modelling and pricing assumptions has occurred. The authors are confident that information sources and derivation of pricing[6] are of acceptable robustness and accuracy to allow for an adequate cost benefit analysis and recommendation. Nevertheless, given the recognised complexities in the economic analysis of green crop fractionation (e.g. variable biological factors and farm crop systems variance; see Wilkins et al., 1977; Heath et al., 1981), such pricing assumptions remain context based. In addition, attention to intangible (qualitative and non-monetary quantitative) cost and benefit categories, particularly in regard to farmer decision making on raw material supply and 'system fit', and the environmental benefits of the integrated

[5] Allows input variability within agribusiness systems and consequently quantitative risk analysis.
[6] Integrated protein extraction system rationale, operational management implications and associated assumption basis for component pricing of raw material inputs and marketable product outputs are detailed in Sinclair (2009a,b), and complement the further farm system and bio-process costing and pricing assumptions in this report.

protein extraction system, are also addressed in this report to mitigate some assumption risk.

- *Optimism bias*. Optimism bias or 'appraisal optimism' occurs when the most favourable estimates of net benefits are presented as the most likely estimates. There is a demonstrated tendency for many analysts to exhibit optimism bias (refer Anon. 2005a), particularly in underestimation of future costs and overestimation of future benefits. The authors of this report attempt to address this issue through sensitivity analysis and discount rate selection, concomitant with transparent assumptions and justification. There is also a tendency to err to the conservative within the sensitivity analysis to ensure adequate robustness.
- *Discount rate*. The use of a weighting procedure (viz. discounting) allows future cash flows to be converted to present values, and reflects the time preference or time value of money, and its opportunity cost. The interest rate used in discounting is referred to as the discount rate, and its' determination has significant implications for project evaluation and choice (see Malcolm et al., 2005; Gardner et al., 2005). The discount rate typically includes both a rate of time preference and allowance for uncertainty and risk, and whilst the Weighted Average Cost of Capital (WACC) is deemed the minimum accepted discount rate for business investment analysis (refer Gardner et al. 2005), it requires knowledge of acceptable debt: equity levels for the business investor. In the absence (or paucity) of investor equity and risk behaviour precedents for this project proposal business (i.e. plant fractionation bio-processing), a more easily determined and accepted real discount rate of 10% has been used and deemed appropriate in the first instance for this preliminary analysis, including allowance for a moderate risk premium for investments with some paucity of precedent or establishment (refer also Anon. 2005 and Gardner et al., 2005 for rationale in this area). Nevertheless sensitivity analysis on the discount rate has been undertaken to evaluate the effect of a change on the NPV (Section 7, Part C).
- *Financial viability*. With respect to the viability of meeting capital loan and interest payments with cash flow, this study has not undertaken specific financial positions for the farm systems nor bio-process stages, with no accommodation for individual debt: equity assumptions, nor 'liquidity' factors (incl. working capital, refer Shadbolt and Gardner, 2005) per se, being inferred. It is assumed that as a result of this feasibility CBA, decisions to progress, in more detail (concomitant with business planning), cash flow, taxation and profit analyses would be in order.

Obvious limitations *in the scope* of this project are exclusion of review or analysis in regard to high intensity protein extraction and fibre processing leading to, for example;

Biochar or other fibre value products, chemical or solvent production, biofuel and ethanol production, waste product utilisation and higher value product markets including cosmetics, personal care, human food ingredients, medical and pharmaceutical considerations. While these product flows are obviously considered of potential for value adding and process enhancement, preliminary assessment of the re-establishment of protein extraction technologies and farm system integration in a New Zealand context suggested retention to a 'core business scenario' in order to determine initial viability. This perhaps simplistic but practical approach to project assessment is considered cost-effective and with a strategy for minimised risk (refer Sinclair, 2009a), and also reflects the defined project objectives and scope limitation required to meeting funder obligations within the realistic project time and resource constraints imposed (refer also Anon. 2005a).

4. Methodology

Farm systems analysis within an integrated PE system (Part A)

Pastoral farm systems were evaluated using industry accepted deterministic system software models; namely for sheep and beef systems, FARMAX™ (FARMAX 2007), and pastoral dairy systems, UDDER (Larcombe,1999), as complied and 'run' by industry consultants using their respective 'expert opinion'.

The cash inputs and outputs for the farm businesses draw heavily from preceding literature and industry source review for this study (refer Sinclair 2009a,b) and relevant current industry sources[7] , in order to derive realistic revenue stream and variable costs inputs for the farm enterprises within an integrated PE system. A farm activity analysis based on the gross margin methodology regarding revenue and variable costs has been allocated to both livestock and crop (green forage supply) activities (e.g. refer Malcolm et al., 2005) as interpreted by Martin (2005) as a gross farm return, and represents the cash flow available for overhead costs, operating surplus and disposable income. Note that livestock activity analyses do not include allowance (adjustment) for value of change in animal inventory within the livestock trading schedule in this instance, as cash budget only scenarios are being evaluated (see Shadbolt and Gardner, 2005). The incorporation of current pastoral farming enterprises within an integrated PE system is viewed as a tactical and operational decision, within a partial budget analysis framework (refer Gray, 2005). As such, adjustments are made variable cost inputs but no allowance is made for

[7] Data as appropriate from industry sources and media publications, plus MAF Pastoral Monitoring Report (MAF ©2008); Lincoln University Financial Budget Manuals (various).

fixed (overhead) costs, interest and taxation, or depreciation; hence not a Farm Cash Operating Surplus. In addition, it is assumed for both sheep and beef and dairy systems, that no additional capital cost items are outlaid for changing to an integrated PE system. This assumption implicitly implies that for sheep and beef systems; existing cropping infrastructure and supplementary feeding resources exist; and for pastoral dairy systems, existing supplementary feeding infrastructure[8] (silage/baleage storage and feed-out) plus winter feed pads or shelter sheds (e.g. Herd Homes® Shelters) exist prior to PE system incorporation as appropriate. The theorized beneficial margin values with nitrogen discharge allowances allocated (NDAs) with PE system incorporation on-farm are analyzed as additive to current gross returns on-farm as a net annuity calculated value per land unit (refer Section 5.2.1 for rationale).

The construction of 'what if' scenarios using sensitivity analysis involved construction of simple deterministic spreadsheet models (MS Excel based) and the creation of two-way data analysis sensitivity tables to assist in scenario and risk management interpretation (refer Martin, 2005). Key 'input' variables are determined and analysed in regard to a major 'output' variable deterministic on potential profitability or cash revenue. A key output variable used in this study, in view of both livestock and green forage (PE lucerne and PE pasture) enterprise considerations, were Gross Farm Returns (GFR; Eqn. 1), the sum of the individual gross returns for each farm enterprise (Martin, 2005).

$$GFR = \sum_i (P_i \times Q_i - VC_i) \qquad \text{Eqn. (1)}$$

Where

P_i = unit price for product

[8] With regard to DPJ use on farm, the capital, maintenance and operating costs for suitable DPJ tank storage and application to silage (on-farm, refer Sinclair, 2009b for rationale) has been imputed as an annualised equivalent enterprise specific 'lease-type cost' in this instance.

Q_i = output or yield for a particular product

VC_i = variable costs associated with producing the product

Bio-processing plant fractionation process and establishment (Part B)

The bio-process rationale and precedent plant design, coupled with raw plant material input factors and pricing, and the bio-process marketable output pricing and product attribute characteristics draws heavily from preceding literature and industry source review for this study(refer Sinclair 2009a,b). Additional bio-process engineering design and costing principles are outlined in Section 6, Part B.

Investment profitability has been measured using Net Present Value (NPV), an accepted criterion of profitable capital asset use within agribusiness investment decision making where both cash flows and the time value of money are considered (refer Gardner et al., 2005; Malcolm et al., 2005); specifically by using a discount rate and series of future payments (costs, negative values) and income (revenue, positive values) over a specified time period (Eqn. 2).

$$NPV = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - C_0$$

Eqn (2)

Where

t is the time of the cash flow

n is the total time of the project

r is the discount rate

C_t is the net cash flow (future cash benefits less future cash costs) at point in time t

C_0 is the capital outlay at the beginning of the investment time ($t = 0$).

A real discount rate of 10% was used (refer Section 3.1). The feasibility study looks into the mass balance, capital cost, operating cost, revenue and "Whole of Life Cost" (WLC) over a 20 year term, with further specific investment methodology described in Part B (viz. section 6.5). The NPV analysis was completed using real values (constant values) as opposed to nominal terms, with the implicit assumption that the real costs and revenues (prices) will not change relative to each other the life of the project (i.e. treated equally). Whilst this may not always be the case, and appropriate adjustments for inflation can be made; for this study, and in agreement with standard practice at this stage of the project assessment (refer Anon. 2005a; Malcolm et al., 2005), the costs and benefits are valued in real terms in view of our interest in the net return expressed in a common money value. Note that depreciation costs within a discounted cash flow analysis are not deducted (refer Appendix Va, Part B), in view of non-cash interpretation and that capital costs for the project are fully allocated in the year they are incurred (first year generally).

With regard to NPV values, an investment appraisal of a project with a positive NPV at a given discount rate, e.g. 10%, is accepted based on the value of the net benefits exceeding the capital costs and opportunity costs of alternative investment revenue (at 10%) foregone. Negative NPV values are thus rejected on this criterion (see e.g. Malcolm et al., 2005; Gardner et al., 2005).

System dynamic modelling and risk management (Part C)

Whilst the two way data variable sensitivity tables provide insight into simplified quantitative risk analysis at the farm system level, the use of more advanced stochastic modelling for scenario analysis is preferred where more complex agribusiness systems of multivariate dimension exist (see Martin, 2005), as is the case for the integrated PE system. The ability to add randomness to previously deterministic spreadsheet models involves application of more dynamic modelling combined with Monte-Carlo simulation, also known as multivariate sensitivity simulation (MVSS). The integrated PE system model and pricing rationale described in Parts A and B of this report form the basis for a dynamic financial modelling and risk assessment model construct, using an icon-based simulation software package Vensim® (Anon. 2005b). Consequently MVSS was performed[9] using multivariate range scanning to determine sensitivity confidence levels around the cumulative NPV cash flow, over the existing 20 year investment life cycle. Uncertainty in multiple parameters was assessed within the MVSS using concurrent multivariate parameter testing and 'random-uniform' probability distribution for the variable range values (minimum and maximum), over 200 model simulation events for each sensitivity analysis.

5. PART A: Results of pastoral farming system integration within a protein extraction bio-process system

5.1 Sheep and beef systems and lucerne crop production

The sheep and beef farm systems selected were;

- a North Island (NI) sheep and beef breeding property with lucerne, in semi-intensive Central NI location (NI Control) with all lucerne grown grazed (forage available for livestock production), and the same property scenario with

[9] Ranges are set on target variables for sensitivity analysis, with model simulation over multiple runs randomly selecting values for the targeted variables.

adjustments with 50% of lucerne area allocated to an integrated PE system (NI + PE).

- A South Island sheep breeding property and cropping, based in Mid-North Canterbury semi-intensive to intensive pastoral region, with all lucerne crop grazed (SI Control), and the same property scenario with adjustments with 50% of lucerne area allocated to an integrated PE system (SI + PE).

Note: the sheep and beef + lucerne farm systems modelled did not include bio-process product return to the property (i.e. no extract fibre silage/baleage and DPJ; refer Sinclair, 2009b, for rationale on this based on feedback from industry sources). It is also assumed that the farmers are current lucerne growers with the crop management skills to enable adequate lucerne production and crop resilience within razing and cropping situations.

The farm system descriptions and stock reconciliations and traded livestock classes are described in both Table 1, and Section 5.5 Appendices (Part A), Appendix Ia. The NI farm system incorporated Friesian bull beef and grazing heifers also, while the SI farm system, minus a beef herd, but with inclusion of a dairy heifer system. Note that tonnages of PE crop lucerne sold related to 'proxy' baleage made on-farm (to adjust for FARMAX™ model structure).

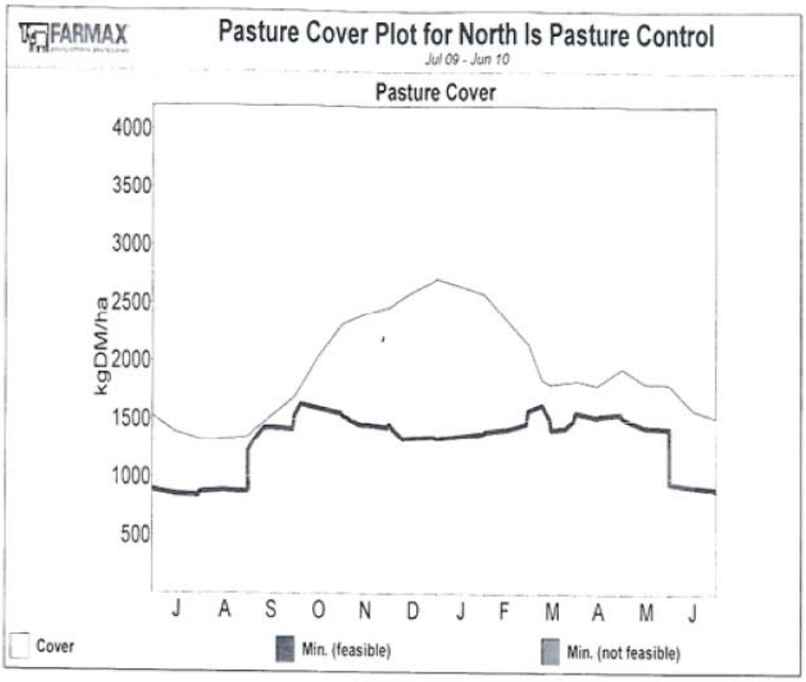
Table 1 Comparative farm system modelling for livestock enterprises for sheep and beef (with lucerne) farm systems in both the North Island (NI) and South Island (SI); namely Control (base) farm systems and same farm systems adapted to include protein extraction (PE) lucerne forage supply (viz. + PE)

Farm system model Assumptions	NI Control	NI + PE	SI Control	SI + PE
Total effective farming area	717 ha	717 ha	417 ha	417 ha
Lucerne area	286 ha	286 ha	166 ha	166 ha
Lucerne crop use	Grazing (100%)	Grazing (50%) PE Crop (50%)	Grazing (100%)	Grazing (50%) PE Crop (50%)
Effective grazing area	717 ha	574 ha	417 ha	334 ha
Forage supply	Pasture growth pattern scaled to 10,000 kg DM/ha, Lucerne 12,500 kg	As per NI Control	Pasture growth pattern scaled to 10,000 kg DM/ha, Lucerne	As per SI Control

	DM/ha 15 ha Pasja forage brassica crop (annual)		16,000 kg DM/ha 20 ha Choumollier forage crop (annual)	18.4 ha Choumollier forage crop (annual)
Livestock enterprise	3285 Romney ewe, 119% lambs weaned. 130 beef cows, 85% weaning		3500 Coopworth ewes, 130% lambs weaned	

Comparative pasture cover for NI and NI+PE farm systems are provided in Figure 1 and reflect feed budget modelling to match livestock requirements with manageable pasture cover. In Figure 1, the bold line is minimal feasible cover to meet livestock requirements, and graphic chart area the modelled pasture cover as affected by livestock class and productivity dynamics, grazing capacity (stocking rates), pasture growth rates and growth parameters, and rotational paddock covers pre-grazing. This represents the complexity in feed management within pastoral dynamic systems, and the compromises and pasture cover risk management employed. Such model adjustments are reflected in the differences in livestock classes and carrying capacity (shown in Section 5.5 Appendices (Part A), Appendix Ia) between Control and + PE farms as lucerne grazing area is reduced[10]. Whilst there is evidence of a brief seasonal feed deficit in early spring for NI + PE (marked graph area for NI + PE, Figure 1), essentially both modelled systems were similar in pasture cover dynamics. No notable variation for SI Control and SI +PE in regard to pasture cover plots were noticed (data not shown). The livestock class and stocking rate manipulations were designed to achieve minor pasture cover plot variance in order to remove this as an 'error variable' for interpretation.

[10] There are multiple livestock class and number combinations available based on an individual farm manager preference, however the combinations represented in the FARMAX modelling for this project feasibility assessment reflect the 'expert opinion' of the farm systems modeller employed, and are considered both realistic and representative.



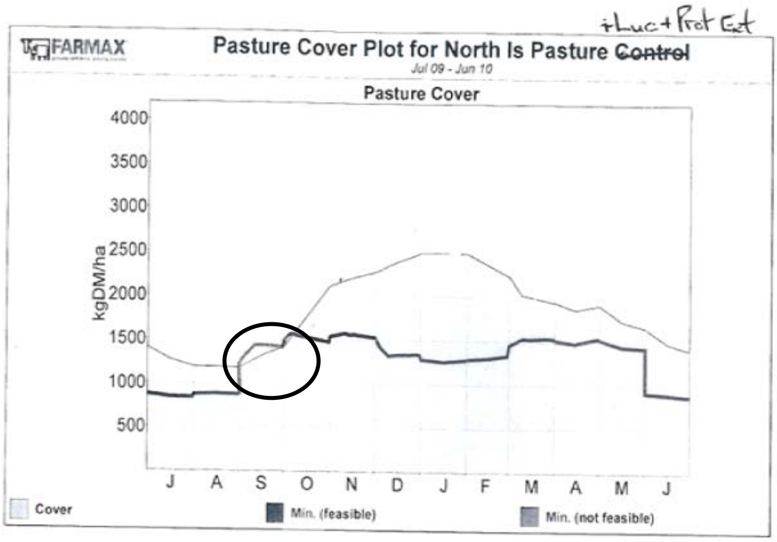


Figure 1 Comparative pasture cover plots for NI Control and NI + PE (refer text)

The results of gross farm revenue (GFR) calculations from deterministic spreadsheet modelling (refer Section 5.5 Appendices (Part A), Appendix Ia) are illustrated graphically in Figures 2 and 3. The variance in livestock gross revenue (Figure 2) reflects the lower livestock carrying capacities, and associated variance in livestock classes, to accommodate reduced effective grazing area for the + PE farm systems. The lesser decrease in livestock return for the SI + PE farm system relative to its' Control is reflective of the negation of a ram lamb buy-in policy, yet effective per hectare retention of farm-bred prime lamb sales.

However, despite lower livestock revenue, at 25 c/kg DM for PE lucerne ex farm gate a total farm gross revenue margin of 14 to 17% per land unit (hectare) is evident (Figure 3). This suggests that in this farm system modelling scenario, the noted farmer survey response for lowest price of 25 c/kg DM for PE lucerne ex farm gate (refer Sinclair, 2009b) appears possibly acceptable under this economic analysis. Conversely, at 15 c/kg DM, there is a noted disadvantage (reduced GFR by up to 8%).

The sensitivity analysis shown in Table 2 represents interpretation of the effects of key input variables; namely, average beef meat production price (from cull cow, bull beef, steer), average sheep meat production price (from lamb, ewe hogget and cull ewes), price for PE lucerne 'wet' harvest, and PE lucerne production, on the key output variable, GFR. The average beef and sheep meat prices are key inputs into the weighted price average used for calculation of the livestock revenue (note table insert, Section 5.5 Appendices (Part A), Appendix Ia). Sensitivity analysis evaluation of PE system with control farms, using *ceteris paribus* break-even 'margin' comparison, suggests that around 18 c/kg DM for PE lucerne for both NI and SI farm comparisons would be required to equate to Control (current) farm system GFR.

Note also that inclusion of a PE lucerne supply enterprise results in the appropriation of variable cost reduction due to reduced variable livestock costs (such as per animal heath, grazing management and casual labour components), conversely retention of a grazing-only lucerne system has lower crop variable costs (reduced fertiliser and weed/pest management costs).

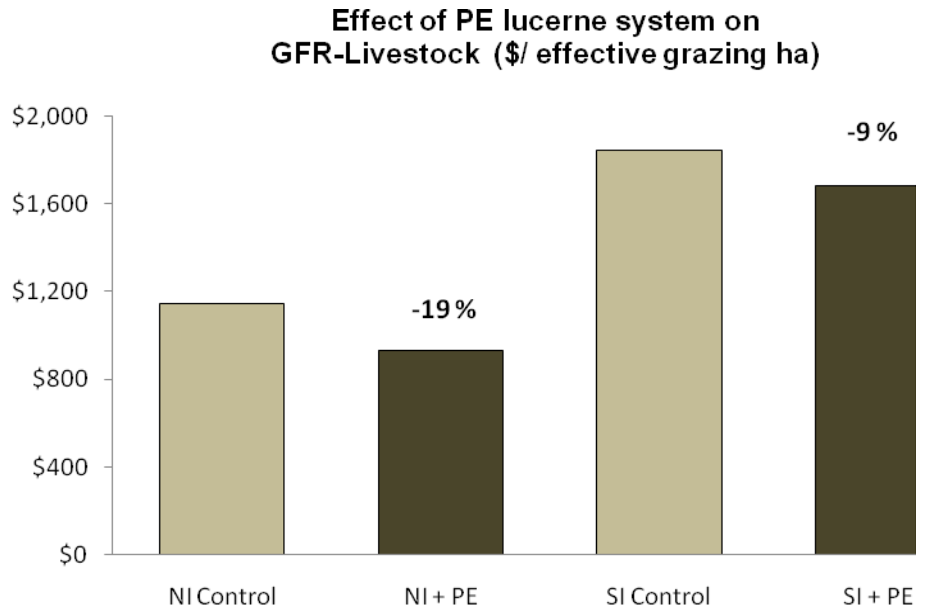


Figure 2 Comparative gross farm return (GFR) for livestock enterprises for Control and PE farm systems in both the North Island (NI) and South Island (SI).

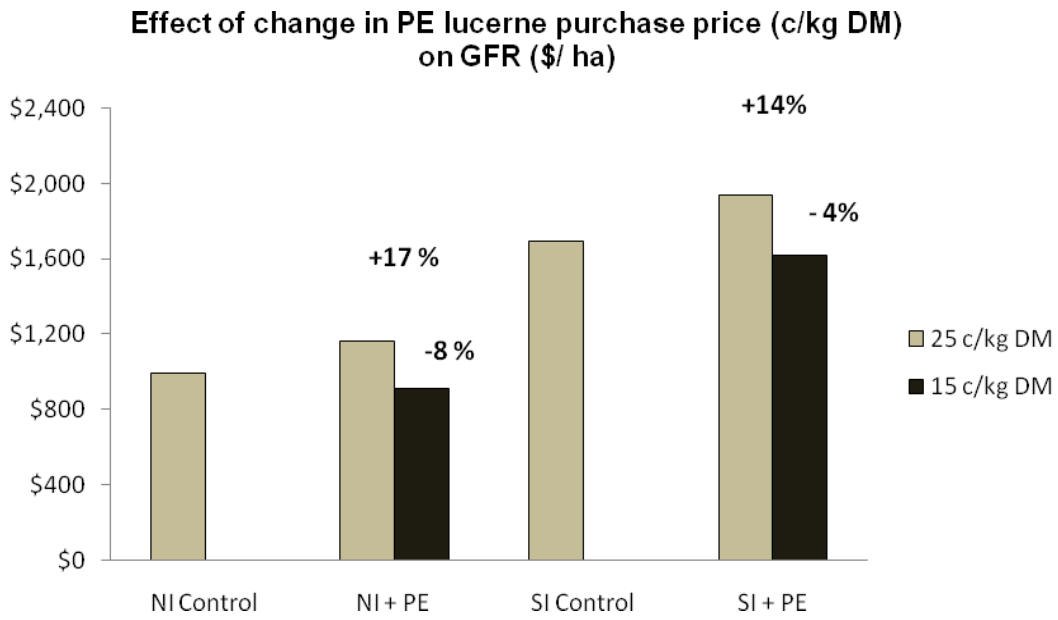


Figure 3 Comparative gross farm return (whole farm) for Control and PE farm systems in both North Island (NI) and South Island (SI) over two PE lucerne pricing schedules. Percentiles refer to difference between PE farm system and comparative Control farm system

Table 2 Sensitivity analysis for Gross Farm Return (GFR)[A]

Sensitivity Analysis

Gross Farm Return_ NI Control					
		Price average for sheep meat production			
GFR per ha	$ 992.25	$3.00	$3.50	$4.50	$5.00
Price average for beef meat production	$3.00	$589	$641	$746	$799
	$3.50	$695	$748	$853	$905
	$4.00	$802	$854	$959	$1,012
	$4.50	$908	$961	$1,066	$1,118

Gross Farm Return_ NI Control + PE					
		Price for PE lucerne 'wet' harvest (farm gate)			
GFR per ha	$ 1,163.16	10	15	25	30
Price average for beef meat production	$3.00	$704	$829	$1,078	$1,203
	$3.50	$757	$882	$1,131	$1,256
	$4.00	$811	$935	$1,184	$1,309
	$4.50	$864	$989	$1,238	$1,362

Gross Farm Return_ NI Control + PE					
		Price for PE lucerne 'wet' harvest (farm gate)			
GFR per ha	$ 1,163.16	10	15	25	30
PE Lucerne production (kg DM/ha)	8,000	$699	$779	$939	$1,019
	10,000	$739	$839	$1,039	$1,138
	12,000	$779	$899	$1,138	$1,258
	14,000	$819	$959	$1,238	$1,378

Gross Farm Return_ SI Control					
		Price average for sheep meat production			
GFR per ha	$ 1,695.48	$3.00	$3.50	$4.50	$5.00
Price average for beef meat production	$0.00	$1,139	$1,331	$1,715	$1,907
	$0.00	$1,139	$1,331	$1,715	$1,907
	$0.00	$1,139	$1,331	$1,715	$1,907
	$0.00	$1,139	$1,331	$1,715	$1,907

Gross Farm Return_ SI Control + PE					
		Price for PE lucerne 'wet' harvest (farm gate)			
GFR per ha	$ 1,938.06	10	15	25	30
Price average for sheep meat production	$3.00	$1,091	$1,250	$1,569	$1,728
	$3.50	$1,218	$1,378	$1,696	$1,855
	$4.50	$1,473	$1,632	$1,951	$2,110
	$5.00	$1,600	$1,760	$2,078	$2,237

Gross Farm Return_ SI Control + PE					
		Price for PE lucerne 'wet' harvest (farm gate)			
GFR per ha	$ 1,938.06	10	15	25	30
PE Lucerne production (kg DM/ha)	10,000	$1,341	$1,440	$1,639	$1,739
	13,000	$1,401	$1,530	$1,789	$1,918
	16,000	$1,460	$1,620	$1,938	$2,097
	19,000	$1,520	$1,709	$2,087	$2,276

[A] Shaded areas within GFR grid represents values less than the comparable 'Control' farm system. The initial GFR cell values at top right of grid (two-way data inclusion prerequisite) are based on a 25 c/kg DM PE purchase (farm gate) price for lucerne (+ PE systems), and averaged meat production pricing as per insert table (refer Section 5.5 Part A Appendix Ia).

5.2 Dairy systems and temperate pasture utilisation

The pastoral dairy farm systems selected were;

- North Island (NI) Waikato/BOP based monitor farm example, optimised[11] but not within an integrated PE system (viz. NI_Dairy_Control). Dry cows wintered on farm on pasture, young stock grazed off.
- North Island (NI) Waikato/BOP based monitor farm example, optimised and within an integrated PE system. 20% of the farm effective grazing area assigned to pasture production for green forage supply (PE Pasture) arising from three (3) harvest periods *in the spring only*. Bio-process product return via purchase of protein extract fibre (silage) and DPJ (PEF + DPJ) occurs for supplementary feeding on-farm (viz. NI_Dairy20). Dry cows wintered on farm on pasture[12], young stock grazed off.
- North Island (NI) Waikato/BOP based monitor farm example, optimised and within an integrated PE system. 20% of the farm effective grazing area assigned to pasture production for green forage supply (PE Pasture) arising from three (3) harvest periods in the spring, and 10% area allocation to a single harvest in the autumn, four (4) harvest cuts in total (viz. NI_Dairy20+10). Dry cows wintered on farm on pasture, young stock grazed off.
- South Island (NI) Canterbury based monitor farm example, optimised but not within an integrated PE system (viz. SI_Dairy_Control). Dry cows wintered off farm[13] in winter (grazing block), young stock grazed off.
- South Island (NI) Canterbury based monitor farm example, optimised and within an integrated PE system. 20% of the farm effective grazing area assigned to pasture production for green forage supply (PE Pasture) arising from three (3) harvest periods *in the spring only* (viz. SI_Dairy20). Dry cows wintered off farm in winter (grazing block), young stock grazed off.

Summaries of the key bio-physical parameters for both NI and SI region farm scenarios are provided in Tables 3 and 4, and summarised key financial parameters provided in Section 5.5 Appendices (Part A), Appendix Ib, including some assumed variable feed pad/herd shelter cow costs.

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[11] With respect to evaluating base regional MAF (MAF Pastoral Monitoring Report ©2008) monitor farms as examples, the modelling used optimisation to enhance the base farm figures to a more commercially intensive representative situation considered applicable to the study, yet retain realistic farm scenarios.

[12] The GFR analyses assume winter feed pad feeding occurs on NI farms. Whilst capital feed pad/herd shelter costs are ignored, allocated operational and maintenance costs for pad feeding have been assumed, and winter feed pad feeding in particular important for NDA allowance rationale (Section 5.2.1).

[13] No feed pad feeding costs have been allocated in this scenario.

With regard to DPJ use on farm, the capital cost and operating and maintenance for suitable DPJ tank storage and pump systems on-farm for application to silage (refer Sinclair 2009b for farmer option in this area) has been imputed as an annualised equivalent 'equipment lease' and variable PE system cost. Adjustments in variable costs for the integrated PE system are provided in tabular form in Section 5.5 Appendices (Part A), Appendix Ib., and have been included in the GFR analyses[14].

Table 3 Key bio-physical parameters for the comparative dairy farm system modelling in the North Island (Waikato/BOP, with or without participation in an integrated PE system (refer text).

Farm system bio-physical model parameters	NI_Dairy_Control	NI_Dairy20	NI_Dairy20+10
Total effective farming area (ha)	106	106	106
Herd size (milking cows):			
In Winter (stocking rate)	315 (3.0)	300 (2.8)	300 (2.8)
In November	306	291	291
Feed supply dynamics:			
Pasture used (t DM/ha)	11	10	10
Maize silage fed (t DM) Feed IN	71	58	65
PKE[B] fed (t DM) Feed IN	61	58	58
Grass silage fed (t DM)	66	0	0
Grass silage purchase (t DM)	0	0	0
PEF + DPJ fed (Feed IN; t DM); (% of DM supply out to PE system)	0	114 (67%)	125 (67%)
Forage conserved on farm (t DM)	66	171	188
PE Pasture for sale (t DM)		171	188
PE pasture harvest (t DM/ total ha)		1.6	1.8
N application to pasture / Irrigation	Y / N	Y / N	Y / N
Production parameters:			
MS per ha	968	975	965
MS per cow wintered	326	345	341

[A] Pasture consumption, not pasture growth
[B] Palm Kernal Extract

In regard to NI dairy farms (Table 3), optimising the PE systems resulted in reduced cow numbers.

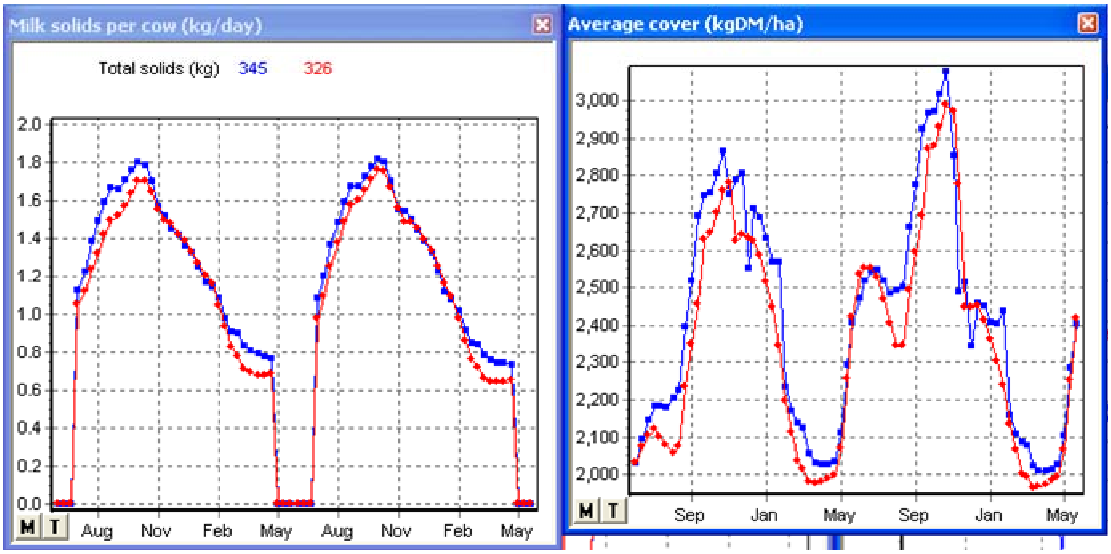
[14] The Control and PE models may be financially optimistic, in that no wastage for PEF and DPJ feeding (or other supplement feeding) was allocated (although all farm systems treated equally in this regard). However feed pad costs have been imputed for supplement feeding, particularly PEF and DPJ feeding, where on-pad effluent disposal benefits are used for NDA assumptions.

Table 4 Key bio-physical parameters for the comparative dairy farm system modelling in the Sorth Island (Canterbury, with or without participation in an integrated PE system (refer text).

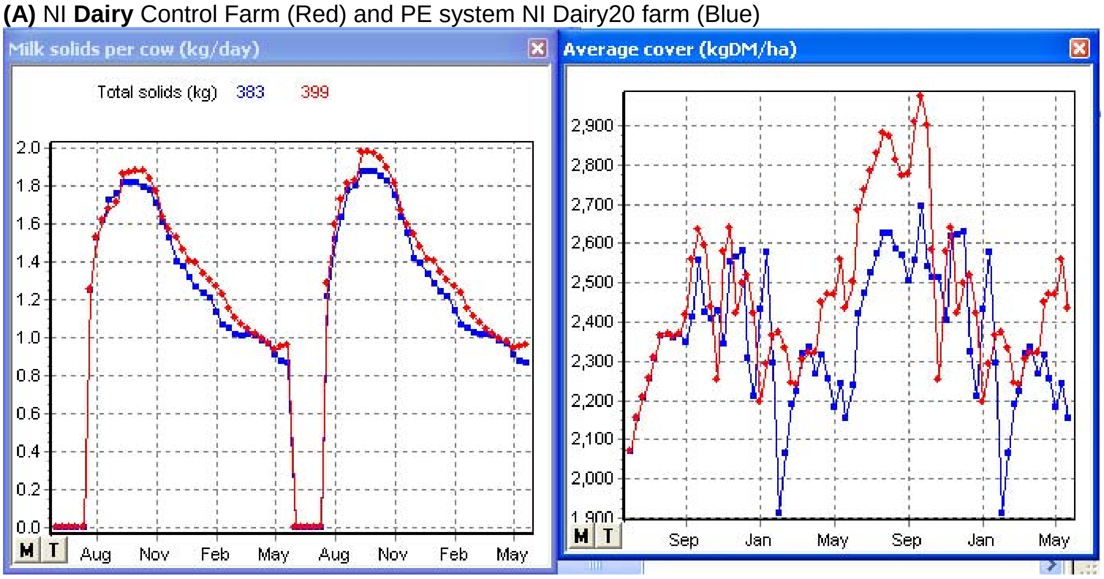
Farm system bio-physical model parameters	**SI_Dairy_ Control**	**SI_Dairy20**
Total effective farming area (ha)	210	210
Herd size (milking cows):		
In Winter (stocking rate)	733 (3.5)	733 (3.5)
In November	718	718
Feed supply dynamics:		
Pasture used (t DM/ha)	14	13
Maize silage fed (t DM) Feed IN	0	0
PKE[A] fed (t DM) Feed IN	193	193
Grass silage fed (t DM)	264	53
Grass silage purchase (t DM)	112	0
PEF + DPJ fed (Feed IN; t DM); (% of DM supply out to PE system)	0	317 (64%)
Forage conserved on farm (t DM)	152	550
PE Pasture for sale (t DM)		497
PE pasture harvest (t DM/ total ha)		2.6
N application to pasture / Irrigation	N / Y	N / Y
Production parameters:		
MS per ha	1392	1335
MS per cow wintered	399	383

[A] Palm Kernal Extract

The spring cut only and spring and autumn cut PE system farms (NI_Dairy_20 and NI_Dairy20+10 respectively) had similar proportional bio-process product return (PEF + DPJ) to farm for supplementary feeding (67%), however whilst grass silage conservation was not used (vs. NI Control farm), there was continued use of bought-in maize silage (minor replacement) and PKE. The farm system modelling involves balancing pasture production with livestock requirements, including strategic supplementation, to optimise milk solids production. The NI control and PE systems had similar seasonal milk solids and pasture cover dynamics (Figure 4A), although the spring only cut PE system had the highest milk solids per ha production. However it was noted during the modelling that the autumn cut PE system (NI_Dairy20+10) had difficulty achieving pasture cover requirements for conservation. The SI PE dairy system (viz. SI_Dairy20) achieved higher pasture conservation yield (reflective of irrigated pasture) than NI PE systems (Table 4).



(A) NI **Dairy** Control Farm (Red) and PE system NI Dairy20 farm (Blue)



(B) SI Dairy Control Farm (Red) and PE system SI Dairy20 farm (Blue)

Figure 4 Comparative milk solids production (kg per cow per day) and average pasture cover (kg DM/ha) for North Island (A) and South Island (B) regional Control and PE system farms (UDDER model graphics).

The PER + DPJ returned to SI dairy systems generally replaced grass silage conservation and purchase (only minor maize silage reduction in NI); however replacement ratio was not 1:1 (reflective of the product attributes, namely variance in nutritional quality, refer Sinclair 2009a,b). The SI PE system farm also had lower pasture cover and milk solids production (Table 4, Figure 4B). Evaluation of feed supplementation regimes (Section 5.5 Appendices (Part A), Appendix Ib) shows for NI PE systems, PEF + DPJ was fed in mid-lactation (milking cows) and to dry cows in winter. Conversely, the SI PE dairy system, due to cow wintering off-farm, fed PEF + DPJ during the summer (mid to late lactation).

Integration within a PE system resulted in higher variable costs for PE system dairy farms (expressed within farm working expenses; Section 5.5 Appendices (Part A), Appendix Ib). Increased pasture forage conservation and feed input costs are contributing factors, inclusive of increased fertilise requirements for forage conservation and export from farm with some reduced nutrient return with the PE system.

Model estimates of GFR are provided in Figure 5, where PE system farms recorded lower gross returns, reflective of milk solid production and farm working expense variable costs. The gross return of NI_Dairy20_10 system compared to the NI_Dairy_Control farm was further disadvantaged by Autumn pasture cover constraints, extra feed input costs and affects on milk solids production.

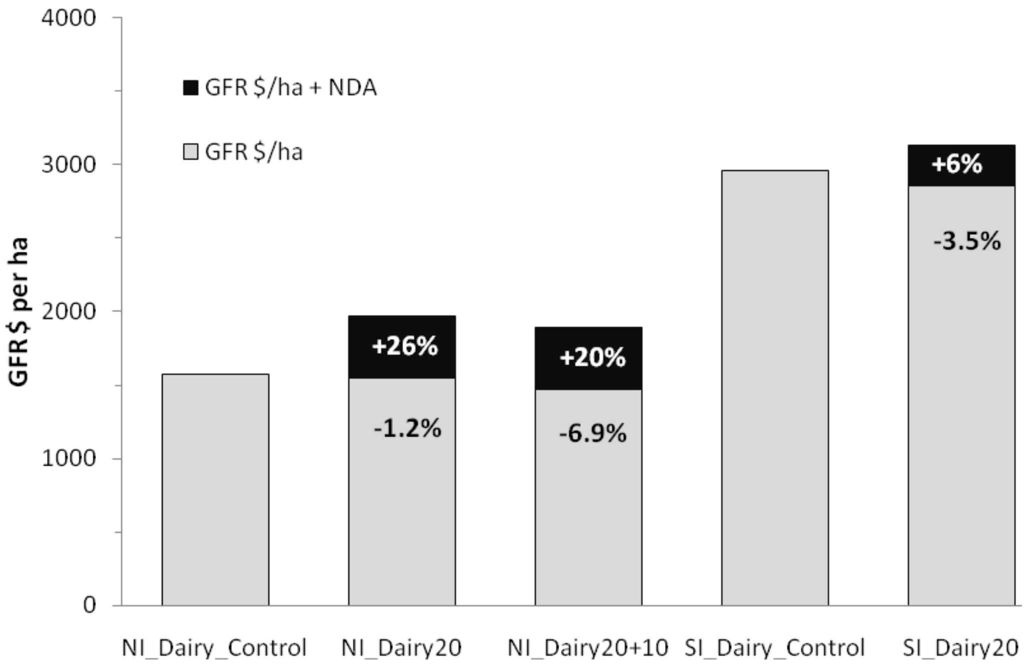


Figure 5 Comparative Gross Farm Revenue for NI and SI dairy systems, without (Control) or with PE systems (Dairy20; Dairy20+10). Percentiles refer to difference between PE farm system and comparative Control farm system (refer text).

What is also evident however in Figure 5 is the marginal return advantage of the PE farm systems where NDA returns are factored (refer Section 5.2.1).

The sensitivity analysis shown in Table 5 represents interpretation of the effects of key bio-process input and output variables; namely, PEF + DPJ purchase price and PE Pasture sale price, on the key output variable, GFR.

Table 5 Sensitivity analysis for Gross Farm Return (GFR)[A]

Sensitivity Analysis						
NI (WaikatoBOP) integrated PE systems						
GFR ($/ha)		**per tonne DM price for PEF + DPJ**				
	t DM PEF + DPJ	$ 150.00	$200.00	$240.00	$300.00	$350.00
NI_Dairy20	**114**	$ 1,648	$ 1,595	$ 1,552	$ 1,487	$ 1,433
NI_Dairy20+10	**125**	$ 1,576	$ 1,517	$ 1,470	$ 1,399	$ 1,340
GFR ($/ha)		**per tonne DM price for PE pasture sale**				
	t DM PE Pasture	$ 150.00	$200.00	$250.00	$300.00	$350.00
NI_Dairy20	**171**	$ 1,390	$ 1,471	$ 1,552	$ 1,632	$ 1,713
NI_Dairy20+10	**188**	$ 1,293	$ 1,381	$ 1,470	$ 1,559	$ 1,647

Sensitivity Analysis						
SI (Canterbury) integrated PE systems						
GFR ($/ha)		**per tonne DM price for PEF + DPJ**				
	t DM PEF + DPJ	$ 150.00	$200.00	$240.00	$300.00	$350.00
SI_Dairy20	**317**	$ 2,990	$ 2,914	$ 2,854	$ 2,763	$ 2,688
GFR ($/ha)		**per tonne DM price for PE pasture sale**				
	t DM PE Pasture	$ 150.00	$200.00	$250.00	$300.00	$350.00
SI_Dairy20	**497**	$ 2,617	$ 2,735	$ 2,854	$ 2,972	$ 3,090

[A] Shaded areas within GFR grid represents values obtained using the base model run pricing data for both bio-process derived feed input costs and green forage price output to the PE system. Note that for base model runs, NI Control and SI Control farms had GFR of $1571 and $2955 per ha respectively.

The GFR calculations included PE system costing adjustments (note Section 5.5 Appendices (Part A), Appendix Ib). Sensitivity analysis evaluation of PE systems with control farms, using *ceteris paribus* break-even 'margin' comparison, suggests

- For NI_Dairy20 and NIDairy20+10: PEF + DPJ input pricing (del. on farm) of $220 and $150 per t DM respectively; and output PE Pasture sale price (ex farm gate) of $265 and $310 per t DM respectively.
- For SI_Dairy20: PEF + DPJ input pricing (del. on farm) of $170 per t DM; and output PE Pasture sale price (ex farm gate) of $295 per t DM.

5.2.1 Environmental management considerations and theorised tangible economic benefits

Whilst methane greenhouse gas mitigation and management is assumed as a non-tangible for this CBA analysis (i.e. *potentially* applicable with PEF and DPJ feed return

and ruminant nutrition parameters, however not yet substantiated or measured with PE systems on-farm and equivocally theorised accordingly; refer Sinclair, 2009a), there are valid, albeit still to be validated ‘in the field’, grounds for recognising the nitrogen (N) leaching and nitrous oxide (N_2O) emission mitigation and management benefits with an integrated PE system with regard to pastoral dairy farm systems (refer Sinclair 2009a). In this instance, the reduction with N leaching has been recognised as an economically tangible benefit in accordance with the nitrogen discharge allowances (NDA) rationale for environmentally sensitive catchments being implemented by regional environmental councils in New Zealand (refer EW, 2008; LTPT, 2008).

It is assumed for NI_Dairy20 and NI_Dairy 20+10 farms that winter feed pad/shelter feeding occurs with nutrient reduction allowances optimised, whereas for SI_Dairy20, in the absence of winter feeding and no feed pad allocation, summer feeding (PEF + DPJ) allowances have been based on paddock feeding-based benefits only, with lesser values reflecting absence of contained catchments (e.g. Herd Homes® Shelters) and less effective effluent disposal management (see review by Sinclair 2009b).

A sensitivity analysis for NDA allocation and PE dairy systems is provided in Table 6, where values for additive margin allocation to farm GFR (e.g. as illustrated in Figure 5) are based on NDA purchase value protocols (refer LTPT, 2008) as an assumed up-front ‘lump sum’ based on a market trade value for N (annual kg N loss reduction per ha). The payment has been treated as an annualised per ha sum based on calculated ‘annuity from present values’ using accepted financial analysis principles and annuity tables (e.g. refer Makeham and Malcolm, 2003).

Table 6 Added margin ($ to current GFR) using a range of NDA annualised values within a sensitivity analysis table.

Sensitivity Analysis					
NDA valuations (Annuity per ha from Present Value)					
Annuity (20 yr)		**NDA value per kg N ($ per kg)**			
$ per ha	$ 602.00	$250.00	$350.00	$450.00	$550.00
kg N per ha	10	$ 201	$ 281	$ 361	$ 441
NDA reduction	15	$ 301	$ 421	$ 542	$ 662
	20	$ 401	$ 562	$ 722	$ 883
	30	$ 602	$ 843	$ 1,083	$ 1,324

Annuity of PV , years @ 5% 0.080243
From financial 'Annuity from Present Value' tables
Assumes Lump sum invested and paid out as an annuity over 20 years

In the case of the illustrated benefits with NDA addition to GFR for PE system farms in Figure 5, NI dairy systems used an annuity value of $421, and SI dairy systems $281,

based on values derived from Table 6 for a NDA value of $350 per kg N (implied market value) and annual N reduction of 15 or 10 kg per ha respectively.

5.3 Concluding comments and recommendations (Part A)

In discussing and recommending both the results and prospective future modes of action, the realisation of the bio-physical complexity in modifying pastoral farm systems and interpretation of outputs occurs. The farm modelling undertaken for this feasibility study involved the use of industry accepted pastoral farming systems modelling software (and expert opinion modellers), in order to interpret the complexity of both removal, and return, of green forage products from a forage based system, whilst also attempting to retain some realistic comparison between control and PE systems in terms of livestock and crop enterprises and farm productivity. With respect to dairy farm systems, the added variable factor of both tangible and intangible environmental benefits was also investigated.

An integrated Protein Extraction System-can it work at the 'on-farm' level?

1. Operational considerations. With regard to the operational viability of an integrated PE system, both sheep and beef (PE lucerne) systems and dairy (PE pasture) systems were accommodating to green forage sale, albeit with livestock enterprise adjustments to match a revised pasture cover to animal requirements feed budget. Whilst previous evaluation of the operational 'fit' on farm with plant protein fractionation has also recorded viable outcomes (refer reviews of Sinclair 2009a,b), this report has used more advanced decision support tool modelling software availability to ensure that manipulations of forage production are perhaps more realistically interpreted. The results show operationally feasible integration of the PE system at the on-farm level for both intensive sheep and beef (with cropping) and pastoral dairy farm systems. Note however that unlike previous sheep and lucerne system linear modelling by McDonald et al. (1981) in regard to leaf-protein extraction process in New Zealand, the current sheep and beef and PE lucerne crop scenario did not receive bio-process co-product return (based on industry feedback and system rationales, refer Sinclair 2009b). An additional input for this feasibility study was also the inclusion of both North Island and South Island farm system scenarios for the integrated PE system. While conceptual and equivocal, results suggested that SI sheep and beef and PE lucerne systems may have robustness with livestock and crop enterprise adjustment, but NI sheep and beef systems may capture higher return given the larger PE Lucerne crop area modelled. The dairy farm PE systems showed predominantly spring surplus forage harvesting as viable, with some adjustments

to cow numbers and/or supplementary feeding regimes to accommodate the system change.

2. Economic analysis. The use of partial budgeting, gross farm revenue analyses and base two way table variable sensitivity analysis were employed to evaluate the innovation returns from introducing an integrated PE system. Whilst operationally feasible, economic evaluation suggests that for PE lucerne production, farm gate pricing at 25 c/kg DM ($250 per t DM) appears reasonable for improved GFR (over current system returns) to enable consideration for an enterprise change. This pricing has imputed ‘premium’ or incentive value (see McDonald et al., 1981) over the approx. 18 c/kg DM value to be comparable to current systems. Lucerne farmer expectations for survey interviews (Sinclair 2009b) suggested PE Lucerne pricing of broadly around 25 to 35 c/kg DM to effect an enterprise change. With respect to dairy farm PE systems, NI dairy systems suggested input feed cost values for PEF + DPJ to obtain GFR comparable to current system, were in the range of $150 to $220 per t DM, and conversely output PE Pasture pricing was $265 to $310 per t DM. The SI dairy PE system required $170 and $295 per t DM respectively for feed input cost (PEF + DPJ) and PE Pasture sale price. If we assume say a 15% premium (refer Sinclair 2009b for farmer rationale) for PE pasture pricing to entice farmer system innovation to the PE system, PE pasture pricing around $330 per t DM may be indicative, based on this studies farm modelling. Farmers surveyed in this feasibility study suggested around $250 to $300 per t DM for PE Pasture (based on interview comments; Sinclair 2009b) to effect an enterprise change consideration.

We now consider raw material (green forage) supply from New Zealand pastoral farm systems to the plant protein fractionation bio-process. Assuming the PE lucerne and PE pasture DM tonnages required annually for the bio-process facility (refer Section 6, Part B Appendix III), and PE farm system yields modelled, a gross estimate (minimum) of 25 PE lucerne farms and 120 PE system dairy farms would be required for contractual supply. However, the logistics and seasonality of supply offer potential major constraints (refer Sinclair 2009a), especially the observed general absence or undesirability of autumn PE pasture supply with reliance on the bulk of PE pasture harvest being spring – based only. For instance, using the engineering bio-process green crop- inflow calculations used in the review of Sinclair (2009a), a theorised radius of operation for a

bio-process plant required for PE lucerne and PE pasture supply[15] used in this CBA report would probably equate to a range of 20+ km.

Socio-environmental implications

Opportunities for on-farm dairy (and sheep and beef) system greenhouse gas and nutrient management mitigation options within a pastoral based plant protein extraction bio-process have been detailed previously by Sinclair (2009a). Whilst theorised mitigation potential exists within an integrated protein extraction system, via extract fibre and DPJ return to the farm and feed pad system incorporation, for dietary manipulation of methane (CH_4) that could potentially benefit both enteric and manure CH_4 emissions, quantitative assumptions remain speculative at this stage. In this regard, insufficient and conjectural information (both bio-physical and economic[16]) has negated an economic analysis of this system component at this juncture, and suggests that future research and development opportunities exist to investigate and validate livestock greenhouse gas assumptions within an integrated PE system. However, in regard to nitrous oxide (N_2O) and nitrate (or generic Nitrogen, N) leaching, greenhouse gas mitigation and nutrient N management options exist on-farm within which an integrated protein extraction system can assist.

The theorised tangible impacts, assuming current examples of N trading and catchment/region NDA regimes, have been investigated for dairy systems with regard to an integrated PE system and resultant environmental benefits. Results of farm modelling, and theorised NDA market value sensitivity analysis, suggest that an integrated pastoral dairy farm PE system, with appropriate winter feed management and effluent disposal regimes (refer also Sinclair 2009a,b) could result in improved gross farm returns, compared to Control farm systems, exceeding 20% when using lump sum NDA market value annual annuity payment principles.

Business structures

With regard to appropriate business structures for an integrated protein extraction system (refer Gardner and Shadbolt, 2005, for ownership issues and business structures within agribusiness), at this stage in the feasibility process, and for simplicity, contracted supply

[15] Note that PE Pasture derived from 20 to 30% of land area, PE lucerne as per model crop areas in Section 5, Part A, Appendix 1 a.

[16] Refers to the absence of quantitative field system data for an integrated PE system and livestock CH_4 emissions and the subsequent paucity of qualitative and quantitative impacts regarding economic appraisal for CO_2-e measurement and management. The current agricultural political and environmental policy environment (refer Anon. 2009), and a concurrent NZ Government Select Committee Emissions Trading Scheme (ETS) review (NZ House of Representatives ETS review schedule; May 2009; www.parliament.nz) ensures a present changeable situation where objective feasibility assessment is both compromised, and speculative at best.

from independent enterprises to a third party owned and operated protein extraction plant is deemed to occur. Although speculative, company business structure could for instance see the third party being a publically listed company (incl. farmer shareholders), or a farmer supplier cooperative structure with joint venture partners. It is noted that previous initiatives for commercial protein extraction plant establishment in New Zealand have involved both farmer cooperative and joint venture partnership arrangements (refer Shearer, 1985; Rod McDonald pers. comm.). While both beyond the scope and perhaps presumptuous to suggest likely governance structures at this interim, it is worth noting the importance for appropriate governance business structures to allow for fair and equitable return to owners, albeit balanced by the businesses operational and working capital management and cash flow requirements (see Gardner and Shadbolt, 2005).

5.3.1 Recommendations (Part A)

- Modelled New Zealand pastoral farming systems (sheep and beef, dairy) can feasibly supply quality lucerne and pasture green forage to a bio-process facility within current farming enterprise management; however theorised radius of supply and dominance for spring and summer based forage supply only from these sources provides logistical and seasonal constraints to be considered. Given the relative high forage supply pricing (PE forage sales) requirements by the farming systems (cf to current system GFR), this raises issues of affordability for the bio-process plant per se, and suggests consideration for other forage supply arrangement alternatives.
- A dairy farm integrated PE system has the genuine potential to contribute to GHG mitigation and management minimisation, and assuming a nitrogen allowance trading market, potentially provide on-farm GFR within the premium range likely to induce farmer conversion to the system. Further R&D to quantify the GHG management and reduction potential by an integrated PE system within dairy farming feed management options appears warranted, assuming that the plant fractionation bio-process itself is seen to be a sustainable option.

5.4 References (Methodology, Part A, Part C)

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5.5 Appendices (Part A)

APPENDIX IA – SHEEP AND BEEF SYSTEMS WITH LUCERNE, GRAZING (CONTROL) OR PROTEIN EXTRACTION (PE)

	units	NI Control	NI + PE	SI Control	SI + PE	
Effective grazing area (ha)		717	574	417	334	
1.0 Livestock Activity						
	units					
Meat production	kg per ha	318	296	384	318	
Wool production	kg per ha	45.1	53.4	78.1	89.7	
Livestock sales-Ewe hoggets	no.	16	16	125	125	
Livestock sales-RWB heifers	no.	33	33			
Grazing dairy heifers (4-18 mths)	no.	500	0			
Grazing dairy heifers (13-18 mths)	no.	150	150			
Bought-in lambs (trading)	no.			3000		
Bought-in lambs (mixed)	no.	3320	820			
Breeding bulls	no.	2	2			
Breeding rams	no.	5	5	7	7	
Friesian Bull calves (4 mth)	no.	125	125			
Friesian Heifer calves (3 mth)	no.			350	150	
Livestock Gross Income						
Meat production		$ 973,357.61	$ 711,048.24	$ 712,569.60	$ 472,643.40	
Wool production		$ 155,216.16	$ 147,127.68	$ 156,324.96	$ 143,807.04	$ 4.80 Net per kg wool price (av. lamb and ewe/hogget)
Livestock sales-Ewe hoggets		$ 880.00	$ 880.00	$ 6,875.00	$ 6,875.00	$ 55.00 per hd
Livestock sales-RWB heifers		$ 21,450.00	$ 21,450.00	$ -	$ -	$ 650.00 per hd
Livestock sales-Dairy heifers (owned 3-18 mths)		$ -	$ -	$ 420,000.00	$ 180,000.00	$ 1,200.00 per hd
Grazing dairy heifers (4-18 mths)		$ 242,250.00	$ -	$ -	$ -	57 weeks
Grazing dairy heifers (13-18 mths)		$ 34,650.00	$ 34,650.00	$ -	$ -	21 weeks
		$ 1,427,803.77	$ 915,155.92	$ 1,295,769.56	$ 803,325.44	
Less livestock inventory purchases						
Bought-in ram lambs (trading)		$ -	$ -	$ 135,000.00	$ -	$ 45.00 per hd
Bought-in lambs (mixed)		$ 182,600.00	$ 45,100.00	$ -	$ -	$ 55.00 per hd
Breeding bulls		$ 4,000.00	$ 4,000.00	$ -	$ -	$ 2,000.00 per hd
Breeding rams		$ 1,250.00	$ 1,250.00	$ 1,750.00	$ 1,750.00	$ 250.00 per hd
Friesian Bull calves (4 mth)		$ 41,250.00	$ 41,250.00	$ -	$ -	$ 330.00 per hd
Friesian Heifer calves (3 mth)		$ -	$ -	$ 175,000.00	$ 75,000.00	$ 500.00 per hd
		$ 229,100.00	$ 91,600.00	$ 311,750.00	$ 76,750.00	
Net Livestock income		$ 1,198,703.77	$ 823,555.92	$ 984,019.56	$ 726,575.44	
Livestock Enterprise specific operating (Variable) costs						
	per ha	$ 530.00	$ 530.00	$ 515.00	$ 515.00	ref. to farm working expenses less overheads
Decrease in costs with PE						
Reduced livestock management costs	per ha		$ 25.00		$ 20.00	
Nominal allowance for reduced casual labour?, animal health etc. with stock adjustment	per ha	$ 530.00	$ 505.00	$ 515.00	$ 495.00	
		$ 380,010.00	$ 289,870.00	$ 214,755.00	$ 165,330.00	
Livestock GM or Gross Return		$ 818,693.77	$ 533,685.92	$ 769,264.56	$ 561,245.44	
Livestock GR per effective grazing ha		**$ 1,141.83**	**$ 929.77**	**$ 1,844.76**	**$ 1,680.38**	
2.0 Crop Activity						
Tonnes Lucerne sold to PE	t DM	0	1788	0	1328	
Production per land unit	kg DM/ha	12500	12500	16000	16000	
PE Price per kg DM	c/kg DM	0	25	0	25	
PE Price per tonne DM	$/t DM	$ -	$ 250.00	$ -	$ 250.00	
Area dedicated to PE Lucerne	ha		143		83	
Area dedicated to grazed Lucerne	ha	286	143	166	83	
PE Lucerne Crop Gross Income		$ -	$ 446,875.00	$ -	$ 332,000.00	
Crop Enterprise specific Variable Costs						
	per ha	700	700	700	700	Growing costs only-no harvesting or conservation
Decrease in costs with grazed lucerne only						
Fertiliser application	per ha	200	200	200	200	
Pest and weed management etc.	per ha	125	125	125	125	
	per ha	375	512.5	375	512.5	Adjusted for 'grazing' and 'crop' area land use allocation
		$ 107,250.00	$ 146,575.00	$ 62,250.00	$ 85,075.00	
Lucerne GM or Gross Return *		-$ 107,250.00	$ 300,300.00	-$ 62,250.00	$ 246,925.00	
Crop GR per cropping ha		**-$ 375.00**	**$ 2,100.00**	**-$ 375.00**	**$ 2,975.00**	
Gross Farm Return		$ 711,443.77	$ 833,985.92	$ 707,014.56	$ 808,170.44	
GFR per ha		**$ 992.25**	**$ 1,163.16**	**$ 1,695.48**	**$ 1,938.06**	

$/hd/week-annualised
$ 8.50
$ 11.00

Weighted price averages for sheep meat and beef production#				
$ per kg cwt	**NI Control**	**NI + PE**	**SI Control**	**SI + PE**
Sheep meat (av.)	$ 4.50	$ 4.50	$ 4.45	$ 4.45
Beef (av.)	$ 3.80	$ 3.80	$ -	$ -
Sheep:	0.67	0.55	1.00	1.00
beef meat ratio	0.33	0.45	1.00	1.00
Weighted price average	**$ 4.27**	**$ 4.19**	**$ 4.45**	**$ 4.45**

cwt = carcase weight

RWB = Running With Bull

* Lucerne grazing retuns are captured in the livestock revenue.

APPENDIX IB – PASTORAL DAIRY SYSTEMS, GRAZING (CONTROL) OR PROTEIN EXTRACTION (PEF + DPJ IN; PE PASTURE OUT)

North island (WaikatoBOP) Dairy system				
Variable costs adj (GM). re PEF + DPJ				
Saved other feed IN (-)		$ whole farm		
DPJ tank/pump (+)	2000	$ whole farm	annualised	
Feed pad/shelter (+)	6600	40%	% use allocation per cow	
Feed pad/shelter		55	OP/maint Cost per cow	
Saved harvest costs (-)	8975	$ whole farm	5	c/kg DM
Total adj. (-)	-375	$ whole farm	179.5	t DM

South Island (Canterbury) Dairy system				
Variable costs adj (GM). re PEF + DPJ				
DPJ tank/pump (+)	2000	$ whole farm	annualised	
Saved harvest costs (-)	24850	$ whole farm	5	c/kg DM
Total adj. (-)	-22850	$ whole farm	497	t DM

Some Key Financial Parameters					
	NI_Dairy_ Control	**NI_Dairy20**	**NI_Dairy20+10**	**SI_Dairy_ Control**	**SI_Dairy20**
Farm Working Expenses $ per kg MS #	3.47	3.50	3.57	2.98	3.05
Milk payout $ per kg MS	5.10	5.10	5.10	5.10	5.10
PE Pasture sale $ per t DM	250.00	250.00	250.00	250.00	250.00
PEF and DPJ purchase ## $ per t DM	240.00	240.00	240.00	240.00	240.00

\# Not adjusted for PE system (refer tables above)

\## based on bio-process sale (delivered on-farm) price of $180 / t DM PEF and $700 / t DM DPJ

Mix ratio of 0.88:0.12 for PEF:DPJ repectively on-farm

Feed Supplementation Regimes					
	NI_Dairy_ Control	**NI_Dairy20**	**NI_Dairy20+10**	**SI_Dairy_ Control**	**SI_Dairy20**
Maize Silage-Milking cows	Sep: Feb-Apr	Sep : Feb-Apr	Sep: Feb-Apr		
Maize Silage-Dry cows					
Grass Silage-Milking cows				Jul-Sep : Feb-May	
Grass Silage-Dry cows	May-Jul			Aug-Sep : May	Aug-Sep
PKE - Milking cows	Aug-Sep	Aug-Sep	Aug-Sep	Jul-Sep : Apr-May	Jul-Sep : Apr-May
PEF + DPJ-Milking cows		Jan-Feb	Jan-Feb		Dec-Mar
PEF + DPJ-dry cows		Jun-Jul	Jun-Jul		**Cows wintered off-farm**

6. PART B: A preliminary feasibility assessment regarding a proposed centralised bio-processing plant, incorporating the extraction of protein from green forages

6.1 Mass balance and process flow diagram

6.1.1 Basis

The basis of the mass balance is shown Table 1. Due to the seasonal supply of the agricultural feedstock the factory operates seasonally. The values below are the same as those used in a pervious economic assessment carried out in 1981[1].

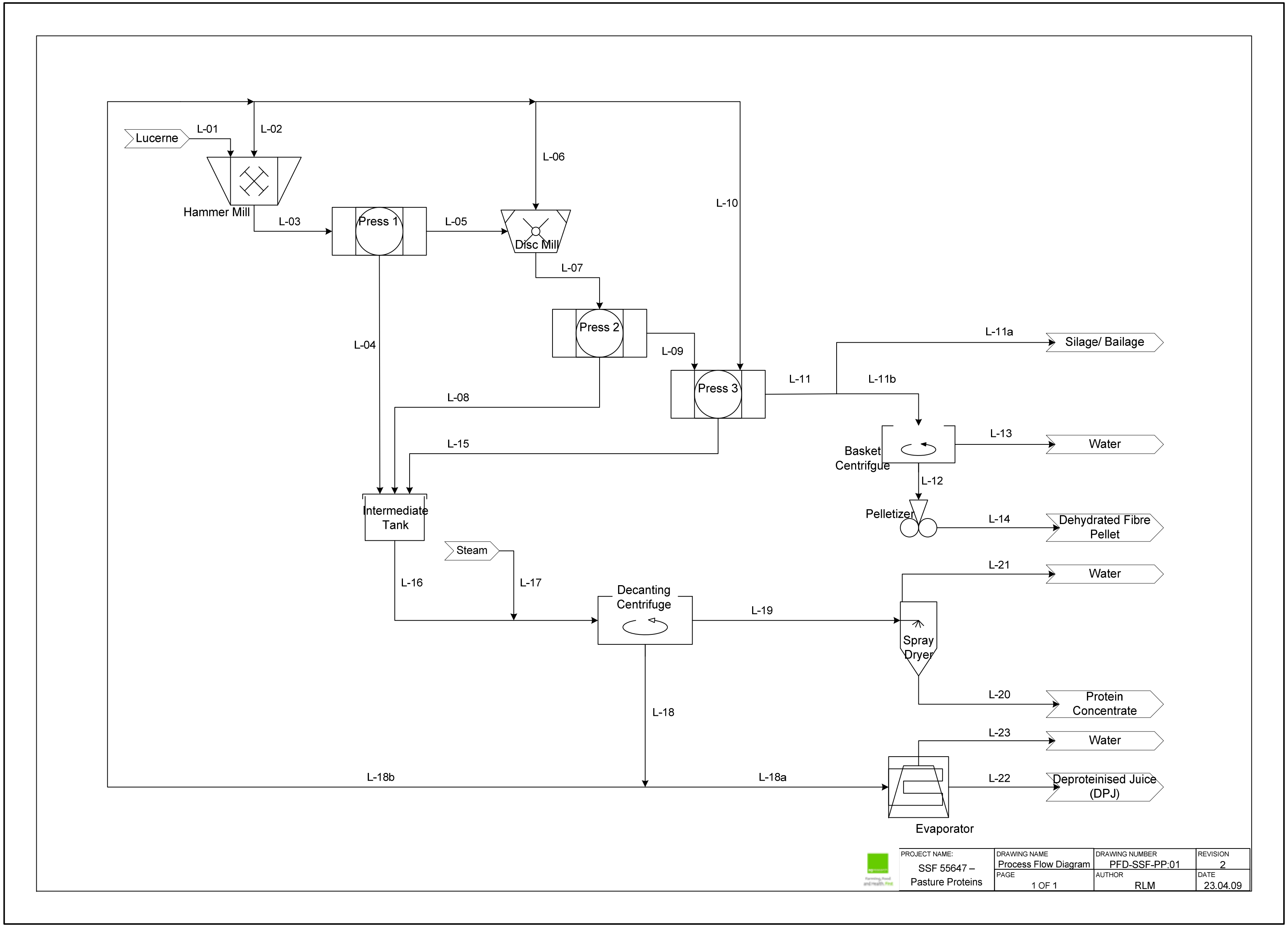
Table 1 Basis of Mass Balance

Operating Hours	2880	hours/year
	16	hours/day
	6	days/week
	30	weeks/year
Pasture Harvested	288000	tonnes/year
	100	tonnes/hour

6.1.2 The bio-process

The extraction of proteins from pasture involves the wet pasture to be coarsely ground using a hammer mill. Recycled dilute deproteinised juice (DPJ) is added to the milling process. The course pulp then passes through a first press. The press cake solids are then milled a second time in a disc mill with DPJ. The solids then pass through a second and third press to reduce the moisture content of the solids. The remaining solids are either further dried and pelletized or either baled or turned into silage.

The liquor from all three presses is mixed together and then heated by steam injection to 90°C which results in the proteins coagulating. The coagulum is separated in a decanting centrifuge. The DPJ is then split, with approximately 50% recycled; the remainder is concentrated by evaporation and sold as a molasses substitute. The leaf protein concentrate (LPC) solids are dried and sold as animal feed. The protein solids degrade over time and therefore need to be stored under inert conditions (e.g. nitrogen atmosphere). The leaf protein concentrate (LPC) solids are dried and sold as animal feed. The protein solids degrade over time and therefore need to be stored under inert conditions (e.g. nitrogen atmosphere).



Process Flow Diagram (PFD)

6.1.3 Mass balance

An overall mass balance is shown in Table 2. A full break-down of the mass balance for each stream shown in the Process Flow Diagram (PFD) is in Appendix I.

Table 2 Overall mass balance on a wet basis (tonnes/hour).

	Moisture Content	In	Out
Lucerne / pasture	20%	100	
Steam (7 bar)		13.1	
Fibre			
Pellets	15%		3.1
Silage / Baleage	60%		26.4
DPJ (60% MC)	60%		7.8
LPC (5.2% MC)	5.2%		4.9
Condensate			70.9

As insufficient information was available, a number of assumptions were made in order to carry out a complete mass balance over the main plant (factory) items for the process. The assumptions were:

1. The mass balance has been calculated for Lucerne as the feed and the compositional differences between Lucerne and pasture is negligible.
2. The composition of the feedstock is:

Feed Dry Matter (%DM)	20
Protein ppt. (%DM)	31
Fibre (% DM)	38
Other (%DM)	31

3. The extraction yields and composition of the press 1 and 2 along with the total extraction yield are:

		Protein	Other	Water
Press 1	%	40	40	60
Press 2	%	25	15	
Total extracted	%	75	62	

4. Steam to the factory is available at 7 bar.
5. The moisture content (MC) of the feed material for the following equipment is:

Hammer Mill	%	50
Disk Mill	%	20
Press 3	%	10

6. The split for the silage/ baleage and fibre pellet is 80:20

There are two important factors to note in the mass balance:

- Recycling of the DPJ has been included in the mass balance calculation as shown in the PFD. By using the assumed moisture content for the feeds to the hammer mill, disk mill and press 3, the mass balance calculated that 47% of the DPJ is recycled. McDonald[1] had used the assumption of 50% DPJ was recycled. However investigations had never been carried out to confirm nor optimise this. Recycle rate values from an operation in the United States of America had been used.
- Significant amount of data was not available for the three stage pressing process. Values were missing for the extraction rates and quantities of recycled DPJ. This means that the equipment might not be correctly sized and there could be errors in the cost estimates. However, this is a preliminary cost analysis and a contingency factor has been applied. This does highlight that this is an area where pilot scale investigations are required to gather the required information.

The full mass balance is in Appendix I.

6.2 Capital Cost

6.2.1 Equipment

As this is a preliminary cost analysis only main plant items (MPI's) were included in the capital cost estimate. The main plant items are shown in the PFD (Section 6.1.2).

The MPI's have been approximately sized and initial capital cost estimates for individual items have either been quoted by suppliers (ball-park estimate), estimated from previous quotations sourced from similar manufacturing processes (Equation 1) or estimated using Process Capital Cost Estimation for New Zealand[2]. Older cost estimates were updated to this year (2009) using the Ministry of Work & Development Construction Cost Index, (MWDCCI).

$$\frac{C_2}{C_1} = \left(\frac{S_2}{S_1}\right)^n$$

Equation 1

C_2 = Capital Cost of the project with capacity S_2
C_1 = Capital Cost of the project with capacity S_1
n = index

The estimated capital costs for the MPI's are shown in Table 3.

Table 3 Break down of Capital Cost

Main Plant Item	Cost $
Hammer Mill	434,000
Press 1, 2 & 3 - Belt press	1,140,000
Disk Mill	129,000
Decanting Centrifuge	445,000
Evaporator - Scraped Film	9,370,000
Spray Dryer	9,700,000
Basket Centrifuge	210,000
Pelletizer - Briquette Press	104,000
Storage Bunker	230,000
Nitrogen Generator	138,000
Total Equipment	**$ 21,900,000**

Notes:

- A nitrogen generator has been included as the dried LPC needs to be stored under inert conditions otherwise degradation of the product due to oxidation could occur. The cost of the nitrogen generator is indicative and the unit has not been specifically sized for this process.
- If a cost for a specific item could not be sourced, the cost for a similar item was used as a best estimate.
    - The cost of the scraped film evaporator has been estimated as a falling film evaporator.
    - The belt presses have been estimated as plate and frame filter presses.
- The size of the processing plant (100 t/h) is large in terms of New Zealand manufacturing. Many piece of processing equipment would not be readily available locally. For some MPI's several identical items of equipment would be required to run in parallel.

6.2.2 Lang factors

The proposed factory is assumed to be a green-field factory carrying out solid-fluid processing. Lang Factors (f) have been used to account for the direct and indirect costs not specifically accounted for in order to build the plant and these are listed in Table 4.

Table 4 Items Estimated Using Lang Factors

Direct Costs	Indirect Cost
▪ Installation	▪ Engineering and Supervision
▪ Piping, pumps and heat exchangers	▪ Construction expenses
▪ Buildings	▪ Contractors' fees
▪ Service facilities	▪ Overheads
▪ Instrumentation and control	▪ Contingency
▪ Electrical	▪ Insurance
▪ Site preparation	
▪ Purchased equipment	

A value for f is estimated for each direct and indirect cost. These individual f factors are added together and multiplied by the capital cost of the MPI's to give the total capital cost estimate for the project. For this plant, the Lang factors sum to 4.31, which brings the total capital cost to $94.4 million.

The full working on the capital cost is shown in Appendix II.

6.3 Operating cost

The annual operating costs to run the proposed 100t/h wet pasture processing plant were estimated. Indirect expenses such as insurances, overheads, local taxes and general expenses such as R&D, distribution and sales were not been included in the operating cost estimate. The breakdown of the estimated operating cost is shown in
Figure 1. The estimated total annual operating cost is $33.3 million with costs associated with the feed material being $ 22.6 million not including transportation.

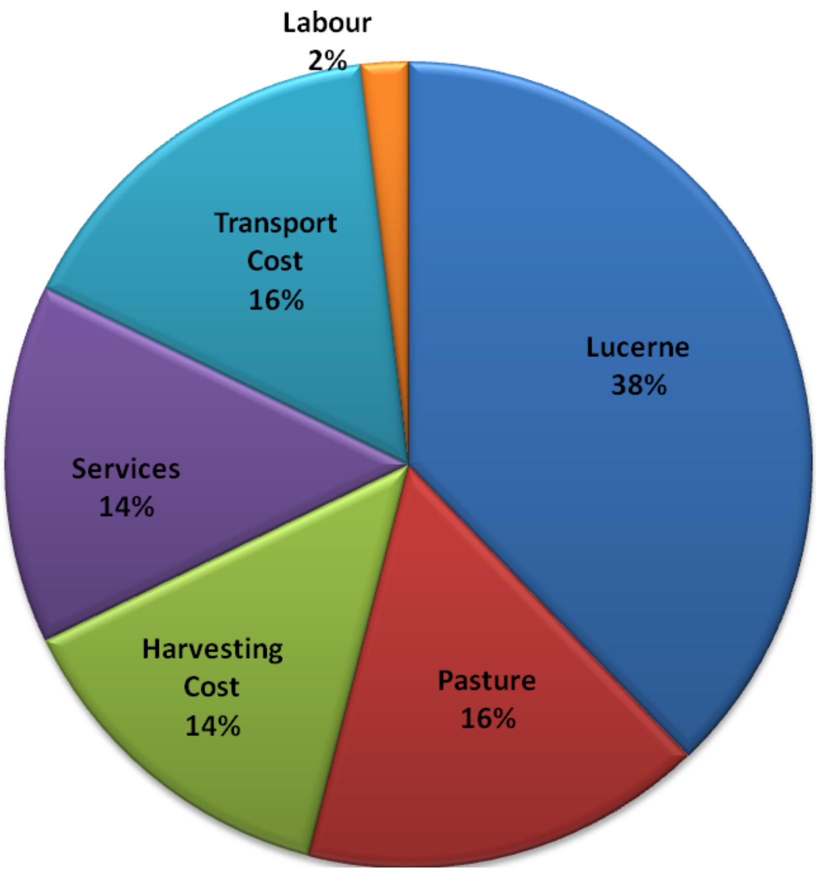


Figure 1 Distribution of Annual Operating Cost

Notes:

- The cost of the feed material is estimated at $350 and $250 per tonne DM for Lucerne and pasture respectively. The purchase of feed material accounts for 56% of the operating cost.
- The feed to the plant is assumed to be 60% Lucerne and the 40% pasture.
- The transportation cost includes transport of the feed stock to the plant and delivery of the silage and baleage to the farm.
- Services:
    - o The products are for animal feed and bore water is of acceptable quality, (deionised water not required).
    - o The price of steam has been priced at $15.50/ tonne.
    - o Quantity of steam is indicative and spray drier and evaporator requirements have not been specifically calculated.
    - o The number of units of power used as been estimated. This is a preliminary costing and insufficient information is known to calculate accurate figures for power usage of the plant.

- Labour:
    - o It has been assumed there are 11 operators in total, averaging 5.5 per 12 hour shift.
    - o There is a supervisor for each of the 2 shifts and a plant manager.

Appendix III contains a full break down of the operating cost

6.4 Revenue

The revenue generated is from several different product streams (Table 5). The product streams differ depending on the feedstock to the plant, whether it is Lucerne or pasture. There is no market for pasture fibre pellets; hence, all fibre solids from pasture feed are sold as either baleage or silage.

Table 5 Revenue generated by the proposed plant

Products	Production t/y	Dry Matter %	Price $/t DM	Revenue $
Baleage				
Lucerne	19533	40%	200	1,600,000
Pasture	15421	40%	180	1,100,000
Silage				
Lucerne	19533	40%	180	1,400,000
Pasture	15421	40%	180	1,100,000
Dehydrated Fibre Pellet				
Lucerne	8671	85%	700	5,200,000
Deproteinised Juice (DPJ)	22089	40%	700	6,200,000
Protein Concentrate (LPC)	13946	95%	1650	21,800,000
			Total Revenue	**$ 38,400,000**

Nearly 60% of the revenue is generated through the sale of LPC. Only 12% of the revenue comes from the sale of the baleage and silage.

Notes:

- A 50:50 split is assumed for fibre that is turned into baleage and silage.
- The annual production includes some loses in each stream, these loses vary between 2 % and 8 % depending on the stream.
- The LPC has been priced at the market equivalent price for fish meal protein concentrate. However, vegetable proteins typically have a significantly lower market value, close to $600 per tonne DM.
- The price for the other products is defined by the market.

Appendix IV contains the full table of the breakdown of Revenue.

6.5 Whole of Life Cost

6.5.1 Method

A whole of life cost (WLC) analysis is provided in Appendix Va. The land is purchased in the Year 0 of the factory's operation. The land has been estimated to be 5 ha of industrial land and located in the central north island. The land space required in quite large due to the storage requirements of the plant. The price of the land has been estimated to be $800,000.

In Year 1 the equipment is purchased and the factory built. The building cost is estimated at 10% of the total capital cost. The first year of production is Year 2. The plant has a 20 year project life; at the end the plant is assumed to have no scrap value.

Investment:	
Land	$ 800,000
Plant	$ 94,400,000
Buildings	$ 9,440,000
Operating Cost	$ 33,300,000 annum
Revenue from Sales	$ 38,400,000 annum

Notes

- Depreciation of buildings was calculated at 4.8 % straight line.
- Depreciation of the processing plant was calculated at 14.4 % diminishing value.
- Tax has been calculated at 33 %
- The Minimum Acceptable Rate of Return (MAR) is set as 10%.
- Tax after the first year of production is transferred to the second year as we do not know if we have made a profit.

6.5.2 Cumulative Net Present Value (NPV)

At the end of the life of the plant a positive NPV value indicates profit from the plant and consequently economic feasibility. The cumulative NPV of the Proteins from Pasture project is – (negative) $51.7 million and hence the project with the assumptions used at present is not feasible (Appendix Va).

If LPC was priced at the market equivalent of vegetable based protein meal ($600 per tonne DM) the proteins from pasture project would make a loss each year with the cumulative net present value being -$126 million.

6.6 Sensitivity

A sensitivity analysis was performed to determine what variables could be altered in order to improve the feasibility and hence should be the focus of future investigations. A series of scenarios were run through the cost model, these involved altering the plant capacity, capital cost, operating cost and revenue. The cumulative net present values for each of the scenarios are shown in Figure 2.

6.6.1 Plant capacity

The proposed plant is very large, with the capacity to handle 288,000 tonne green matter per harvest. The scaling factor rule (Equation 1 – section 6.2.1) was applied to work out the feasibility of the Proteins from Pasture Project if plant was reduced by fifty percent.

By reducing the plant capacity and associated cost the Proteins from Pasture Project does not break-even within the 20 year term. The feasibility does improve slightly from the proposed case with a cumulative NPV of -$38.2 million.

6.6.2 Capital cost

Capital costs of the plant are estimated to be $94 million, if the capital cost of the plant were reduced by 50%, the project does not break-even within the 20 year term. The economics of the project are improved when compared to the proposed case with the cumulative NPV of -$19.9 million.

6.6.3 Operating cost

The operating cost for the plant is $33.3 million, if the operating cost for the plant were reduced by 50%, the project breaks-even in year 12.

A very large proportion, 67%, of the operating cost is the price of the feed-stock and associated harvesting cost, this percentage jumps to 77% when the transport cost of the feed are included. Reductions of the cost associated with the feed-material should be investigated. A scenario ‘run’ at reduced lucerne and pasture forage costs IN ($200 and $150 respectively; representing 43% and 60% farm gate price reductions respectively), while noticeably improving net cash flow, still resulted in a cumulative NPV of -$12.8 million.

6.6.4 Revenue

The total revenue generated from selling all products is $38 million, if the revenue was increased by 150% to $58 million, the project would break even in year 10 and generate a cumulative NPV of $37.7 million.

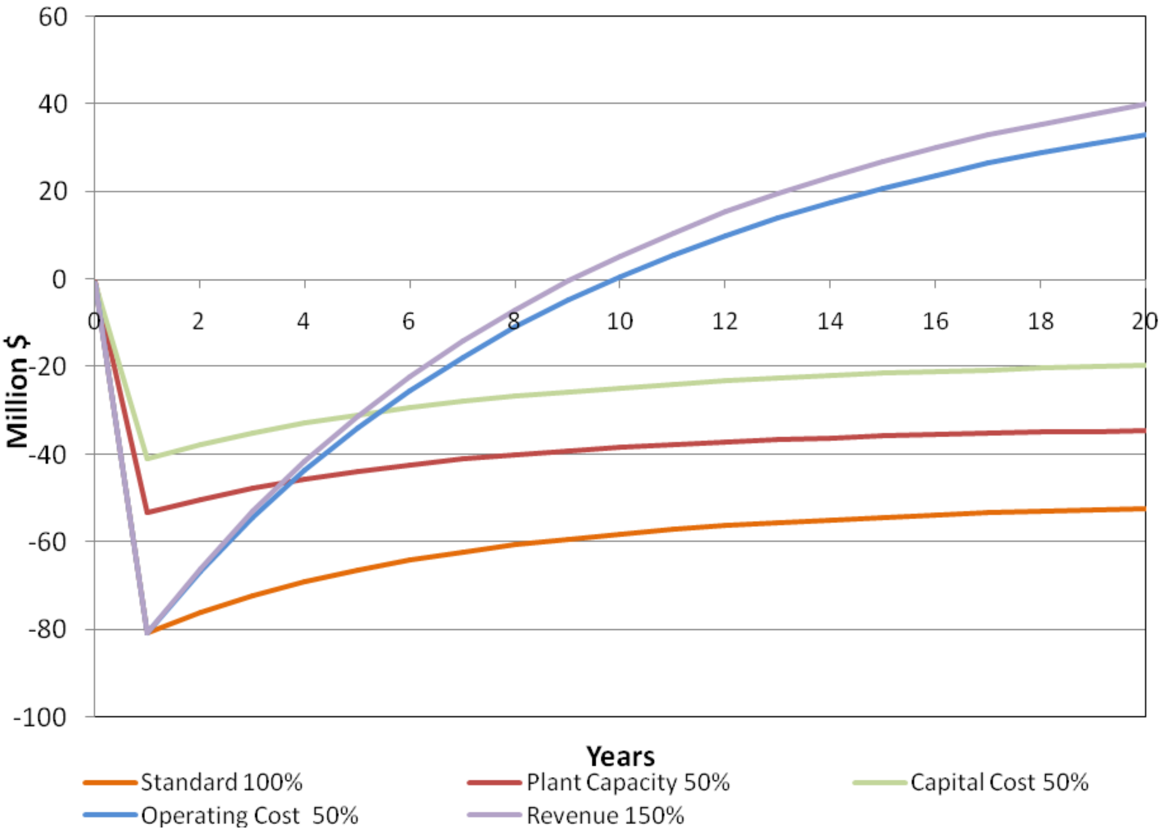


Figure 2 Sensitivity analysis of cumulative net present value

6.6.5 LPC price

From the mass balance, to produce 1 tonne of LPC (dry basis), 4.2 tonne of pasture (dry basis) is required. The purchase price of the feed when harvesting and transportation are included averages $393 per tonne DM. It cost $1670 to purchase feed material to make 1 tonne DM LPC which is sold at $1650 – At this market price the project is essentially processing the feed material for free!

A break-even period of 2 to 3 years would make the Proteins from Pasture a highly feasible investment opportunity. The price of LPC needs to be increased as there is little room for movement in the price of the other revenue streams as they are set by an established market. A four-fold increase in the price of LPC to $7500 per tonne DM would be required to break even in year 3. Revenue for the project would increase to over $116 million per annum. Over the 20 year term of the project it would be predicted a total of $345 million would be generated in returns.

$7500 per tonne DM is an unlikely price for the LPC product if it is sold as a protein meal for animal stock as this is a low-value market. It is likely that LPC would need to be further refined and then aimed at other higher value applications. Higher value applications that could command a sufficiently high price include cosmetics, personal care (shampoo, hand creams, etc), human food ingredients, medical and pharmaceutical.

6.7 Conclusion and recommendations (Part B)

This preliminary feasibility study shows that with the current assumptions, process and products, it is not profitable to invest and build a processing facility to extract protein from pasture. However, from the sensitivity analysis, areas have been identified, that would make this project economically viable.

The purchase price of the Lucerne and pasture along with harvesting and transportation is very high, averaging $393 per tonne DM. Reducing the cost associated with the feed-stock would significantly improve the economic viability.

Alternatively, higher-value product markets for LPC should be investigated, at present LPC is aimed at a low-value market of animal feed. If the price of LPC roughly doubled, $3500 per tonne DM and the operating cost of the plant reduced by 25%, the project would break-even in approximately year 6. Higher value product markets include cosmetics, personal care, human food ingredients, medical and pharmaceutical.

It is recommended that further work be carried out at a pilot-scale level to gain information to confirm the mass balance and associated equipment costs. The following information is required:

- Yields of each press and the moisture requirements of each press.
- Recycling of DPJ.
- Composition of each stream in the process – sugar content, protein content, total solids etc.

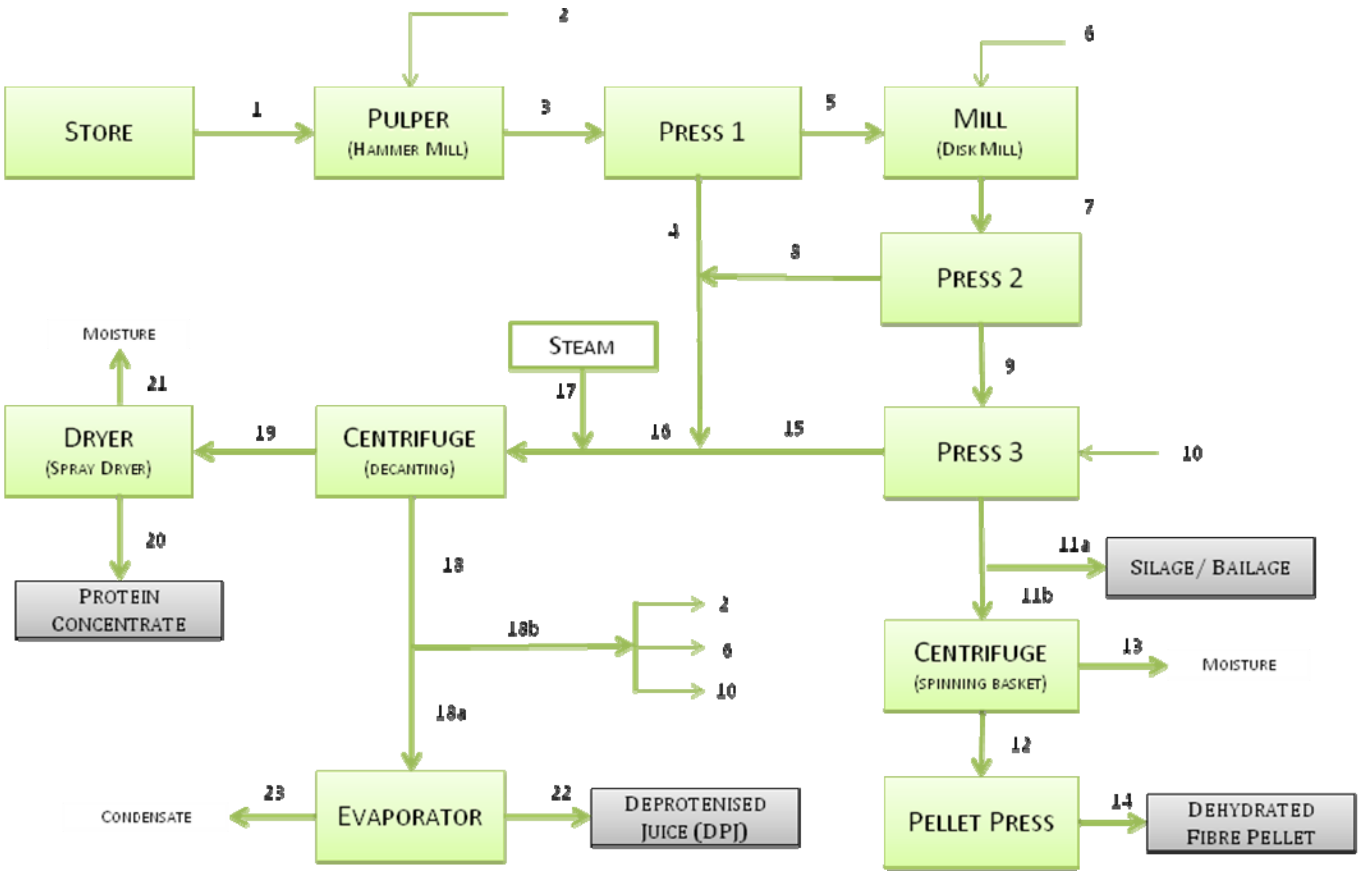
6.8 References (Part B)

[1] McDonald, R. M.; Ritchie, J. M.; Donnelly, P. E.; Bushnell, P. G.; Mace, M. J. *Economics of the leaf-protein extraction process under New Zealand conditions*; CAMIS 07173; MAF Ruakura Research Centre Internal Report 1981; p 29 Appendices 190pp.

[2] Earl, W. B., *Process Capital Cost Estimation for New Zealand 2004*. Society of Chemical Engineers New Zeland Inc: Christchurch, 2005.

6.9 APPENDICES (PART B) APPENDIX I – MASS BALANCE

Box Diagram:



Stream Number		1	2	3	4	5	6	7	8	9	10
Stream Name		Feed to Pulper	Recycle DPJ	Pulp to press 1	Liquor from Press 1	Press 1 solids to Mill	DPJ to Mill	Slurry to Press 2	Liquor from Press 2	Solid to Press 3	DPJ to Press 3
Process Temperature	°C	20	20	20	20	20	20	20	20	20	20
Lucerne	t	20.0									
Fibre	t	7.6		7.6		7.6		7.6		7.6	
Protein	t	6.2	0.9	7.1	2.8	4.2	0.14	4.4	1.2	3.1	0.06
Others	t	6.2	0.6	6.7	2.5	4.3	0.1	4.4	0.7	3.6	0.04
Water	t	80.0	48.6	128.6	104.3	24.2	7.8	32.1	10.5	21.6	3.5
Total	t/h	100.0	50.0	150.0	109.6	40.4	8.1	48.4	12.4	36.0	3.6

Variables - Assumed values in red

Operating Hours	h/y	2880
	h/d	16
	d/w	6
	w/y	30
Lucerne Harvested	t/y	288000
	t/h	100

Composition	**Lucerne**
Dry Matter (DM)	20%
Fibre	38%
"Protein" (ppt)	31%
Other	31%

Extracts from Crop		Protein	Solubles	Water
Press 1	%	40	40	60
Press 2	%	20	12	
Total extracted	%	75	62	
Liquid to Pulper				
MC	%	50		
Liquid to Mill 2				
MC	%	20		
Liquor to Press				
MC	%	10		
Split				
Silage: Pellet	%	80		

Silage: Bailage % 50

11 Solids from Press 3	11a Silage/ Baleage	11b Fibre to Centrifuge	12 Dehydrated Fibre to Pellet press	13 Water from fibre	14 Fibre Pellet	15 Liquor from Press 3	16 Total press Liquor	17 Steam (7 bar)	18 DPJ from Centrifuge
20					20	20	40	170	90
7.6	6.1	1.5	1.5		1.5				
2.5	2.0	0.5	0.5		0.5	0.6	4.7		2.3
3.0	2.4	0.6	0.6		0.6	0.6	3.8		1.5
19.8	15.8	4.0	0.5	3.5	0.5	5.3	120.1	13.1	128.6
33.0	26.4	6.6	3.1	3.5	3.1	6.6	128.6	13.1	132.4

Product Specifications

Fiber		
Moisture Content	%	60
Pellet MC	%	15
Deproteinised Juice		
Solids Concn	%	40
LPC		
Solid Content	%	94.8
DPJ Dilute		
DM		2.88
CP (on DM)		20

Steam Requirements

Liquor Temp	°C	40	
Outlet Temp	°C	90	
Heat Capacity	$kJkg^{-1} K^{-1}$	4.19	*Assume fluid properties of*
Heat Required	kJ	2.69E+07	*water*
Enthalpy Hfg	kJ/kg	2047	
Steam Required	kg/h	13148	
	t/h	13	

7 Bar Steam

Hf	721.561	kJ/kg
Hfg	2047.43	kJ/kg
Hg	2768.99	kJ/kg

18a	18b	19	20	21	22	23
DPJ to Evap	DPJ to Recycle	Protein Solids (LPC)	Dry LPC	Moisture from Dryer	Conc^{n} DPJ (Molasses)	Condensate
	20	90				
1.3	1.1	2.3	2.3		2.3	
0.8	0.7	2.3	2.3		0.8	
68.7	59.9	4.7	0.2	4.5	7.1	61.6
70.7	61.7	9.4	4.9	4.5	7.9	61.6

.1) we have a dilute feed of approximately 3.3% solids (sugars) to be evaporated to 40% sugar content. The evaporation rate is 63 t per hour

APPENDIX II – EQUIPMENT SIZING & COST

Hammer Mill

Cost 2001	$AU	125,000
Conversion AUD to NZD	1:	1.149
	$NZ	143,625
Loading	t/y	56,800
Current Loading (2x)	t/y	60,000
Cost	$NZ	296,853
MWDCCI 2001 Dec	4320	
MWDCCI 2009 March	6309	
MWDCCI Ratio	1.460	
Current Cost	**$NZ**	**434,000**

Press 1, 2 & 3 - Belt press

Capacity	Pulp t/h	Total MC	Press Area m^2
- Press 1	100	86%	200
- Press 2	44	66%	100
- Press 3	40	63%	100

(*press area has been guestimated)*

Estimated 2004			SCENZ
- Press 1	**$NZ**	453,900	
- Press 2	**$NZ**	230,900	
- Press 3	**$NZ**	230,900	
MWDCCI 2004 Dec	4986		
MWDCCI 2009 Mar	6234		
MWDCCI Ratio	1.250		
Current Total Price	**$NZ**	**1,140,000**	

Disk Mill

Capacity	t/h	40	
Power	kw	500	
Number Required		2	
Estimated 2004	**$NZ**	103,095	SCENZ
MWDCCI 2004 Dec	4986		
MWDCCI 2009 Mar	6234		
MWDCCI Ratio	1.250		
Current Price	**$NZ**	**129,000**	

Decanting Centrifuge

Capacity - Total	t/h	142	
Dry Solids	t/h	8.53	
	kg/s	2.37	
Temperature	°C	90	
Estimated 2004	**$NZ**	355,585	SCENZ
MWDCCI 2004 Dec	4986		
MWDCCI 2009 Mar	6234		
MWDCCI Ratio	1.250		
Current Price	**$NZ**	**445,000**	

Evaporator - Scraped Film

Evaporation rate	t/h	63	
Feed Concentration	%	3%	
Final Concentration	%	40%	
Estimated 2004	**$NZ**	7,496,022	SCENZ
MWDCCI 2004 Dec	4986		
MWDCCI 2009 Mar	6234		
MWDCCI Ratio	1.250		
Current Price	**$NZ**	**9,370,000**	

Spray Dryer

Water Evaporation Rate	t/h	4.5	
Estimated:			
Installed Price 2004	$	7,955,604	SCENZ
MWDCCI 2004 Dec	4986		
MWDCCI 2009 Mar	6234		
MWDCCI Ratio	1.250		
Current Price	**$NZ**	**9,950,000**	
2006 Quotation Updated			
Water Evaporation Rate	t/h	0.217	
Quotation	$NZ	1,350,000	
MWDCCI 2006 Dec	5318		
MWDCCI 2009 Mar	6234		
	1.172234		
Quotation	**$NZ**	**9,700,000**	

Basket Centrifuge

Capacity - feed	t/h	6.6	
	kg/s	1.8	
Density (est)	kg/m3	800.0	
	m3/s	0.002	
Input MC		60%	
Output MC		15%	
Estimated 2004	**$NZ**	166,799	SCENZ
MWDCCI 2004 Dec	4986		
MWDCCI 2009 Mar	6234		
MWDCCI Ratio	1.250		
Current Price	**$NZ**	**210,000**	

Pelletizer - Briquette Press

Capacity	t/h	3.6
MC		0.2
Press Capacity	t/h	1
Price	**$USD**	15,000
Exchange Rate	1.73	
Price	**$NZD**	25,950
Units Required	4	
Current Total Price	**$NZD**	**104,000**

Storage Bunker

Bunkers Required	5	
Capacity/bunker	t	1471
Dimensions	m	10 x 27 x 2.4
Current Total Price	**$NZD**	**230,000**

Nitrogen Production

Nitrogen Generator	**$NZ**	**138,000**

(quotation - Atlas Copco)

Lang factors:

Details	Lang Factors	Cost NZ$
Equipment (delivered)	1.00	21,900,000
Equipment, Installed	0.40	8,760,000
Piping & Conveyors	0.45	9,860,000
Electrical	0.12	2,630,000
Instrumentation	0.13	2,850,000
Pumps and Heat Exchangers	0.12	2,630,000
Battery-limits building and service	0.30	6,570,000
Excavation and site preparation	0.10	2,190,000
Auxiliaries	0.48	10,500,000
Field Expense	0.35	7,670,000
Engineering	0.35	7,670,000
Contractor's fees, overhead, profit	0.12	2,630,000
Contingency	0.39	8,540,000
Total	4.31	94,400,000

Appendix III – Operating Cost

Split					
Lucerne	0.6				
Pasture	0.4				

Days operating 180 days/year

	Unit Cost		Units Required		Annual Cost $/y
Feed Material					
Lucerne	$/tDM	350	tDM/y	36,000	12,600,000
Pasture	$/tDM	250	tDM/y	21,600	5,400,000
Harvesting Cost	$/tDM	80	tDM/y	57,600	4,608,000
					22,600,000
Services					
Cooling water	$/t	0.05	t/y	500,000	25,000
Steam	$/t	15.50	t/y	113,435	1,800,000
Transport Cost	$/tDM	60	tDM/y	87,994	5,300,000
Power	$/GJ	23.30	GJ/y	120,000	2,800,000
Waste water	$/m^3	1.24	m^3/y	181,375	220,000
					10,100,000
Labour					
Bailage Contractor	$/h	100	h/d	8	
			d/w	3	
			w/y	30	72,000
Operator	$/h	17	h/shift	8	
			No of shifts	2	
			Op/shift	5.5	270,000
Supervisor	$/y	45,000		2	90,000
Plant Manager	$/y	66,000		1	66,000
					426,000
Administration Cost	$/y	200000			200,000
			Total Annual Operating Cost		33,300,000

APPENDIX IV - REVENUE

Fibre products:

Lucerne	0.6
Pasture	0.4
Luceren Silage: Pellet	0.8
Pasture Silage: Pellet	1.0
Bailage : Silage	0.5

Products	Production		Dry Matter (DM)		Price	Revenue
	t/h	t/y	%DM	t	$/t DM	$
Bailage	13.2					
Lucerne	7.4	19533	40%	7813	200	1,600,000
Pasture	5.8	15421	40%	6168	180	1,100,000
Silage	13.2					
Lucerne	7.4	19533	40%	7813	180	1,400,000
Pasture	5.8	15421	40%	6168	180	1,100,000
Dehydrated Fibre Pellet						
Lucerne	3.1	8671	85%	7371	700	5,200,000
Deproteinised Juice (DPJ)	7.8	22089	40%	8835	700	6,200,000
Protein Concentrate (LPC)	4.9	13946	95%	13221	1650	21,800,000
					Total Revenue	38,400,000

APPENDIX VA – WHOLE OF LIFE

Year			0	1	2	3	4	5	6	7
Feed	tonne/year		0	288000	288000	288000	288000	288000	288000	288000
Investment	Land		800,000							
	Plant			94,400,000						
	Buildings			9,440,000						
Manufacturing Costs	Production				33,300,000	33,300,000	33,300,000	33,300,000	33,300,000	33,300,000
Revenue from Sales					38,400,000	38,400,000	38,400,000	38,400,000	38,400,000	38,400,000
Gross Profit before Depreciation					5,100,000	5,100,000	5,100,000	5,100,000	5,100,000	5,100,000
Depreciation	Plant WDV				94,400,000	80,806,400	69,170,278	59,209,758	50,683,553	43,385,121
	Allowance @ 14.4DV				13,593,600	11,636,122	9,960,520	8,526,205	7,298,432	6,247,457
	Buildings WDV				9,440,000	8,986,880	8,533,760	8,080,640	7,627,520	7,174,400
	Allowance @ 4.8 SL				453,120	453,120	453,120	453,120	453,120	453,120
Total depreciation allowance					14,046,720	12,089,242	10,413,640	8,979,325	7,751,552	6,700,577
Profit before tax					-8,946,720	-6,989,242	-5,313,640	-3,879,325	-2,651,552	-1,600,577
Tax at 33%					0	-5,258,867	-1,753,501	-1,280,177	-875,012	-528,191
Profit after tax					-8,946,720	-1,730,374	-3,560,139	-2,599,148	-1,776,540	-1,072,387
Add back depreciation allowance					14,046,720	12,089,242	10,413,640	8,979,325	7,751,552	6,700,577
Net Cash Flow			-800,000	-103,840,000	5,100,000	10,358,867	6,853,501	6,380,177	5,975,012	5,628,191
NPV Discount Factors (MAR 10%)	0.1		1.000	0.909	0.826	0.751	0.683	0.621	0.564	0.513
Net Present Value			-800,000	-94,400,000	4,214,876	7,782,770	4,681,034	3,961,588	3,372,739	2,888,152
Cumulative Net Present Value		$	-800,000	-95,200,000	-9.10E+07	-8.32E+07	-7.85E+07	-7.46E+07	-7.12E+07	-6.83E+07

Lucerne IN	**$/tDM**	**350**
Pasture IN	**$/tDM**	**250**

8	9	10	11	12	13	14	15	16	17	18	19	20
288000	288000	288000	288000	288000	288000	288000	288000	288000	288000	288000	288000	288000
33,300,000	33,300,000	33,300,000	33,300,000	33,300,000	33,300,000	33,300,000	33,300,000	33,300,000	33,300,000	33,300,000	33,300,000	33,300,000
38,400,000	38,400,000	38,400,000	38,400,000	38,400,000	38,400,000	38,400,000	38,400,000	38,400,000	38,400,000	38,400,000	38,400,000	38,400,000
5,100,000	5,100,000	5,100,000	5,100,000	5,100,000	5,100,000	5,100,000	5,100,000	5,100,000	5,100,000	5,100,000	5,100,000	5,100,000
37,137,664	31,789,840	27,212,103	23,293,560	19,939,288	17,068,030	14,610,234	12,506,360	10,705,444	9,163,860	7,844,264	6,714,690	5,747,775
5,347,824	4,577,737	3,918,543	3,354,273	2,871,257	2,457,796	2,103,874	1,800,916	1,541,584	1,319,596	1,129,574	966,915	827,680
6,721,280	6,268,160	5,815,040	5,361,920	4,908,800	4,455,680	4,002,560	3,549,440	3,096,320	2,643,200	2,190,080	1,736,960	1,283,840
453,120	453,120	453,120	453,120	453,120	453,120	453,120	453,120	453,120	453,120	453,120	453,120	453,120
5,800,944	5,030,857	4,371,663	3,807,393	3,324,377	2,910,916	2,556,994	2,254,036	1,994,704	1,772,716	1,582,694	1,420,035	1,280,800
-700,944	69,143	728,337	1,292,607	1,775,623	2,189,084	2,543,006	2,845,964	3,105,296	3,327,284	3,517,306	3,679,965	3,819,200
-231,311	22,817	240,351	426,560	585,955	722,398	839,192	939,168	1,024,748	1,098,004	1,160,711	1,214,388	1,260,336
-469,632	46,326	487,986	866,047	1,189,667	1,466,686	1,703,814	1,906,796	2,080,548	2,229,280	2,356,595	2,465,576	2,558,864
5,800,944	5,030,857	4,371,663	3,807,393	3,324,377	2,910,916	2,556,994	2,254,036	1,994,704	1,772,716	1,582,694	1,420,035	1,280,800
5,331,311	5,077,183	4,859,649	4,673,440	4,514,045	4,377,602	4,260,808	4,160,832	4,075,252	4,001,996	3,939,289	3,885,612	3,839,664
0.467	0.424	0.386	0.350	0.319	0.290	0.263	0.239	0.218	0.198	0.180	0.164	0.149
2,487,096	2,153,221	1,873,605	1,638,012	1,438,314	1,268,035	1,122,004	996,070	886,894	791,774	708,516	635,329	570,742
-6.58E+07	-6.37E+07	-6.18E+07	-6.01E+07	-5.87E+07	-5.74E+07	-5.63E+07	-5.53E+07	-5.44E+07	-5.36E+07	-5.29E+07	-5.23E+07	-5.17E+07

Lucerne IN	**$/tDM**	**350**
Pasture IN	**$/tDM**	**250**

7. PART C: Results of system dynamic financial modelling and risk assessment of an integrated protein extraction system.

7.1 Results of sensitivity simulations

An investment evaluation model construct, using the system dynamic modelling tool, Vensim®, is illustrated in Figure 1; and used base model data derived from Parts A and B of this report. Initial simplified scenario analysis with single parameter variable changes were 'run' with the model to evaluate the base model with an NPV discount rate at 10% discount, versus 6% (Figure 2), and using current (Part B) versus 75% of current upfront capital investment costs (buildings and plant, B&P), refer Figure 3. Whilst these considered 'at the bounds' (or optimistic?) reductions in discount rate and capital investments costs improved net cash flows in the model, the resultant NPV cash flows remained negative for the duration of the investment period (20 years).

Sensitivity 'run' databases contains standard behaviour for all variables with the model's original constant values, and the range of values specified for the behaviour of the targeted variables "NPV cash flow", "Revenue from Sales" and "bio-process raw material costs". "NPV cash flow" chosen as the major CBA investment appraisal output parameter; and "Lucerne price ex-farm" and "Pasture price ex-farm" as significant (> 50% of sector; refer Section 6, Part B) cost parameters per variable "bio-process raw material costs"; and "price LPC" (> 50% of sector) for the variable "Revenue from Sales".

Sensitivity Run#1 comprises the <u>base model run</u>, using parameter ranges and whole model values from Parts A and B (sections 5 and 6), with parameters ranges and resultant confidence level boundary graphics illustrated in Figures 4 and 5 respectively. In agreement with NPV base modelling (note minor variance with model construct 'rounding' and structure, cf. Part B cumulative NPV value - $51.7 Million, Vensim® model base run, -$47.4 Million) in Part B for bio-process plant, the NPV cash flows remained negative, except for a very low (< 5%) probability boundary (outer bounds of uncertainty) for positive NPV cash flow at the end of the investment cycle (circled area, Figure 5). Note that with the confidence levels or bounds, there is the assumption that the variable spread of values will fall within the possibility of the confidence %, e.g. at 10 years, with 100% confidence boundary, values for NPV cash flow will fall between say -$90 Million and - $20 Million (Figure 5).

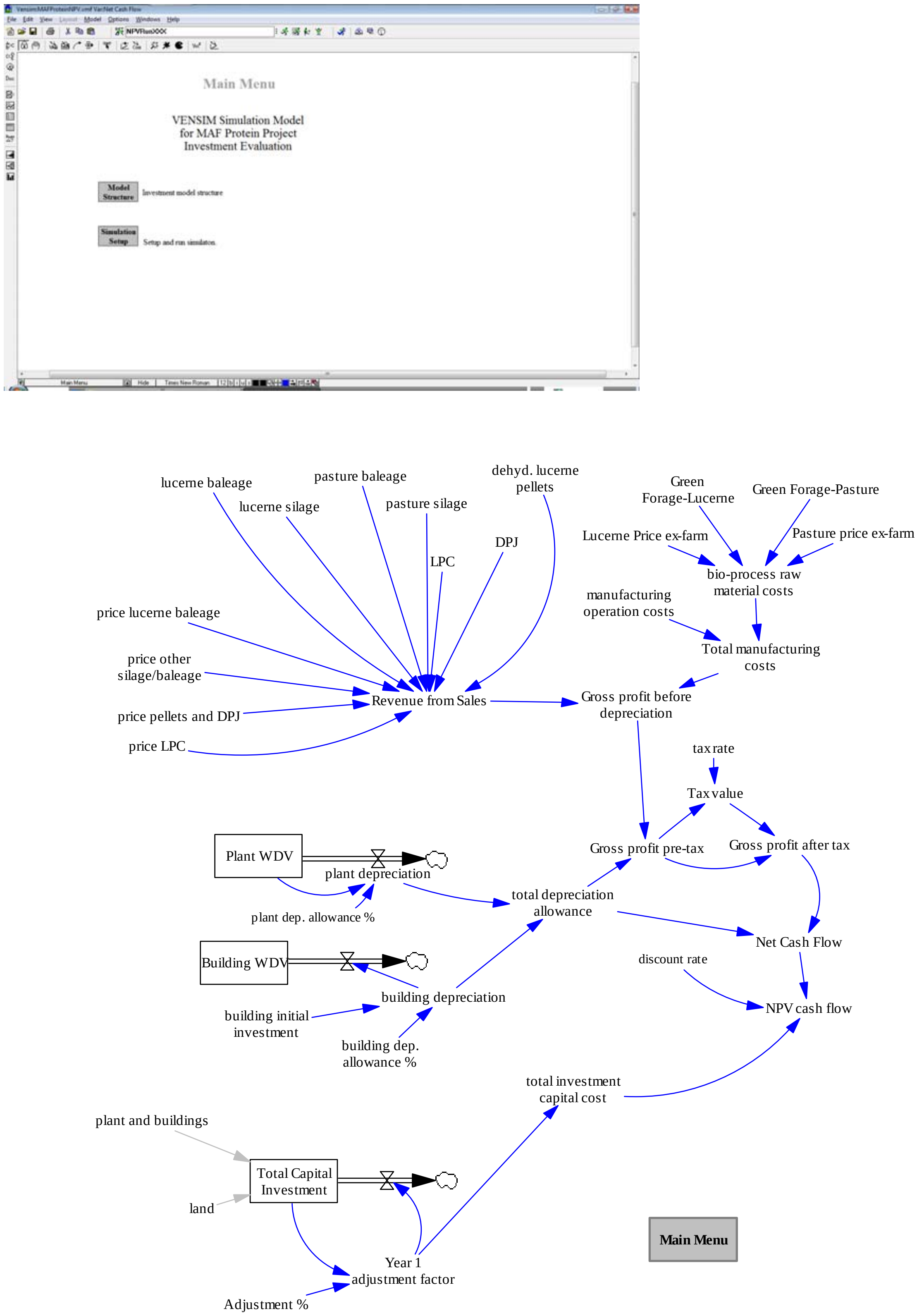


Figure 1 Screen images of the Vensim model construct, comprising menu screens and model stock and flow sketch diagram.

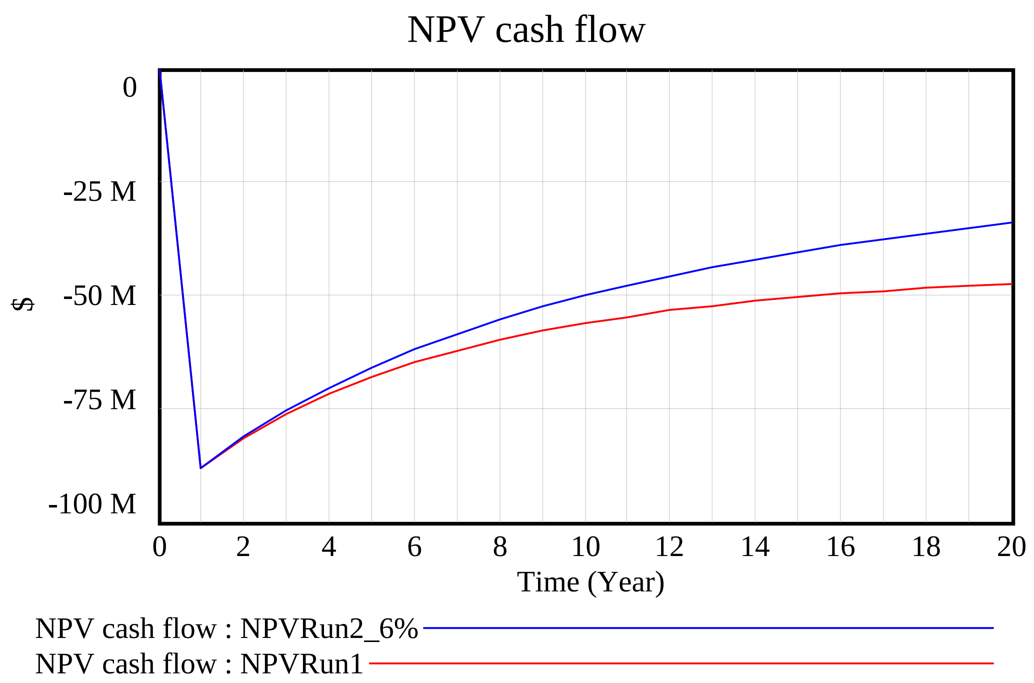


Figure 2 NPV cash flow at measured investment discount rates of 10% (Base model; NPVRun1) and 6% (NPVRun2_6%).

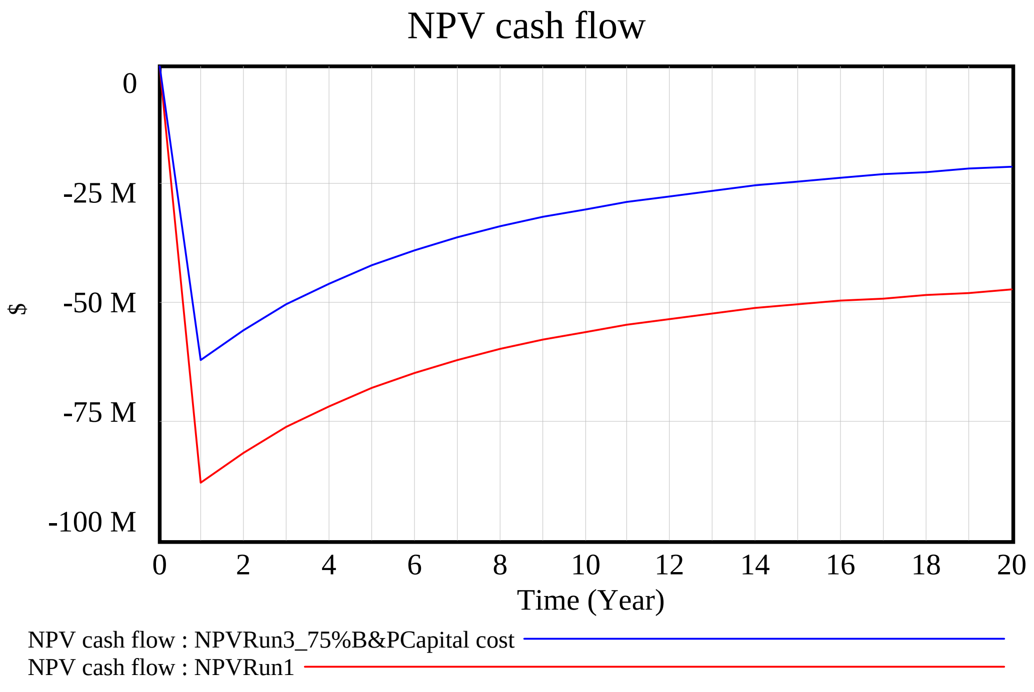


Figure 3 NPV cash flow at current model capital investment costs (Base model; NPVRun1) and 75% of current costs (NPVRun3_75%B&PCapital cost).

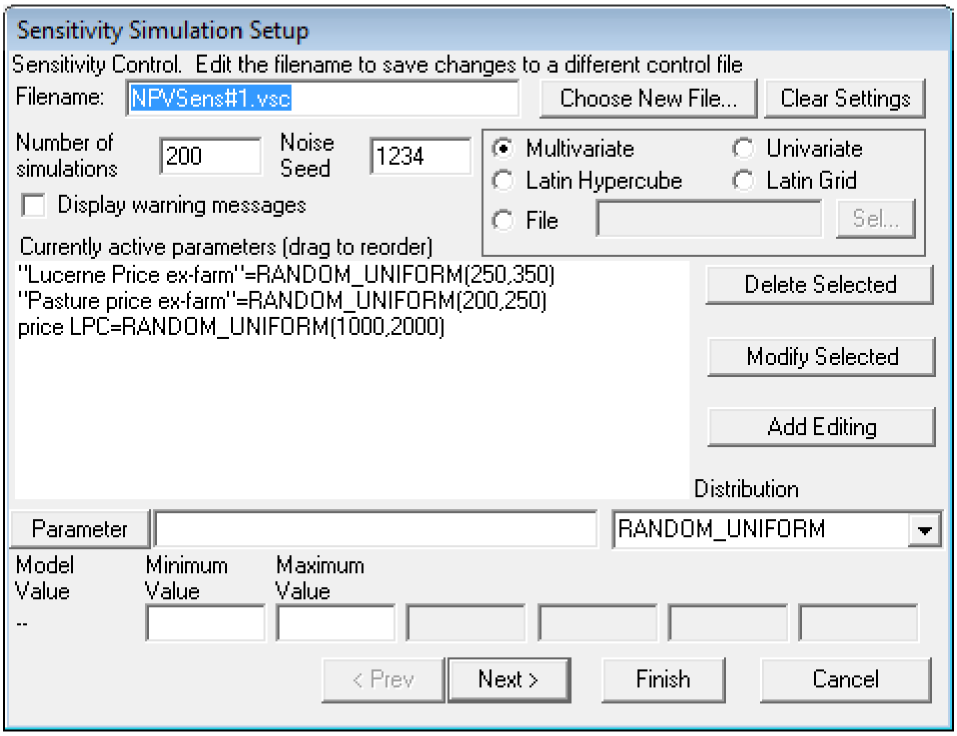


Figure 4 Sensitivity simulation parameters for Sensitivity Run #1 (Vensim® model screen output). Probability distribution (MIN, MAX) values are $ per t DM.

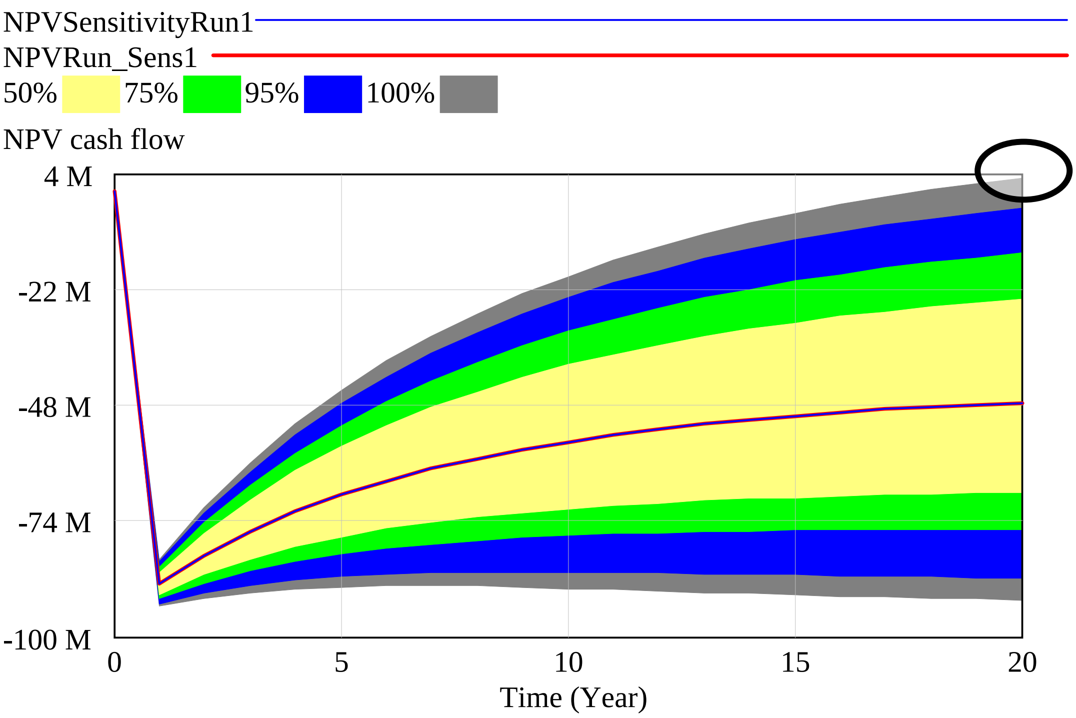


Figure 5 Sensitivity simulation graphics for Sensitivity Run #1 (Vensim® model screen output), at confidence bounds of 50, 75, 95 and 100%.

An overly optimistic (based on preceding project reviews by Sinclair 2009a,b; and results from Part A and B of this report) appraisal of parameter ranges in Sensitivity Run#2 (Figure 6), using PE forage raw material costing close to (and indeed below) current farm system parity (by up to 50%), and LPC pricing exceeding any known precedent levels (by up to, and exceeding, 200%), did result in significant ‘confidence bounded’ positive NPV cash flow (Figure 7, hatched box region). Whilst this scenario, based in the current context of this study, appears unrealistic, it *could* be seen as a *possible proxy* for the situation where the bio-process entity vertically integrates green forage supply from dedicated cropping systems only (and assumes major cost savings in raw material supply), concomitant with substantial increases in value for LPC through higher value markets. Should both the cost savings and increased revenue ranges in Figure 6 be realised then the venture would appear viable (Figure 7). However, the cost savings and revenue gains assumed are substantial, and further evaluation to substantiate such presumptive ranges would be a prerequisite.

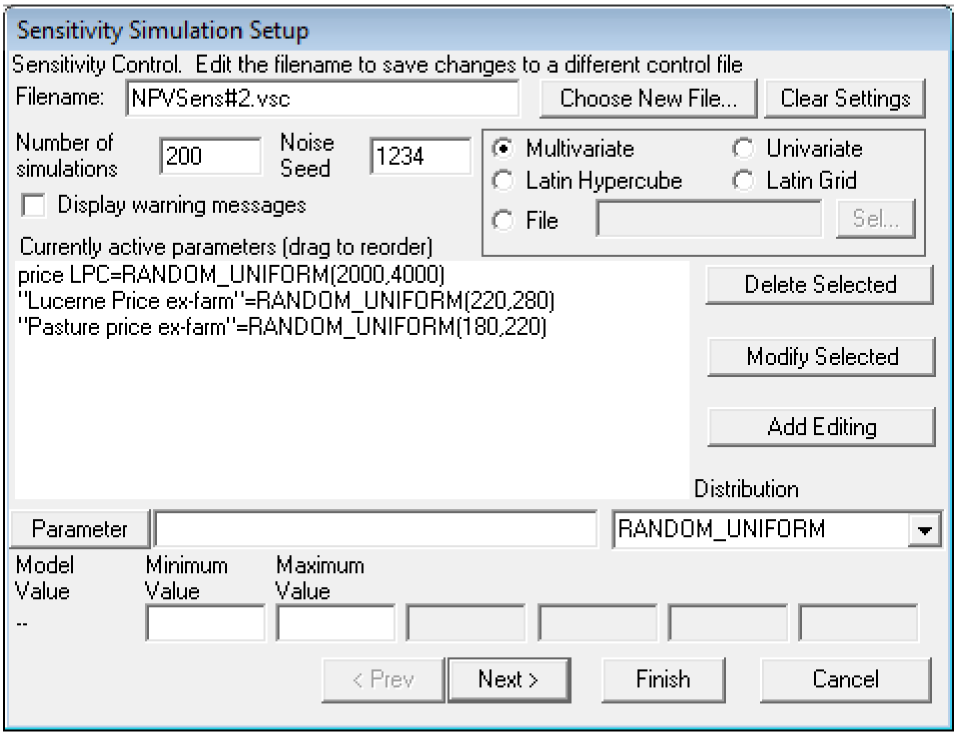


Figure 6 Sensitivity simulation parameters for Sensitivity Run #2 (Vensim® model screen output). Probability distribution (MIN, MAX) values are $ per t DM.

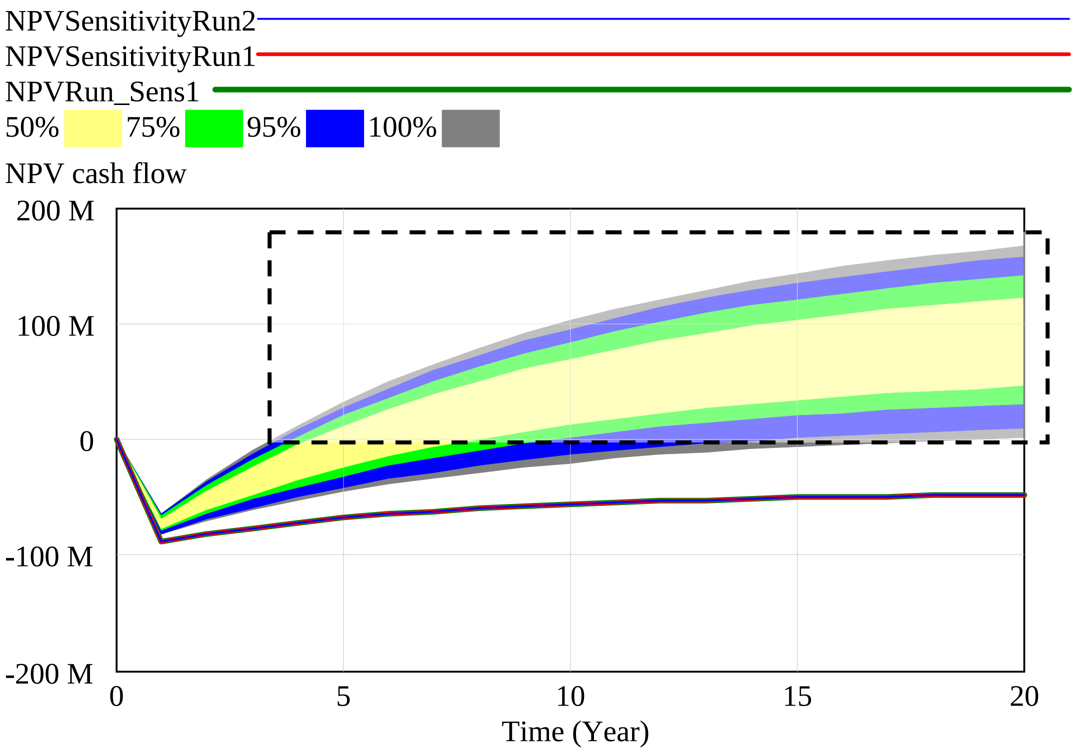


Figure 7 Sensitivity simulation graphics for Sensitivity Run #2 (Vensim® model screen output), at confidence bounds of 50, 75, 95 and 100%.

However, whilst retaining greatly constrained raw material input expenditure, evaluation of more realistic current market LPC pricing ($800 to $2000 per t DM) still resulted in negative NPV cash flows, except for the latter period of the investment life cycle, and at confidence bounds less than 10% (circled area, Figure 8).

This suggests that even with substantial raw material supply cost savings, a reliance on higher revenue capture for LPC exists as a continuing constraint to the venture viability.

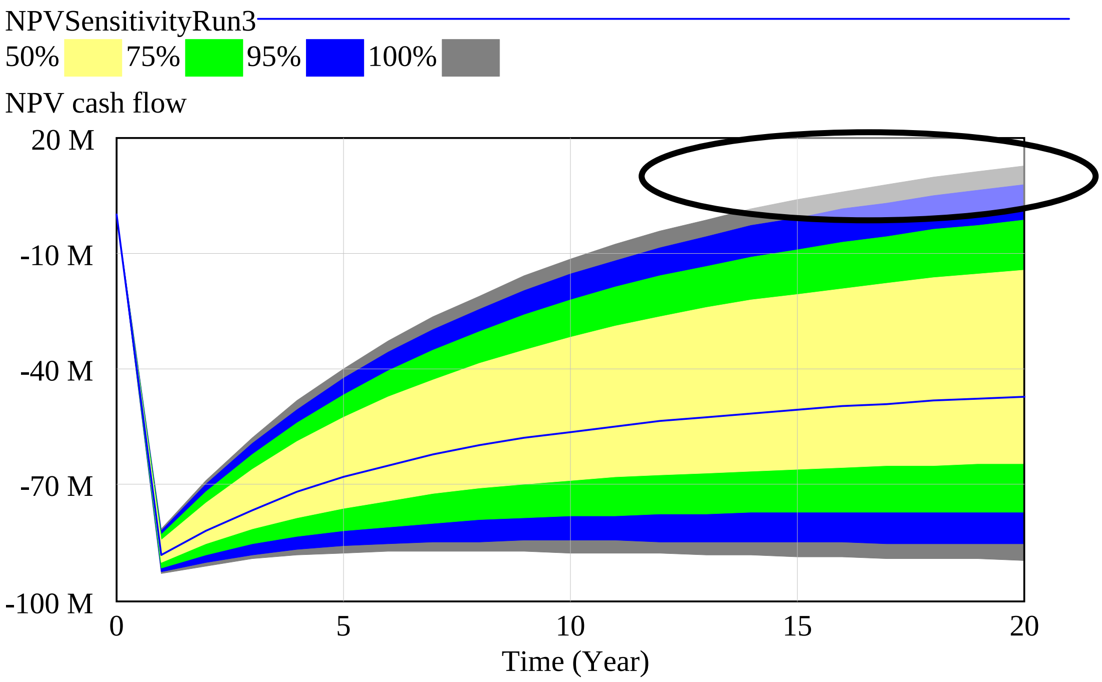


Figure 8 Sensitivity simulation graphics for Sensitivity Run #3 (Vensim® model screen output), at confidence bounds of 50, 75, 95 and 100%.

7.2 Concluding comments (Part C)

The existing base investment model, under further multivariate and multiple Monte-Carlo simulation to increase quantitative risk assessment power, has confirmed the cumulative negative NPV values and rejection of the investment proposal on this criterion. The MVSS performed, in terms of NPV cash flow, have elucidated the current issue of raw material input cost ranges, and LPC market price probabilities, being unprofitable for the bio-process within the current integrated PE system analysis and appraisal. The sensitivity simulations have nevertheless added to information available for the decision making process, but suggest that alternative PE system criteria (such as vertically integrated raw material supply) and options (higher value LPC markets) be considered. Profitable investment scenarios appear unrealistic in the current cost and pricing regimes.