Integrated Value Chain Scenarios for Enhanced Mill Region Profitability

Final Report

Sugar Research and Development Corporation Project CSE010

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SRDC Project CSE010

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By

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1 Executive Summary

The Australian sugar industry has recently faced an unprecedented cost-price ‘squeeze’ from a run of poor seasons and the collapse of the sugar price. As a result there is impetus to consider diversifying products from the raw sugar production value chain. The chain is complex however, and alternative products will necessitate substantial changes to the chain, the impacts of which will be difficult to predict *a priori*. Modelling offers insights into the impacts of, and benefits from changes to value chains. Analyses of the chain should, ideally, be conducted in enough biophysical detail to allow the logistical challenges to be properly analysed. The application of these modelling techniques in a participatory environment would allow groups within mill regions to more thoroughly evaluate diversification options of their sugar value chains in their region, and so move forward with more confidence and greater understanding than occurs with other approaches. While participatory modelling has previously been undertaken for issues in one or two sectors of the Australian sugar value chain, it has not been attempted for the whole of the chain before.

In this project we aimed to facilitate the improved economic efficiency of the sugar industry value chain through developing and participatively applying an innovative modelling capability that allowed industry groups to identify and evaluate sugar value chain diversification options. The project was conducted in partnership with all sectors of the Burdekin and Maryborough industries. The first phase of the project entailed working with the regional groups to identify and prioritise potential diversification options for their region. In both regions whole crop harvesting to maximise electricity co-generation was identified as the highest priority venture for consideration in the project. In the Burdekin, two contrasting mill regions (Invicta and Pioneer) were analysed to maximise the relevance of the results to the region.

An agent-based modelling framework was then developed and used to analyse each mill region. Additional income from electricity and Renewable Energy Certificates sales was weighed against not only the costs of operating and, for some scenarios, constructing the co-generation facility, but also the costs associated with (1) productivity reduction associated with the loss of trash from the field, (2) harvesting and transporting to the mill the additional material, and (3) the impact of increased trash on sugar mill operations.

In general, predicted impacts on the farming and milling sectors were greater than anticipated by stakeholders, because the farm impacts had not been fully considered previously and capital costs were higher than anticipated. Conversely, impacts on the harvesting and transport sectors were less than anticipated because of possible increases in logistical efficiency in these sectors in some regions. For Maryborough annual costs were predicted to be considerably greater than revenues, and the stakeholders in that region decided the venture was not viable. The economic benefit of this decision, which is at least partly attributable to the project, is in the order of $50M. This result alone gives the project a benefit cost ratio between 3 and 34, and an internal rate of return of 20 to 97 %, depending on the degree of attribution.

For the two Burdekin mills co-generation plants with spare capacity do (or soon will) exist in these mills minimising additional capital costs. So revenues were predicted to be close to costs for both mill regions. Regional stakeholders did not proceed with these ventures, but are well placed to conduct more detailed feasibility studies should changes in economic conditions make the ventures more attractive. In the Maryborough and Invicta mill regions, possible improvements in efficiency in the harvest and/or transport sectors were identified and work is underway to refine and implement these in Maryborough.

In addition to the assessment of the co-generation ventures, other outputs from the project include the definition for the first time of:

- The cost of trash as a fuel for co-generation when collected through the harvest and sectors in the three mills, and
- The regional net value of trash blanketing in the Maryborough.

This information allows the regions to better assess issues such as the attractiveness of alternative uses for trash (e.g. stockfeed) or alternative methods of collecting trash (e.g. bailing operations).

Additional outcomes from the project include increased understanding of the issues involved in maximising co-generation and the complexities of the sugar value chains amongst collaborators, as well as acceptance of value of value chain modelling and the outputs produced by these groups**.** Finally, this project has demonstrated that whole-of-value chain modelling can be undertaken in partnership with industry stakeholders to analyse significant, complex regional issues and produce knowledge and benefits that would not have otherwise been revealed.

2 Background

The Australian sugar industry has recently faced an unprecedented cost-price ‘squeeze’ from a run of poor seasons, the collapse of the international price of raw sugar and a strengthening currency. While the situation has recently abated, there is no doubt that the long term outlook for sugar prices is more pessimistic than in recent decades. Faced with this situation, the industry must become more efficient at producing raw sugar and look for alternative activities, or undertake what Hamel and Prahad (1994) describe as “*getting better and becoming different*”. Much attention has been given to improving productivity and profitability in the industry, both through research (e.g. Wood *et al*. 2003) and extension (Juffs *et al*. 2004) – these efforts being aimed at *getting better*. One dimension of *becoming different* is consideration of alternative products from the raw sugar production value chain.

For many years there has been substantial interest in diversification within the industry (e.g. Allen *et al*. 1997), with recent interest focusing on production of renewable energy from ethanol or electricity co-generation (Keating *et al*. 2002; Sutherland 2002). Undertaking these ventures entails new challenges for the traditional organisation of the sugar value chain. For example, feedstocks for these processes are required at different times and possibly from different sources from those associated with ‘traditional’ sugar production in Australia. Other possible new enterprises, such as the production of fibre-based products (paper, packaging, etc.) or lactic acid (Allen *et al*. 1997), pose similar challenges. Some of these changes may demand development and employment of new infrastructure, such as factory-based trash separation (Schembri *et al*. 2002). Others will challenge the traditional logistical operation of the value chain, such as whole crop harvesting to maximise co-generation. Further, some will substantially impact on the farming sector, such as growing sweet sorghum as an alternate feedstock for out of season ethanol production (Webster *et al*. 2004).

What is required for the Australian sugar industry to evaluate the challenges of diversifying the supply chain? Many evaluations have focussed heavily on the economic aspects of diversification (e.g., Keating *et al*. 2002; Sutherland 2002), and included only broad assumptions about the changes to the organisation of the value chain. Ideally, evaluations should be conducted in enough biophysical detail to allow the logistical challenges to be properly analysed. It is likely that this will entail application of modelling and simulation techniques to describe the flow of material and products and their economic costs and value (Gigler *et al*. 2002; Van der Vorst *et al*. 2002). The modelling would provide an objective means of discovering benefits and disbenefits associated with each change or diversification option. Undertaking these modelling analyses using participatory methods, where participants in all sectors of the industry collaboratively explore and evaluate possible value chain changes, could build knowledge of, and confidence in the value chain (Gaucher *et al*. 1998). Such a process would build trust in any decisions regarding the value chain, such as diversification. Trust built would be highly desirable in Australian sugar supply chains which have a somewhat adversarial history (Milford 2002). Thus, coupling these participatory and modelling approaches could prove a powerful tool for evaluating diversification options of sugar supply chains.

There have been many models developed within the Australian sugar industry. However, these models generally only consider activities or processes in a single sector (e.g. Table 1). It is only relatively recently that there has been development of multi-sector models, with these focussing on the interface between the harvesting and transport sectors (Grimley and Horton 1997; Higgins *et al*. 2004). To properly consider diversification options in the raw sugar value chain, all sectors of the value chain would need to be modelled. Ideally a whole-of-value-chain model would draw upon existing sector models, increasing the benefits derived by the industry from its previous investment in these models. Innovative modelling techniques (e.g. agent based modelling) are available to facilitate development of practical models of complex systems, but are not yet common in value chain modelling, especially in the sugar industry. The application of these modelling techniques in a participatory environment would allow groups within mill regions to more thoroughly evaluate diversification options of their sugar value chains in their region, and so move forward with more confidence and greater understanding than would have occurred with previous approaches.

Table 1. Examples of the processes that have been modelled within the different sectors of the Australian sugar industry. (Further details are given in Appendix 1.)

Sugarcane production	**Harvesting**	**Transport**	**Milling**
• Cane and sugar growth, responding to: – Nitrogen – Irrigation – Trash blanket dynamics • Statistical CCS and cane yield estimation	• Harvest haul model • Harvesting group roster optimisation • Harvesting group-to-siding optimisation	• Capacity planning tools for transport • Road transport schedule optimisation • Siding location and pad optimisation • Rail transport schedule optimisation and schedule checking simulation models	• Raw sugar manufacture • Cane handling • Trash separation • Co-generation
Underpinned by: – GIS techniques – Database techniques for whole-of-industry models – Miscellaneous information			

3 Project objectives

The objective of this project was to underpin improved economic efficiency of the sugar industry value chain through developing and participatively applying an innovative modelling capability that facilitates industry groups identifying and evaluating sugar value chain diversification options. This was achieved by:

1. Developing a methodology that: (i) allows industry groups and researchers to collaboratively gain a systems view of the value chain and identify possible diversification ventures, and (ii) provides a modelling framework, describing the main biophysical and economic aspects of the region's value chain, to explore the value chain consequences of adopting these ventures in a mill region.
2. Piloting the application of this methodology participatively with industry partners in the Burdekin and Maryborough regions and refine the methodology in light of the experience gained.
3. Having industry partners in the Burdekin and Maryborough regions identify benefits across all sectors of new value chain ventures analysed, and evaluate the attractiveness of the ventures to the region.
4. Identifying the requirements for large-scale implementation of the methodology, and develop a post-project action plan for this implementation.

Objective 1 has two parts; (i) a **social** objective of establishing collaboration between researchers and industry participants, and building a shared systems view of the value chain in the regions amongst these two groups; and (ii) a **technical** objective of developing a modelling framework that can describe the whole value chain. The processes used to address the **social** objective are described in *Section 4*. An important component of achieving this objective was the prioritisation of the diversification ventures in the region, leading to the definition of the venture to be analysed through value chain modelling. The result of the prioritisation is described in *Section 4*. The definition of the venture and its 'evolution' during the project in response to the action learning cycles (i.e. the outcome of the **social** objective) is described in *Section 5*. The **technical** objective, development of a value chain modelling framework, is described in *Section 6*.

The **process** to achieve Objectives 2 and 3 is the evolution of the ventures' details, as described in *Section 5*. The **results** of this process, that is definition of the benefits (or dis-benefits) and stakeholders' appraisal of the attractiveness of the venture, is described in *Section 7*.

Objective 4, the requirement for large-scale implementation and development of post-project action plans, is addressed in *Section 11* (*11.1* and *11.2*).

The project's objectives were achieved. The achievements of the first three objectives are evaluated in *Section 8* and discussed in *Section 9* of the report, while the achievement of the fourth objective is given in *Section 11*.

4 Stakeholder engagement and identification of regional priorities

4.1 Introduction

The project aimed to develop a methodology that allowed *industry groups and researchers to collaboratively gain a systems view of the value chain and identify possible diversification ventures*. This aim was achieved through multiple interactions with the project stakeholders (local industry groups), using participatory processes and action learning principles. Industry groups were established in each region to:

1. Map the local value chain in participation with the research team, to increase all participants understanding of the value chain;
2. Identify and prioritise potential opportunities for increasing regional profitability through diversification of value chain products, and/or increasing efficiency within the value chain;
3. Provide relevant data, information and expert opinion for the model parameterisation and application;
4. Guide the modelling development, and its application to the defined priorities;
5. Critique and evaluate modelling outputs in terms of technical accuracy and implications for regional value chain developments.
6. Build trust in the integrity of the results and increase understanding of the value chain between project partners.

In this section, we first describe the industry groups formed and their roles within the project in relation to the points given above. We then give details of the activities undertaken to achieve the first two points, and the results of those activities. We then give details of the ongoing interaction with the groups, the process by which points 4 and 5 were achieved. These processes underpinned achievement of the sixth point, described in the *Evaluation* section later in the report.

4.2 Structure of industry groups

There were two groups established in each region. The first of these groups was the Local Reference Group (LRG). The LRG had representatives from all sectors of the value chain, and was the primary Group working with the research team during the project. In essence they were the local ‘champions’ of the project. The second group in each region was the local Technical Working Group (TWG). This group provided the detailed data input (e.g., specifics of mill operation, transport systems, harvesting, cane production, etc.) into the modelling with the research team, where this information was unable to be supplied by the LRG.

In Maryborough, the LRG comprised the CANEGROWERS Executive, Frank Sestak (Maryborough Cane Productivity and Protection Board), Richard Kelly (BSES), and John Power, Peter Downs and Stuart Norton from Maryborough Sugar Factory. In the Burdekin, the LRG was the Regional Industry Board, whose membership comprised the Chairman and the Manager of the Burdekin CANEGROWERS, Chairmen of the four Mill Suppliers Committees, and Mark Day, Robin Juffs and Dr Lisa McDonald of CSR Sugar Ltd.

During the project there were some changes to the individual membership of the groups. In the Burdekin, membership changed considerably following the CANEGROWERS elections in early 2004 and the discontinuation of the CANEGROWERS Manager position in the Burdekin. In Maryborough, Richard Kelly (BSES) resigned and was replaced by Duncan McGregor.

Membership of the TWG in each region is shown in Table 2.

Table 2. Members of the Technical Working Groups in the Burdekin and Maryborough regions.

Burdekin	**Maryborough**
Dr Lisa McDonald, CSR	Peter Downs, MSF
Peter Flanders, CSR	Stuart Norton, MSF
Greg Wieden, CSR	Glyn Peaty, MSF
Gary Stockham, Harvester and Grower	Frank Sestak, MCPPB
Robert Cocco, CANEGROWERS (to May 2004)	Richard Kelly/ Duncan McGregor, BSES

In addition to these local groups, a broader Industry Reference Group was established drawing its membership from organisations representing different sectors of the industry (e.g., ASMC, CANEGROWERS and QSL). This group ensured that the developments in the project are widely applicable within the industry and assisted in communicating the project's achievements throughout the industry and with identifying post-project action plans.

4.3 Definition of regional priorities

To fully understand the opportunities for improving regional profitability through value chain improvements (from product diversification and/or increasing efficiency), the systems nature of the value chain in each region needed to be defined. Having both regional stakeholders and the research team participate in this definition would result in a common understanding of the value chain, and provided a stronger foundation for communication between these groups during the project. Understanding the value chain is also important for identifying how changes in the value chain will contribute to regional priorities.

The systems nature of the raw sugar value chain in each region was defined in the first workshop conducted in each region. A participative process was employed in which members of the LRG mapped their region's value chain within the workshop. The result was construction of a flow diagram of the value chain (e.g. Figure 1) by the whole group. The flow diagram showed the important steps in the chain and how they related to each other, and so facilitated a discussion on how the chain could be improved upon. This process provided a common understanding of the region's value chain of the issues amongst members of both the LRG and the research team, and provided the foundation for prioritising value chain-related issues for consideration in the project.

Following the value chain mapping, both LRG's were asked to define goals for their region, and identify new value chain ventures that they thought had potential to improve regional profitability, and fulfil these goals.

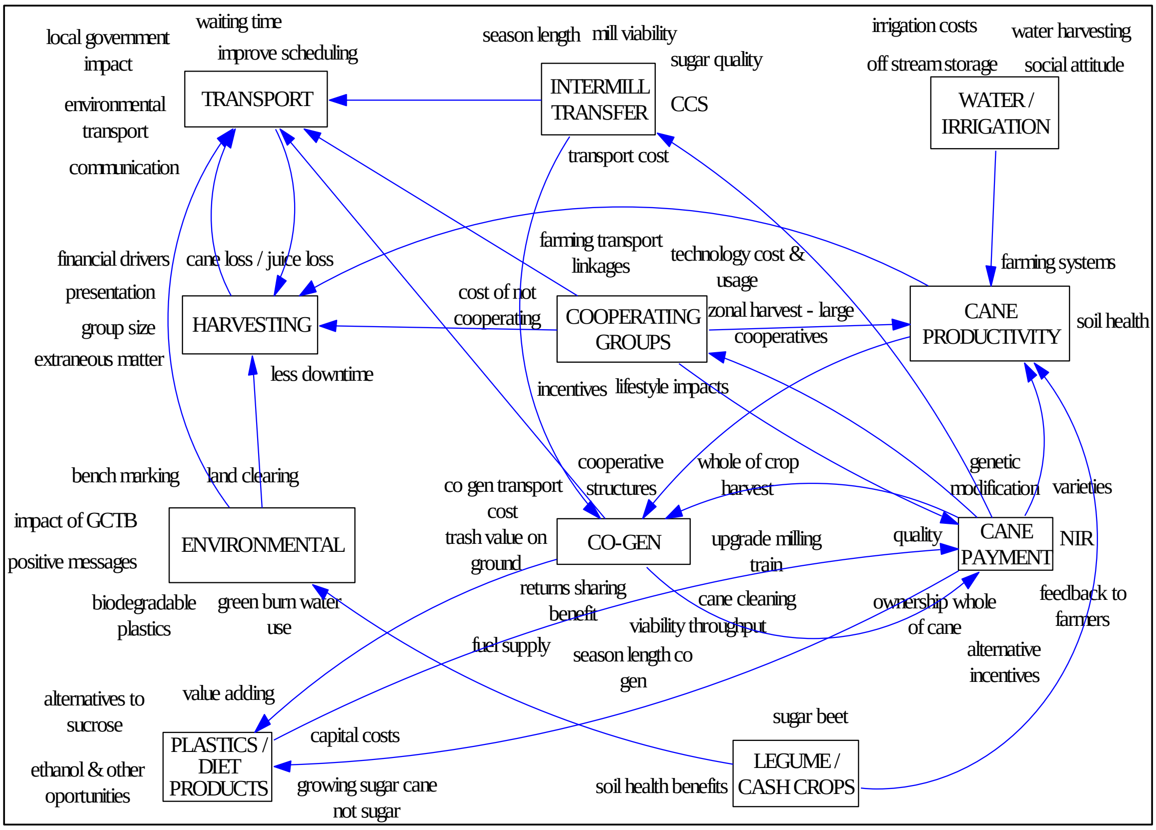
In Maryborough, the LRG identified two goals for the region:

(1) Milling more than one million tonnes of cane each year, and
(2) Maximising the value of trash[1].

They rated use of **trash as fuel for electricity co-generation through whole crop harvesting** as the highest priority venture to be analysed in the project.

[1] The term trash is used loosely in the industry, often meaning non-millable stalk and green leaf sheaths (sometimes referred to as tops) together with live and dead leaves. Live and dead leaves are sometimes also referred to as trash. We will generally use the first connotation of the term (i.e. all plant material in the cane supply other than cane), except where greater precision is required in defining the components of the cane supply.

Figure 1. Flow diagram of the Maryborough region raw sugar value chain as mapped by the Maryborough Reference Group.



In the Burdekin, the Burdekin Regional Industry Board had identified a number of short- and medium-term value chain issues that were important for the region prior to the project. These issues included subjects such as benchmarking, business structures in the region, improving productivity, as well as opportunities for diversification (e.g., using trash for electricity co-generation, producing fuel ethanol). Mapping of the value chain was still undertaken to build a collaborative view of the raw sugar value chain in the Burdekin region. Following the mapping, the Burdekin LRG identified **whole crop harvesting to maximise fuel for electricity co-generation** as the highest priority venture to be analysed in the project. Further, the Group proposed that **two mill regions should be analysed** to maximise the relevance of the results to the region. The regions chosen were Invicta and Pioneer, because of their contrasting cane transport system characteristics.

4.4 Ongoing Interactions with the Regional Groups

After identification of the venture to be analysed in the project at the first regional workshop, a process of regular interactions with the regional groups was needed to allow exchange of information between the research team and the regional stakeholders. These interactions facilitated the development of the value chain model and the analysis of the scenarios. Information was regularly obtained from both the LRG's and TWG's, to allow parameterisation of the model, and the results of the analyses presented to the LRG's for feedback.

Interactions with the TWG's were generally informal, while interactions with the LRG's occurred at workshops every three to four months (Table 3), except when a LRG requested a delay. A delay was requested in both regions in early 2005, when mill staff and growers' representatives were negotiating mill supply contracts. This delay was compounded in the Burdekin by complications arising from the late opening of Pioneer mill.

Table 3. Dates of workshops held with the Local Reference Groups in each region during the project and details of Project Team interactions and value chain model formulation.

Date	Maryborough	Burdekin	Project Team
2003 June			Team and Burdekin LRG members Robin Juffs and Lisa McDonald meets to developing common understanding of project gaols and agree on methodology and operations
Aug-Sept	Startup workshop held – regional priorities defined. Whole crop harvesting identified as top priority.	Startup workshop held – regional priorities defined. Whole crop harvesting identified as top priority	Modelling workshop I: Team develops modelling philosophy: Functional models linked to value chain (VC) shell. Starts development of functional models.
Nov	Revisit priorities in light of Govt. announcement on renewable energy. Presentation of early (functional) model development.		Model development continues.
2004 Feb-Mar	Presentation on progress with value chain model shell and functional models. Feedback on early extraneous matter/fuel amount results.	Reference Group membership changes. Second start up workshop held – regional priorities defined. Whole crop harvesting (again) identified as top priority	Modelling workshop II: Detailed analyses of necessary material and financial 'flows' in the VC shell.
June	Presentation of initial results of **full** VC analysis of scenario (trash used outside season). Feedback modifies scenario – larger co-gen plant, utilise trash within season, add wood chips as fuel.	Presentation on progress early DM results. Feedback on early extraneous matter/fuel amount results.	Team meets to prepare for regional workshops.
July			Modelling workshop III: Finalising economic analyses. Checking for consistency in definitions and assumptions.
Sept			Modelling workshop IV: Checking details of scenarios and consistency in definitions and assumptions.

Date	Maryborough	Burdekin	Project Team
Oct	Presentation of final analysis of **full** VC analysis of max co-gen. Group accepts that there is a net negative result. Feedback modifies scenario – implications of using trash for other purposes.	Presentation of initial results of **full** VC analysis of max co-gen. Feedback on information needed by the LRG to assess scenario results.	Team meets to prepare for regional workshops.
Nov		Presentation of final analysis of **full** VC analysis of max co-gen. Group accepts that there is a net negative result. Feedback modifies scenario – 'remove' capital from PNR; optimise system at INV, look at WCH in areas close to the mill at INV.	Team meets to prepare for regional workshops.
2005 Mar	LRG asks for delay in next workshop due to cane supply contract negotiations.	LRG asks for delay in next workshop due to cane supply contract negotiations. Results of new analyses supplied to, and discussed with CSR staff.	Modelling finalised.
Apr	Presentation of final analysis of **full** VC implications of using trash for other purposes. Project evaluation undertaken.		Team meets to prepare for regional workshops.
Sept		Presentation of final analysis of **full** VC implications of using trash for other purposes. Project evaluation undertaken	Team meets to prepare for regional workshops.

The information exchange occurred at two levels. The first was the technical specification of sector models. In this participative process, specific details were obtained either from, or in collaboration with the TWG's to model a specific sector (e.g., harvest-haul process). Then model outputs, such as the cost of harvesting per tonne of cane in 2003, were presented to the LRG's for critiquing. This process resulted in sector-specific modelling that was both understood, and accepted by the LRG's. The second information exchange involved the clarification and evolution of the details of the scenario being analysed.

4.5 Interactions within the research team

As well as interacting with industry stakeholders, there was need for a significant amount of interaction between members of the research team. These interactions were needed because:

- Team members had specialities in various sectors of the sugar value chain, and
- Team members had significantly different amounts of experience in value chain analyses.

As well, the team was large (to accommodate all the specialties needed for the project) and had never worked together (as one team) before. So, considerable effort was put into team building and communication to enable the team to function effectively. While much of this effort was informal, there were a series of project team workshops undertaken throughout the project (Table 3) to achieve these goals.

Initially, these workshops were aimed at team building and developing a common understanding of the approach taken to the research problem (e.g. June 2003 Table 3). Workshops then concentrated on the task of creating the original modelling needed to undertake the analyses required to address the stakeholder issues. Following this phase, workshops were directed at defining and checking the modelling details. This proved important because of, amongst other things, the different terms used in the science and technology of the different sectors (eg, *trash* on a farm becomes *extraneous matter* at the mill).

Once whole-of-value chain results were being produced, interactions increasingly focussed on effectively communicating these results to the LRG's. Each presenter needed to understand what others were presenting and how it related to his/her material, terms and units used needed to be coordinated, and the implications of the results agreed upon.

These efforts were vital to ensure effective functioning of the project team, and to allow the project to progress at a pace that matched the expectations of the LRG.

5 Action learning - evolution of the venture

5.1 Introduction

The venture defined by both LRG's, whole crop harvesting to maximise fuel for electricity co-generation, is a complex undertaking entailing changes to and impacts on all sectors of the sugar value chain. This complexity meant that many concepts and details of the venture needed to be defined during the analysis. Initially, each LRG specified the details of the venture to be analysed, setting 'big picture' parameters for the analysis. Examples of these specifications included the new capital facilities that would be 'constructed' within the model, use of trash during the maintenance season (or not), etc. We use the term **scenario** to describe these specifications. Analyses were then undertaken of the scenario as specified by the LRG's, and results of the analyses presented back to the LRG's. Following these presentations, the LRG's refined the scenarios seeking improved profitability and further analyses were performed. This was an action learning processe, and resulted in the scenarios in each region evolving during the project, as illustrated in Table 3. The process also resulted in much of the increased understanding of the regional values chains achieved by the project participants.

In this section of the report, we summarise the potential impacts of whole crop harvesting on the sugar value chain. We then describe the evolution of the scenarios in each mill region and reasons for the changes. In general, the detailed discussion of results in subsequent sections will be confined to the analysis of the final scenario, except where the evolutionary process illustrates an advantage of the methodologies used in the project.

5.2 The 'challenge' of whole crop harvesting

Whole crop harvesting represents a substantial change to the traditional supply chain. Harvesters generally aim to minimise the amount of trash harvested with the cane. Harvesting the whole crop slows the harvesting process, increases the amount of material to be transported from the harvester to the mill, and reduces the efficiency of sugar extraction in the milling process (Shaw and Brotherton 1992). At the mill, whole crop harvesting would require new infrastructure for (1) separation of trash and cane at the mill prior to crushing the cane (Schembri *et al*. 2002) to minimise the impact on mill efficiency, and (2) maximising electricity production (increased generation capacity, upgrading mill components, etc.). At the farm level, retaining trash on the soil surface trash increases sugarcane yields in many environments (Thorburn *et al*. 2004), and so its removal may impact the amount of material (cane and trash) available for processing, and hence products (sugar and electricity) available for sale. Thus, the LRG's perceived that the challenge was to determine if the logistical problems of handling increased volumes of material in the harvesting and transport sectors and the negative impacts at the farm and mill factory were out weighed by the additional revenue from increased production of electricity for export and the Renewable Energy Certificates (RECs) associated with the generation of renewable power.

While both LRG's had identified whole crop harvesting as the priority for the project, there were considerable differences between the regions in each sector (summarised in Table 4) that affected the analyses. In the Burdekin region trash was burnt on the vast majority of farms, all of which were irrigated, and cane transported to the mill by a railway system. Further, there was (or would be) bagasse-fuelled co-generation plants with spare capacity at both Burdekin mills. In the Maryborough region, trash was retained on the soil in approximately 60% of farms, farms had varying access to irrigation water, cane transport was undertaken by road, and there was no existing co-generation capacity. Further, in Maryborough there was the possibility of additional fuel (wood chips for a local forestry operation) for a co-generation plant.

Table 4. Differences in characteristics of the two regions in which the case studies were based.

Region	Farm management	Transport	Mills
Maryborough	• Trash generally retained on the soil on farms • Limited or no irrigation	• Road	• Single mill • No electricity co-generation capacity • Possible access to additional fuel (wood chips)
Burdekin	• Trash generally burnt • Full irrigation	• Rail	• Multiple mills • Spare electricity co-generation capacity

5.3 Details of the venture in each region

5.3.1 Maryborough

In Maryborough, the initial specification of the venture was for additional fuel from whole crop harvest to be used to fuel a co-generation plant operating during the maintenance season. Analysis of this scenario showed that storage of trash and bagasse would be problematical and there would be incomplete utilisation of the co-generation plant (Figure 2a). Thus the scenario would be uneconomic. Wood chips are a potential source of fuel for an electricity co-generation plant in Maryborough, so the LRG suggested that the plant should be large enough to utilise all the trash and bagasse during the crushing season and then rely on wood chips during the maintenance season (Figure 2b). The result was that the overall utilisation of the co-generation plant was still too low (as described in detail below).

During the project, the Maryborough LRG was also investigating other markets for trash (e.g., garden mulch, stock feed, etc.). This investigation intensified as results of the project increasingly indicated that maximisation of co-generation was unlikely to be profitable. The analyses conducted in the project showed that trash blankets generally have a positive impact on production and profitability in the region. So, profits from any alternative use of trash needed to be judged against loss of regional profitability from removal of trash blankets. Within the LRG there had also been ongoing debate about the net benefits of trash blanketing: In effect LRG members were asking if the agronomic benefits of trash blanketing were worth the disbenefits of difficult (and more expensive) harvesting, less efficient transport and difficult milling associated with green cane harvesting? Thus the LRG proposed that the regional value of trash blanketing be defined.

5.3.2 Burdekin

As described above, the Burdekin LRG proposed that two mill regions should be analysed to maximise the relevance of the results to the region. The regions chosen were Invicta and Pioneer, because of there contrasting cane transport system characteristics.

5.3.2.1 Invicta mill region

At **Invicta**, the LRG proposed that the initial analyses should be conducted under the constraint of no new capital expended, other than a cane cleaning plant and expansion of existing bagasse storage facility. The analysis predicted that there would be two ‘bottle necks’ in transport of the whole crop from the field to the mill. The first, and most acute, was in-field hauling the cane (i.e. connecting the harvesters to the mill transport system) with whole crop harvesting. The additional volume (and lower bulk density) of the harvested material reduced the mass of material carried by each haul-out. As a result, harvesters were predicted to be spending a much greater proportion of their time idle, waiting for haul-outs, than happened when harvesting burnt cane. The second ‘bottle neck’ was predicted to be in the cane transport system. There are currents limits to the weight (and hence number of bins) that can be pulled by the locos in the Invicta cane transport system. The lower bulk density of the harvested material resulted in a substantial reduction in weight of cane pulled by each

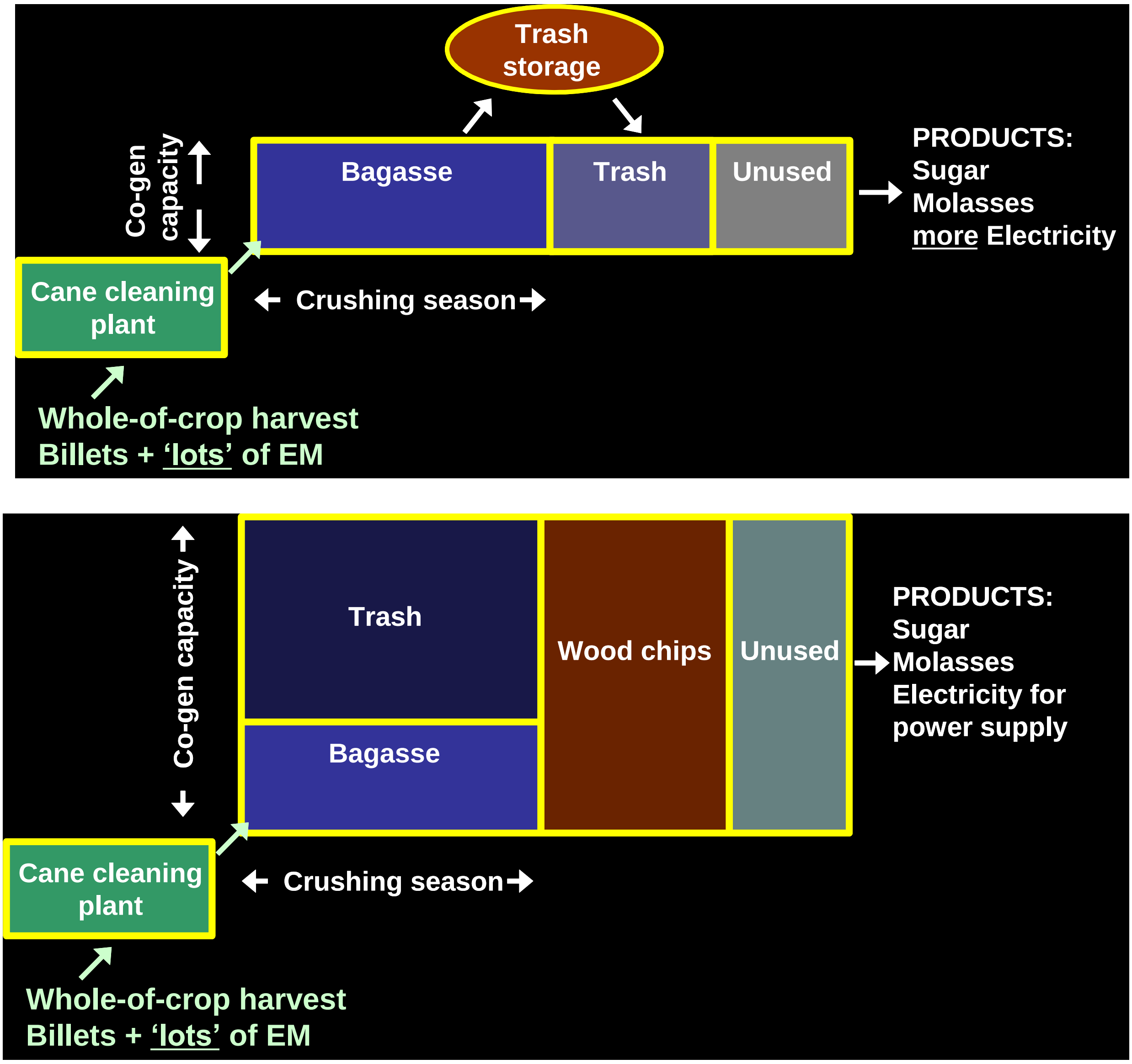


Figure 2. Schematic representation of the electricity co-generation scenarios at Maryborough assuming that additional material from whole crop harvesting was (a) used as fuel in the maintenance season, and (b) was used during the crushing season allowing the plant to be fuelled by wood chips in the maintenance season.

loco with the maximum number of bins currently allowed. In discussion of these results, possible ways to overcome these bottle necks were identified and tested in subsequent analyses. These were increasing the number of haul-outs with each harvester and increasing the number of bins pulled by the locos until the total weight pulled by the locos in this scenario was similar to that in the base case.

The Invicta mill region is 'long and thin', so distances between individual farms and the mill quite variable. Thus the LRG asked whether there might be greater net benefits in harvesting the whole crop in regions close to the mill, where transport distances, and hence costs, will be lowest. The analysis of whole crop harvesting in only part of the Invicta regions was undertaken assuming that all farms serviced by a particular branch line would harvest the whole crop. The analysis was initially conducted for the branch line closest to the mill, then additional branch lines successively further away from the mill were added.

5.3.2.2 Pioneer mill region

The initial scenario for **Pioneer Mill** was to have a stand-alone co-generation and cane cleaning plant fuelled by trash from whole crop harvesting. This scenario proved uneconomic because of the capital cost of establishing a co-generation plant for the amount of fuel generated by whole crop harvesting. Following this analysis it came to light that there would be spare capacity in the co-generation plant being constructed at Pioneer Mill, and the Burdekin LRG advised that the value in supplying that spare capacity from whole crop harvesting (Figure 3) be determined.

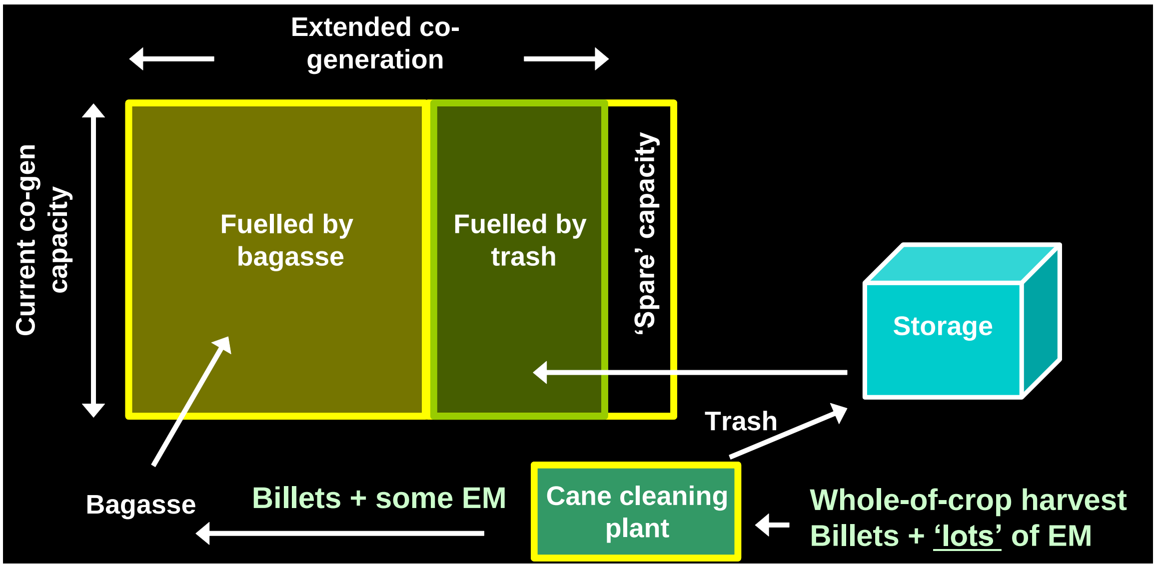


Figure 3. Schematic representation of the final electricity co-generation scenario at the two Burdekin mills, with additional material from whole crop harvesting was used as fuel to utilise the spare capacity in co-generation plants existing at the mills.

5.3.3 General issues

As well as the evolution of the scenarios, there were specific issues identified by the two LRG's for further analysis. An important issue was the amount of trash associated with the sugarcane plant. Knowing the amount of trash is important as it affects revenues (through the amount of bagasse for co-generation) and costs (through harvesting and transport inefficiencies). The latter effect arises because increased trash reduces the bulk density of the mixed cane supply (i.e. cane billets plus trash). Based on anecdotal information and/or limited measurements, the LRG's believed that trash would be as high as 30% of the total mixed cane supply with whole crop harvesting.

A method (described below) was developed for application of the value chain model to explicitly estimate the amount of trash in each block of cane in the region being studied. However, there is uncertainty in any estimation and other factors, such as varieties, may systematically effect relationships between sugarcane and trash yields. So the sensitivity of different relative amounts of trash in the mixed cane supply was explored with the Burdekin LRG for the Invicta region.

Another issue was identifying the cost of trash (derived from whole crop harvesting) as a fuel for co-generation. There maybe alternative fuels for co-generation, such as wood chips in Maryborough or coal in Mackay. There are also alternative ways of using trash as a fuel, such as bailing trash blankets after green cane harvesting, and transporting the bails to the co-generation plant. There was general interest in the cost comparison between these alternatives, as well as the regional differences in the cost of trash from whole crop harvesting. These costs were estimated and presented to the LRG's.

6 Value chain model development and application

6.1 Value chain modelling framework

Value chains can be modelled in different levels of complexity, ranging from simple ‘back of the envelope’ approaches to models that capture a great deal of the biophysical detail in the system. The first approach suffers because the analyses contain simplistic assumptions about the biophysical and logistical attributes of the system, and these assumptions are ‘propagated’ through the analysis. Thus the results are almost entirely a product of the base assumptions and they provide little real insight into the complexities of the system. However, this approach is attractive because of (1) the speed with which the analysis can be undertaken, and (2) the ease with which it can be translated into a financial or economic analysis. The second approach, while capturing the biophysical and logistical detail of the system and providing a comprehensive and general representation of the system, can result in a large complex model, which takes a long time to develop and is virtually incomprehensible to people outside the development group. We sought a compromise between these two commonly employed approaches; that is to develop a model that captured adequate biophysical and logistical detail for the region being modelled, whilst being comprehensive to the LRG’s and developed rapidly.

The value chain model was developed on agent-based modelling philosophies. That is, agents were formulated which represented each of the sectors in the value chain, and the various linkages between the sectors. In general the agents defined the physical outputs (i.e. the cane and extraneous matter generated) and costs in individual sectors of the value chain (growing, harvesting, transport and processing). The ‘agents’ were embedded in a modelling framework (Figure 4) that controls the interactions between sectors; that is physical outputs and costs flowing down the chain, subject to feedback (such as logistical constraints) flowing up the chain. Total revenue is calculated within the framework from the amount and price of the products (sugar, molasses and electricity) produced. Greater details of the modelling framework are given in Appendix 2.

6.2 Functional model development

The ‘agents’ embedded in the modelling framework were based on a functional model that represented the detailed biophysical, logistical and economic flows in each sector (sugarcane production, harvesting [and infield haulage], cane transport and the factory). Functional models were written in a spreadsheet format and were generally simplified versions of the detailed models shown in Table 5. Apart from road transport, these detailed models previously existed in the sugar industry. The extraction of the simplified functional models from the detailed models was achieved in one of two ways: (1) by fixing many of the variables and parameters in detailed models for the specific conditions in the case study regions; or (2) by writing a simplified spreadsheet model that closely approximates the functionalities of the detailed model necessary for the analysis. The development of the functional models in each sector is summarised below, with a more detailed description of each functional model given in Appendix 2.

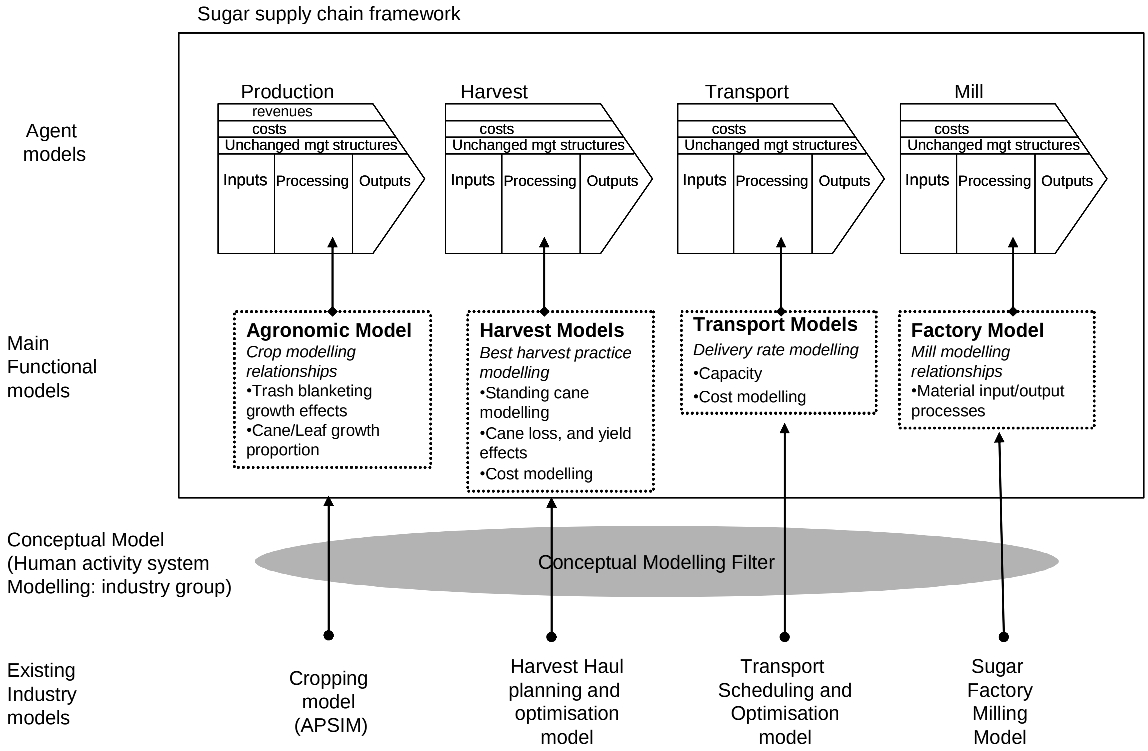


Figure 4. The sugar supply chain modelling framework illustrating the relationship between the detailed existing models, functional models and agent models.

Table 5. Models used to represent each sector in the modelling framework for the sugar supply chain.

Sector			
Farm	**Harvesting**	**Transport**	**Factory**
APSIM-Sugarcane: Keating *et al*. (1999), Thorburn *et al*. (2001, 2004, 2005)	*Harvest-Haul model*: Sandell and Prestwidge (2004)	*Road*: Higgins (2006) *Rail*: Pinkney and Everitt (1997), Higgins and Davies (2005)	Hobson and Wright (2002)

6.2.1 Sugarcane production

The relationship between sugarcane yield and the amount of trash retained on the soil was predicted by simulating long-term sugarcane yields with and without a trash blanket using APSIM-Sugarcane (Keating *et al*. 1999; Thorburn *et al*. 2001, 2004, 2005). It is not practical (or possible) to accurately characterise every block in a mill region. So, the range of soil types and irrigation managements were identified the Maryborough region based on expert opinion of the LRG. The result was generic classification of ‘good’, ‘average’ and ‘poor’ soils, with parameters representing likely water holding capacity, root depth and nitrogen fertility. Availability of water was seen as the main determinant of irrigation scheduling, with irrigation water being either ‘unlimited’, ‘limited’ or ‘dry land’ (i.e. unavailable). Rules for irrigation application were developed for these three circumstances.

Long-term simulations of sugarcane yield were undertaken for each of the nine possible soil-irrigation conditions and a range of trash removals at harvest. Trash removal ranged from no removal (i.e. representing trash blanketing) to 95% removal, representing whole crop harvesting or pre- and post-harvest burning. The long-term simulations were undertaken so that the trash management practice had been conducted for long enough that the soil crop system was in equilibrium.

The result was simulation of average yield decrease (%) when trash was removed for each of the nine possible soil-irrigation conditions (Figure 5). Each block was classified into one of these nine soil-irrigation conditions by members of the LRG. If the block has a history of trash blanketing, the yield was reduced according to soil-irrigation conditions. Trash blankets also reduce weed control costs, and the cost of weed control ($/ha) in the absence of trash blankets was estimated by the LRG and included in the analysis.

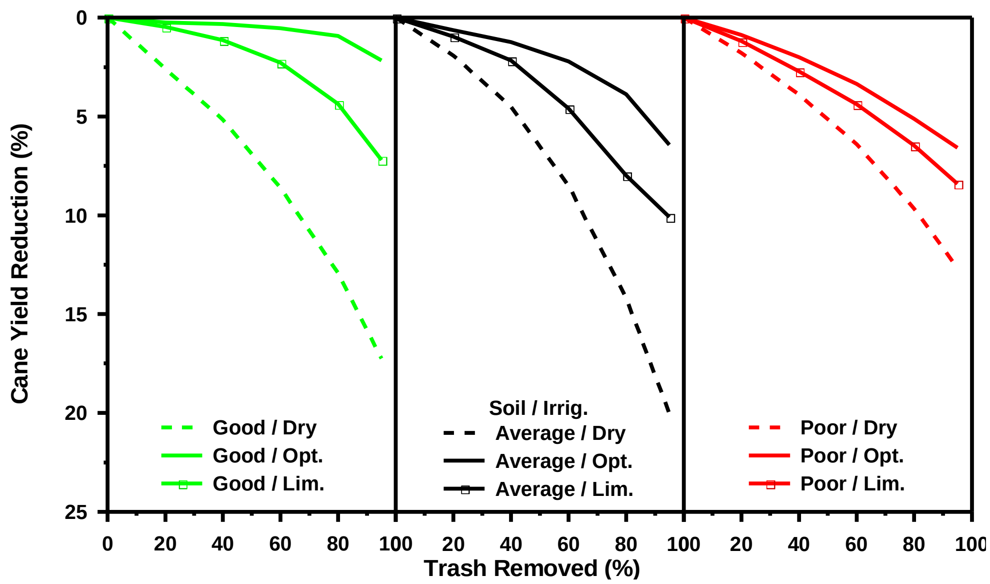


Figure 5. Simulated average reduction in sugarcane yield due to trash removal across three soils (good, average and poor) and three irrigation regimes (optimum, limited and dry land) at Maryborough.

6.2.2 Harvest and in-field hauling

Estimates of the scheduling and costs of harvesting and hauling the sugarcane to transportation pads or sidings under the different scenarios were made using an adapted version of Sandell and Prestwidge's (2004) Harvest-Haul model. The model requires inputs for (1) the block being harvested (crop yield, block area, row length, distance to siding, allocation to siding, allocation to harvester group), and (2) the harvesting equipment (capital equipment type, size, specifications and value) in the region.

A range of methods were used to gather these data and model parameters, as previously described by Sandell and Prestwidge (2004) and Prestwidge et al. (2006). GIS techniques were used to estimate block row length (as the longest side of the block) and haul distance (the straight line distance from the block centroid to siding centroid, multiplied by √2 to account for travelling around block boundaries). Block productivity and area data, block to siding allocations and block to harvester group allocations were obtained from mill productivity records. For the harvesting equipment, a survey was conducted in Maryborough to determine capital equipment type, size and specifications. This information was already available in Pioneer and Invicta regions. The equipment was valued using a capital value schedule developed for the project.

A range of assumptions were made for the harvest haul modelling. Some, such as the time taken to turn at the end of a row of cane and fuel burn rates, were gathered from previous unpublished trial data. Others, such as region-specific information on wage rates and repair and maintenance costs, supplied the LRG and TWG in each region.

The model also used inputs from the modelling framework, including the amount of cane and trash that were in the field prior to harvest, harvest losses, trash and dirt in the mixed cane supply. The model interacted with the Transport model by suppling harvester delivery rates and accepting time harvesters spent waiting for bin deliveries to the pad or siding.

The Harvest Haul model includes a routine to ensure that the optimum number and capacity of haul-outs are used when harvesting each block from the total number available to the harvester. For whole crop harvesting scenarios in the Invicta Mill region it became apparent that additional haul-out capacity would enhance the efficiency of in-field transportation of the additional biomass. For this purpose this routine was enhanced to calculate the optimum number of haul-outs required for each group (not constrained by the actual equipment available), balancing additional capital costs against improved operational efficiency.

The Burdekin LRG suggested to consider the viability of whole crop harvesting only in those areas closer to the mill were transport costs were lower. The model was adapted to do this by linking blocks to branch lines so that different areas could be considered separately.

6.2.3 Cane transport

The road transport functional model was adapted from Higgins (2006). The model estimated infrastructure requirements and transport costs given the input of cane tonnages (from the modelling framework). For rail transport, a functional model was developed as a set of linear equations from the transport scheduling model of Pinkney and Everitt (1997). For the two mills with rail transport, the LRG supplied data on transport distances to mill from pads, as well as capital costs and vehicle capacities. Another input, harvest group pour rates were averaged over the entire season. The average daily delivery rate to the mill was estimated as the total mixed cane supplied to the mill by the season length in days.

6.2.4 Sugar factory

The Mill model, derived from the sugar mill production model (Hobson and Wright 2002), estimated raw sugar, molasses and electricity end-products from cane supply components (cane stalk, trash and dirt). CCS is predicted to vary according to the proportions of cane and trash supplied to the factory. The model is configured to include the main infrastructure of the factory, including, where appropriate, trash separation, bagasse storage, bagasse handling and electricity generation. Trash separation was evaluated assuming separation efficiencies associated with the implementation of factory based separation technology developed by Schembri *et al*. (2002). The mill component model also calculates sugar production, bagasse handling, bagasse storage and power generation costs and corresponding revenues.

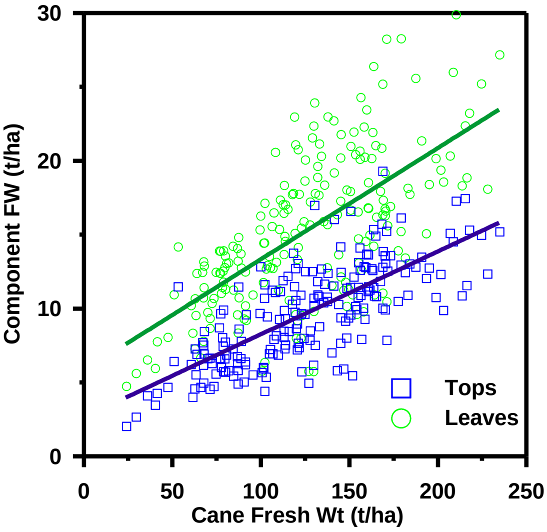
6.3 Application of the value chain modelling framework

6.3.1 Block data

All analyses were based on the 2003 crop, harvester groupings, and infrastructure for the three mills. The 2003 block productivity data recorded what was *produced* by the harvester (the sum of billets, extraneous matter and dirt), not what was *presented* to the harvester (i.e., standing in the field prior to harvesting). In order to assess the impacts of whole crop harvesting, the amount of cane and trash in the field needed to be predicted. This was done by estimating: (1) cane in the field *prior to harvest*, from cane losses and trash amounts that would have occurred during harvest of the

2003 crop; and (2) amounts of trash that would have been present *prior to harvest* for the given amount of cane. Cane losses and trash amounts were predicted using Sandell and Prestwidge's (2004) Harvest-Haul model, based on details of the harvesting groups and the specific conditions of the block (i.e. whether it was burnt or green). Amounts of trash present *prior to harvest* for the given amount of cane were predicted from relationships between cane yield the mass of trash (Figure 6) developed from results of detailed physiological experiments stored in the SUGARBAG data base (Laredo and Prestwidge 2003).

Figure 6. The weight of tops (non-millable stalk and green leaf sheaths) and leaves (both live and dead) as a function of sugarcane yield from previous physiological experiments.



6.3.2 Scenarios and economic analyses

Initially, the situation (i.e. trash management, harvester settings, transport scheduling, etc) that existed in the three regions in 2003 was first modelled to provide a 'base case' against which to define the whole crop harvesting impacts. Then whole crop harvesting was modelled, assuming that:

- Sugarcane yields in trash blanketed blocks were reduced as predicted with the crop modelling,
- The yield of trash was related to sugarcane yield by the relationships shown in Figure 6,
- Harvester settings were optimised to recover the whole crop,
- Harvest rosters and transport schedules were optimised to minimise the costs associated with harvesting the whole crop,
- Trash was separated at the factory and, where necessary, stored for later use, and
- Additional capital costs were minimised where practical by matching the capacity of new/updated plant and equipment to the volume of biomass to be processed.

The economic analysis followed standard project-evaluation methodology (Gittinger 1982). Incremental values of the assessed technology options were calculated as the difference between the gross margins of each technology option and the without-project base case. The status-quo value chain gave the technological and institutional structure of the base case, while medium-term expectations about input/output prices were used to generate the corresponding expected steady-state financial performance. Note that gross margins included all variable costs from a decision-making, rather than accounting, point of view, so all operating as well as capital expenses associated with assessed investment options were part of the analysis. Hence, the incremental gross margins shown in the analysis indicate the expected change in pre-tax profit attributable to the options. It was assumed that input and output prices will inflate at the same rate in the future, thus a formal inclusion of future inflation effects was not necessary in the analysis using 2004 dollar values.

Prices for electricity, RECs and sugar constitute three crucial and uncertain parameters in the calculation of expected financial returns. Establishment of the national electricity market has led to the convergence of wholesale electricity prices in the interconnected eastern states of Australia (Table 6).

Table 6. Average annual wholesale electricity price ($/MWh) (Source: NEMMCO undated).

Year	NSW	Qld	SA	Snowy	Tas	Vic
1998-1999	33.13	51.65	156.02	32.34		36.33
1999-2000	28.27	44.11	59.27	27.96		26.35
2000-2001	37.69	41.33	56.39	37.06		44.57
2001-2002	34.76	35.34	31.61	31.59		30.97
2002-2003	32.91	37.79	30.11	29.83		27.56
2003-2004	32.37	28.18	34.86	30.8		25.38
2004-2005	39.33	28.96	36.07	34.05	190.38	27.62
2005-2006	44.03	31.28	39.43	34.21	69.21	31.51

Increasing competition means that the long-term wholesale electricity price is likely to be determined by the cheapest and most abundant source, currently that of coal-fired generation. Coombes and Corderoy (2000) estimate the cost of coal-fired electricity to fall between $24 and $36/MWh. In this study a price of $32/MWh was used for the expected medium-term wholesale electricity price in Queensland.

The legislative framework (CoA 2000a, b) introduced a measure of long-term certainty about the renewable energy market in Australia. The legislation prescribed a gradual increase of required renewable electricity production to 2010 and its maintenance to 2020. Tradeable RECs were created as the administrative vehicle of the policy. A penalty of $40/RECs was mandated for non-compliance. As this penalty is not tax deductible, the regulation has effectively put a price ceiling of $57 on RECs (Figure 7).

For Maryborough an expected medium-term RECs price of $30 was used, while the Burdekin calculation reflected CSR’s expectation of a $38 RECs price. Based on market expectations in 2004/05, medium-term sugar price was put at $250. Sensitivity analysis tested the robustness of financial results in the face of significantly different values for all three price parameters.

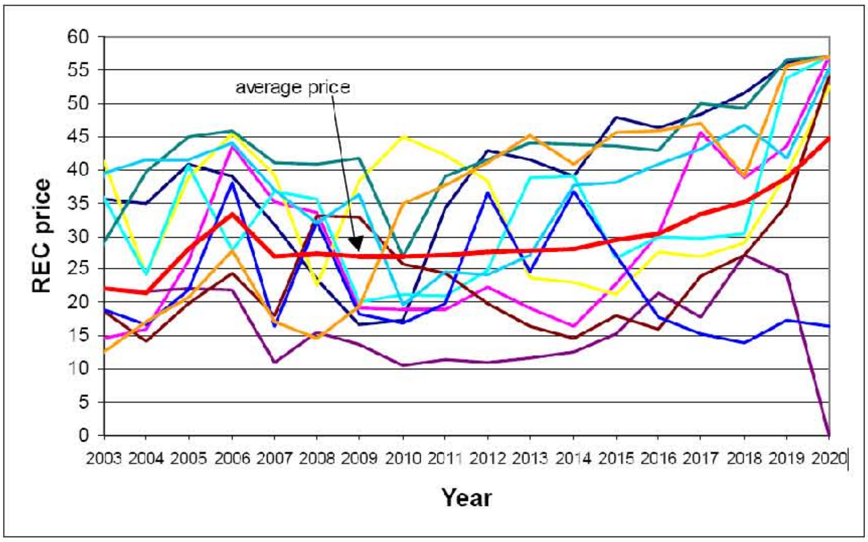


Figure 7. REC price predictions (Source: IES 2002).

7 Results of value chain analyses

7.1 Maryborough

7.1.1 Maximising co-generation

For the scenario depicted in Figure 2b, the total amount of trash free cane stalk (i.e. cane billets) produced was predicted to decrease by 3.7% with whole crop harvesting (Table 7) because of the impact of removing trash blankets on yield. However, the amount of mixed cane (i.e. cane billets and trash) produced after harvesting was predicted to increase by 11.5% because of the greater amount of trash. This was due to the lower harvester losses that were predicted with whole crop harvesting compared with how the region was managed in 2003. The harvesting fleet would have been able to manage this additional material by harvesting for approximately 2 hours more each day. The cane transport system in this region would have also been able to manage the additional mixed cane supply. The region would have needed up to an additional 15 trucks and 85 trailers, although this number would be reduced if an extended time window of harvest was adopted. These additions could also be reduced by adopting improved transport scheduling. The amounts of sugar and molasses produced were predicted to have decreased because of the reduction in sugarcane grown. As expected, electricity production increased dramatically.

Table 7. Summary of the predicted products from the different sectors for the base case (as the regions was managed) and for whole crop harvesting for the Maryborough region in 2003.

Sector	Product	Base case	Whole crop harvest	Change from base case
Farm	Cane stalk (t)	786 854	757 913	- 3.7%
Harvester	Mixed cane (t)	876 230	976 616	11.5%
Transport	(t/day)	7 225	8 053	11.5%
Mill	Sugar (t)	122 177	117 768	- 3.6%
‘’	Molasses (t)	28 928	27 204	- 6.0%
‘’	Electricity (MWh)	3 055	151 447	4857%

The additional revenue predicted from electricity was less than the sum of the increased costs incurred with whole crop harvesting and the decrease in revenue from lower sugar and molasses production (Table 8). The largest costs were in the milling sector, and these were a result of (1) the interest on capital that would have been spent building the co-generation plant and trash separator, and upgrading the factory, and (2) the high capital cost and low maintenance season utilisation of the power plant if all trash was burnt in the crush. As outlined above, the alternative of trash storage was dismissed at an early stage for this region because there was no suitable site for bagasse storage close to the mill. In terms of utilisation, any new co-generation capacity added to produce power from trash harvested during the crushing season resulted in additional capacity that could not be utilised in the maintenance season due to constraints on the availability of alternative supplementary fuel (woodchip). The additional costs in the farming sector were associated with the increased cost of weed control in the absence of trash blankets.

Table 8. Gross marginal changes predicted for revenues and costs in the Maryborough if whole crop harvesting was undertaken to maximise revenue from co-generation in 2003.

Product/sector	Additional revenue (M$)	Additional cost (M$)	Overall change (M$)
Sugar	-1.10		
Molasses	-0.07		
Electricity	9.73		
Farm		0.95	
Harvester		1.10	
Transport		0.76	
Mill		11.11	
			-5.33

7.1.2 Regional value of trash blankets

As described when outlining the evolution of the scenarios above, maximising co-generation through whole crop harvesting is only one possible use for trash in Maryborough. Given that trash generally has a positive impact on crop production in the Maryborough area, there might be negative consequences for the sugar value chain if trash blanketing was reduced as a result of supplying trash to alternative markets (such as sale for stockfeed). Thus, the project team were asked to identify the consequences on the whole sugar value chain of removing trash for other purposes. Also, the Maryborough LRG was interested to find out if the agronomic benefits of trash blanketing were worth the disbenefits of difficult (and more expensive) harvesting, less efficient transport and difficult milling associated with green cane harvesting.

Three scenarios were identified that would address these questions:

1. Full trash blanketing in the whole Maryborough region (with harvest best practice – HBP).
2. Partial trash blanketing in the whole Maryborough region (with harvest best practice – HBP). Partial trash blanketing was approximately equivalent to removal of tops (non-millable stalk and green leaf sheaths).
3. No trash blanket in the whole Maryborough region – i.e. similar to trash being burnt or completely removed.

The second scenario was included as there may be markets for tops, but not leaves.

As done in previous analyses, the results were compared with the base case, i.e. the region as is was in 2003, with the trash management and harvesting as practiced in each block for that crop.

Full trash blanketing (with HBP) was predicted to result in a net benefit for 2003 of $1.2M compared to the region's trash and harvesting management used at that time (Table 9). Partial removal of trash resulted in similar net benefits to those in the region in 2003, showing that a 'thin' trash blanket across the whole regions gave similar outcomes as a full trash blanket over ~ 60% of the region. Complete removal of trash was predicted to result in reduced (-$1.3M) net benefits for 2003.

In the previous analyses, net benefits have been defined relative to the situation as it was in Maryborough in 2003, and so include effects of both the different trash management practices as well as the assumption of HBP. The regional net benefits of only changing trash management, from burning trash on all blocks to full trash blanketing, is given by comparing the full trash blanketing and complete trash removal scenario results in Table 9. The result is a predicted regional net benefit of $2.5M from trash blanketing. This is the first time a mechanistic, whole of value chain analysis has been undertaken of the net benefits of green cane harvesting-trash blanketing.

Table 9. Summary of changed revenue and costs arising from different degrees of trash removal at Maryborough compared to the base case (the region as it was in 2003). The regional net value of trash blanketing, defined as the difference between the complete trash removal and full trash blanketing scenarios) is shown as well.

Scenario	**Additional revenue (M$)**	**Additional cost (M$)**	**Net benefit (M$)**
Full trash blanketing	0.7	-0.5	1.2
Partial trash removal	0.3	0.0	0.3
Complete trash removal	-1.1	0.2	-1.3
Regional net value of trash blanketing	1.8	-0.7	2.5

7.2 Burdekin

Results for scenarios depicted in Figure 3 are given here for both the Invicta and Pioneer mill regions. As well, results of sensitivity analyses and optimisations undertaken to identify ways to minimise additional costs associated with whole crop harvesting are described.

7.2.1 Invicta

7.2.1.1 Whole crop harvesting in whole region

The amount of cane stalk harvested increased by 1.4% as a result of lower cane losses during harvesting the whole crop (Table 10). This resulted in increased revenues predicted from sugar and molasses due primarily to reduced cane loss even after factory separation (Table 11). In this region, there was little trash blanketing and full irrigation so the agronomic impact of whole crop harvesting would have been negligible compared with the base case, unlike in the Maryborough region. As expected, harvesting the whole crop increased the predicted amount of material being harvested and transported by 17.0% (Table 10). Efficient infield hauling and transport of this increased mixed cane supply would have necessitated some changes to these sectors compared to their operation in 2003. For harvesting, the modelling predicted that there would have been a substantial ‘bottleneck’ in infield haulage, connecting the harvesters with the transport system. This was overcome in the modelling through optimising the number of haul-outs per harvesting group. Typically, five haul-outs per harvester was an optimal number. To increase the efficiency of the transport sector, the number of bins pulled by each loco was increased in the modelling (as the bulk density of the cane decreased at higher proportions of trash) so that the total weight of mixed cane being pulled was equal to the weight pulled in 2003. (NB, a check was made to ensure that the length of the locos and bins did not block passing loops.) The impact of these scenarios was that additional costs were predicted to be relatively small in the harvesting sector, but still substantial in the transport sector (Table 11). The percentage increase in electricity over base case was smaller (52%, Table 10) relative to that for Maryborough (4857%, Table 7) as the Invicta mill was already producing substantial electricity from bagasse in 2003. Mill costs (Table 11) were associated with the interest on capital expenditure for the trash separator and increased operating and maintenance costs resulting from the greater utilisation of the co-generation plant. These costs were lower than for the Maryborough region because there was an existing bagasse storage facility and co-generation plant at this mill. The simulations indicated there was sufficient ‘spare’ co-generation capacity in the maintenance season to utilise all available trash produced through whole crop harvesting. The overall financial result was that revenues exceeded costs, but only by a relatively small amount (Table 11).

Table 10. Summary of the predicted products from the different sectors for the base case (as the regions was managed) and for whole crop harvesting for the Invicta region in 2003.

Sector	**Product**	**Base case**	**Whole crop harvest**	**Change from base case (%)**
Farm	Cane stalk (t)	3 447 605	3 496 108	1.4
Harvester	Mixed cane (t)	3 667 665	4 289 820	17.0
Transport	(t/day)	24 809	29 018	14.5
Mill	Sugar (t)	566 107	571 843	1.0
‘’	Molasses (t)	121 078	124 244	2.5
‘’	Electricity (MWh)	102 347	214 891	52.4

Table 11. Gross marginal changes predicted for revenues and costs in the Invicta region if whole crop harvesting was undertaken to maximise revenue from co-generation in 2003.

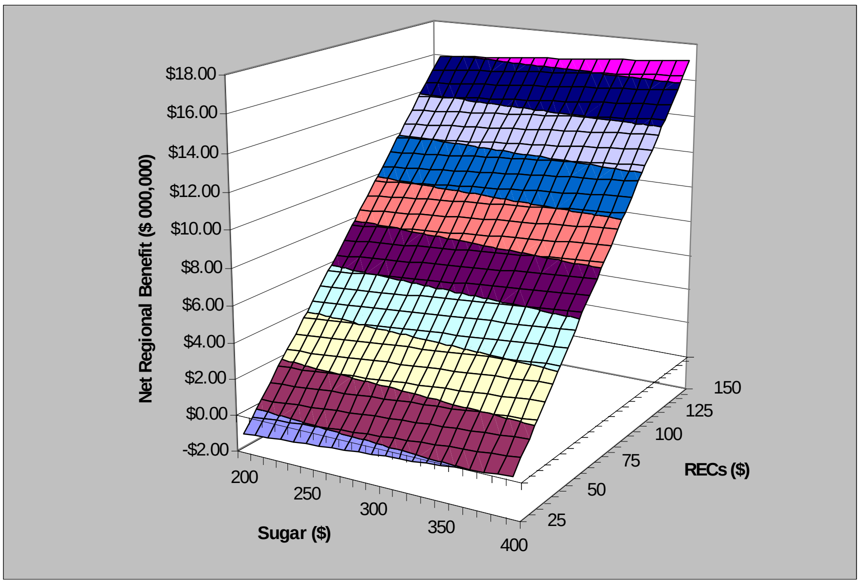
Product/sector	**Additional revenue (M$)**	**Additional cost (M$)**	**Overall change (M$)**
Sugar	1.43		
Molasses	0.16		
Electricity	8.73		
Farm		0	
Harvester		0.36	
Transport		3.47	
Mill		5.43	
			1.06

7.2.1.2 Sensitivity of the outcomes to product prices

While the regional net benefit of whole crop harvesting was small under the assumed product (sugar and renewable energy) prices, the LGR was interested in how the regional net benefit would increase with increases in product prices. Thus an analysis was undertaken to define the sensitivity of the benefit to product prices, and determine if the were non-linear interactions between the two main products.

Regional net benefit increased at a rate approximately $0.13M per $1 increase in the value of RECs (Figure 8). The sensitivity to sugar price was negligible.

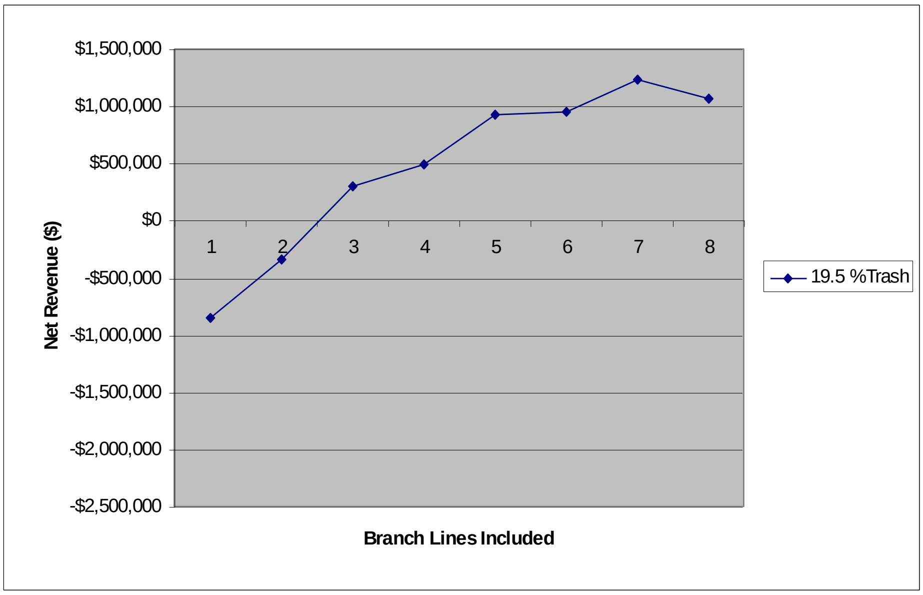
Figure 8. Sensitivity of regional net benefit for the Invicta mill area to changes in the value of sugar and renewable energy certificates.



7.2.1.3 Whole crop harvesting in areas close to the mill

Results of the analysis of whole crop harvesting in only part of the Invicta region indicated that there was no regional net benefit of this strategy. While transport costs were lower for branch lines closest to the mill, the additional revenues were not great enough to compensate for the costs associated with the installation of a cane separation plant and expansion of current bagasse storage facilities. As increasing proportions of the region (i.e. more branch lines) undertook whole crop harvesting, starting from those closest to the mill and adding those increasingly further away, net revenues became positive then tended to stabilise once the closest five (of eight) branch line regions were harvesting the whole crop (Figure 9).

Figure 9. Net benefit as greater amounts of material are collected by harvesting the whole crop in farms serviced the different branch lines in the Invicta region. The branch lines are numbers from 1, being closest to the mill, to 8, most distant from the mill.

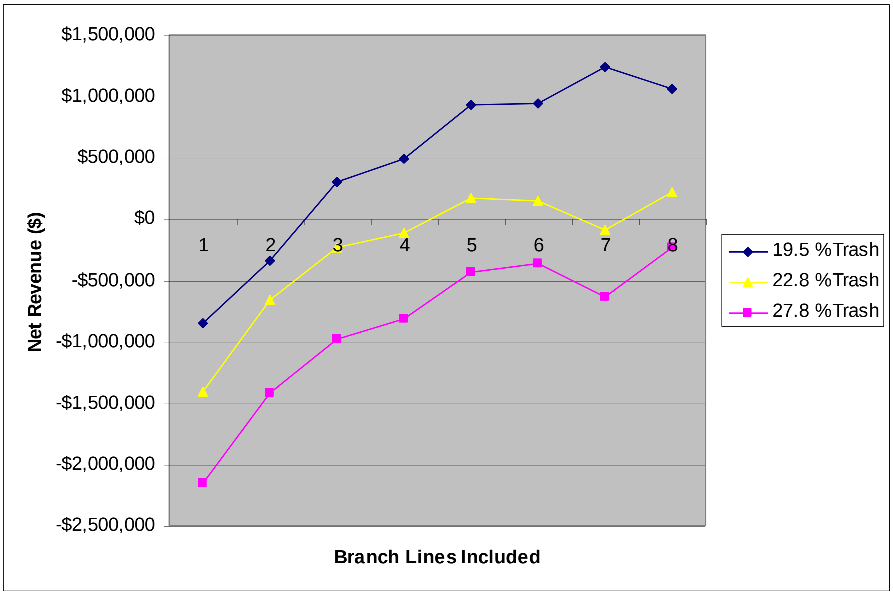


7.2.1.4 Sensitivity to different amounts of extraneous matter

As described above, a comprehensive review of the amount of trash found in previous sugarcane physiological studies (including experiments undertaken in the Burdekin region) was used to calculate trash for each block based on the block's sugarcane yield. In the modelling undertaken in the project, the average proportion of trash across the whole Invicta region was predicted to be 19.5% (and a similar proportion in the other regions as well). However, it is quite possible that trash will vary with other factors, varieties, water stress, etc., so there is value in determining the sensitivity of the regional net benefits to different amounts of trash.

Initially analyses were undertaken with increasing amounts of trash, with the harvesting and transport optimised for 19.5% trash. As trash increased from 19.5 to 27.8%, net benefits decreased (Figure 10) because costs increased more than revenues. The increase in costs at higher levels of trash occurred primarily due to inefficiencies in infield haulage in the harvesting sector. This negative overall result was not reversed by confining whole crop harvesting to areas close to the mill.

Figure 10. Net benefit as greater amounts of material are collected by harvesting the whole crop in farms serviced the different branch lines in the Invicta region with three different amounts of extraneous matter, assuming hauling and transport is optimised for the lowest trash. (The branch line numbering is described in Figure 9.)



However, the result mainly illustrates the inefficiencies that occur when harvesting and transporting material of different characteristics to that for which these sectors were optimised. Thus, analyses were undertaken assuming the hauling and transport were optimised for each different amount of trash. Provided the whole mill area was harvested, net benefits were similar for each level of trash (Figure 11). Interestingly, reducing the proportion of the mill region practicing whole crop harvesting reduced net benefits more at higher levels of trash.

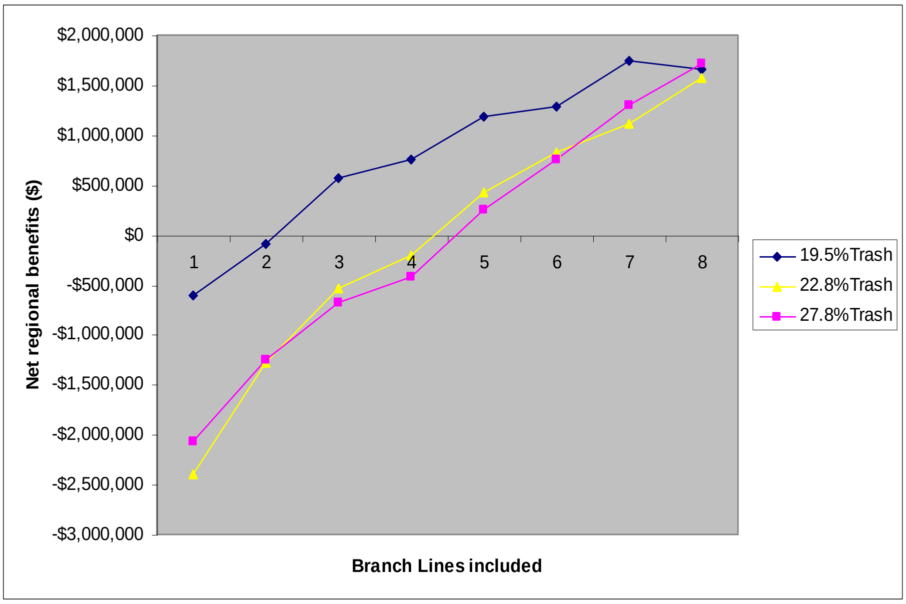


Figure 11. Net benefit as greater amounts of material are collected by harvesting the whole crop in farms serviced the different branch lines in the Invicta region with three different amounts of extraneous matter, assuming hauling and transport is optimised for each amount of trash. (The branch line numbering is described in Figure 9).

7.2.2 Pioneer

7.2.2.1 Net benefit of whole crop harvesting

The overall financial result for the Pioneer region (Table 12) was generally similar to that of Invicta. The scenario for Pioneer was similar to that for Invicta, with the exception that bagasse was supplied to a smaller stand-alone, high pressure and temperature boiler feeding a condensing steam turbine unit at Pioneer. The capacity of this unit had been designed based on the availability of surplus bagasse from the adjoining mill. In this scenario the amount of trash available from whole crop harvesting was marginally in excess of the maintenance season fuel requirements of this plant. Increases in costs in the harvesting and transport sectors were relatively higher (data not shown) than in Invicta. The result was the costs were predicted to slightly exceed revenues in this region (Table 12).

Table 12. Summary of changed revenue and costs arising from maximising co-generation through whole crop harvesting at the Pioneer Mill for utilisation of spare capacity in the 1st co-generation plant. Optimising the number of infield haul outs and increasing the rake size pulled by locomotives is also shown, as are results the scenario as initially defined (a stand-alone 2nd co-generation plant).

Scenario	Additional revenue (M$)	Additional cost (M$)	Net benefit (M$)
Utilise 1st plant spare capacity	5.8	-6.3	-0.5
1st plant and optimal number of haul outs	5.8	-6.2	-0.4
1st plant and increase rake size	5.8	-6.1	-0.3
Initial scenario – stand-alone 2nd plant	5.9	-11.7	-5.8

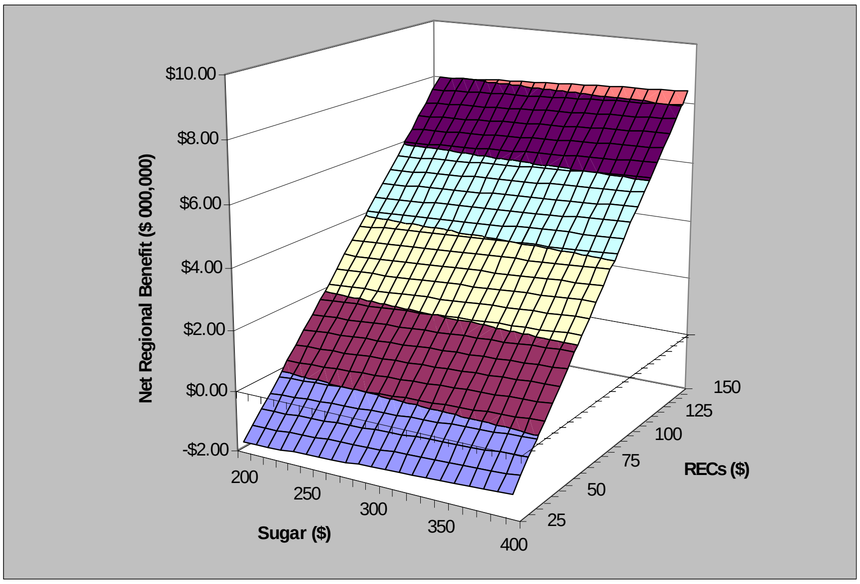
As with the Invicta region, analyses were undertaken to reduce predicted bottle necks in in-field haulage and transport of cane to the mill. Enhancing the in-field hauling and transport operations resulted in relatively small increases in net revenue with the net benefits of doing both still being negative (Table 12). The result shows that the 'bottle necks' predicted for this region under whole crop harvesting were not as significant as for the Invicta region.

It is interesting to compare the results of these scenarios with those for the scenario initially suggested for this mill by the LRG; i.e. a separate, stand-alone 2nd plant, fuelled by the trash from harvesting the whole sugarcane crop. The estimated net benefit of the initial scenario was much worse (-$5.8M, Table 12) than the later scenarios, mainly due to the cost of capital for building the 2nd co-generation facility at this mill.

7.2.2.2 Sensitivity of the outcomes to product prices

As done in for the Invicta mill region, the sensitivity of the benefit to product prices was determined for the Pioneer region to determine at what product prices the net benefit would become positive. Regional net benefit increased at a lower rate, approximately $0.08M per $1 increase in the value of RECs (Figure 12), than in the Invicta region. This lower sensitivity to RECs prices in this mill region occurred because of the small scale of the trash recovery and power generation operation at Pioneer relative to Invicta. For the net benefit of whole crop harvesting to be positive, RECs prices would have to be $45 (i.e. $7 higher than the prices used in these analyses). As with Invicta, the sensitivity to sugar price was negligible.

Figure 12. Sensitivity of regional net benefit for the Pioneer mill area to changes in the value of sugar and renewable energy certificates.



7.2.3 Cost of trash as a fuel for co-generation

Trash is not the only fuel that can be used for co-generation, as shown in the final Maryborough scenario, and whole crop harvesting is not the only method of transporting trash to a co-generation plant. The Burdekin LRG was interested in whether the cost of supplying trash for co-generation could be reduced through green cane harvesting, then post-harvest raking, bailing and transporting trash to the co-generation plant.

Answering this question first required the determination of the cost of trash supplied through whole cost harvesting for the Invicta and Pioneer mill regions. Marginal cost data for each sector were determined, and expressed per tonne of trash calculated in the scenario at a constant moisture content (50 %). The costs were higher for the Pioneer region (Table 13) because of a greater **marginal** cost in the harvesting sector. That is, the harvesting sector in this mill region was operating more efficiently in the base case, and so had little capacity to transport the additional material from whole crop harvesting with the existing harvest-haul equipment.

Table 13. Predicted costs (expressed in $/tonne of 50% moisture trash) associated with trash recovery via whole of cane harvesting in the Burdekin region. Total cost expressed per tonne of dry fibre is also shown.

Item	Operation	Regional costs ($/tonne)	
		Invicta	Pioneer
Additional costs	Farming	0.00	0.00
	Harvesting	0.83	6.08
	Transport	6.66	5.49
	Separation and conveying to stockpile	5.86	6.60
Total cost		**13.35**	**18.17**
Total cost (dry fibre)		**27**	**36**

Data for the cost of baling and transporting trash from the field came from a study by Ridge and Hobson (2000) of a ‘large scale’ (10,000 bales/year, 700 kg/bale) raking, baling and transport operation at Rocky Point (Table 14). Ridge and Hobson (2000) assumed a ground trash density of 22.5 tonnes/ha, an initial post-harvest trash moisture content of 60% and a subsequent moisture prior to baling of 10%, and used 1998 cost data. Costs were inflated to 2004 dollars by the appropriate Consumer Price Index. The cost of transporting to a co-generation plant (Table 13) are substantially lower than those for post-harvest raking and bailing, which essentially requires double handling of the material.

Table 14. Cost, expressed in $/tonne of 10% moisture trash, of post harvest trash operation (Ridge and Hobson 2000). Total cost expressed per tonne of dry fibre is also shown.

Operation	Cost component	Cost ($/tonne)
Baling	Maintenance	7.94
	Wages	1.73
	Fuel	0.86
	Twine	3.46
	Capital	9.31
Raking and loading	Maintenance	0.52
	Wages	4.06
	Fuel	0.98
	Capital	5.27
Cartage		6.90
Total cost		**41.03**
Total cost (dry fibre)		**46**

However, given that bailed trash has a lower moisture content than trash from whole crop harvesting, a more meaningful comparison would be achieved if total costs were expressed in terms of dry fibre. Even with this adjustment, the total cost of trash recovery by whole of cane harvesting and factory separation (Table 13) is still considerably higher than the costs for post-harvest raking and baling as analysed for Rocky Point (Table 14).

The above analysis does not include the impacts of (1) the lower cane with between whole crop harvesting than green cane harvesting, or (2) the increased boiler efficiency using drier fuel with bailed trash. The additional revenues from additional sugar and molasses revenue with whole crop harvesting are estimated to be $7 per tonne of dry. However, these are similar to the additional co-generation revenue of $8 per tonne of dry fibre from increased boiler efficiency from drier fuel.

8 Project Evaluation

8.1 Introduction and approaches

In general the evaluation of this project aims to determine whether the project has met its objectives. The objectives state and/or imply certain outputs and outcomes. The outcomes can have social dimensions, i.e. impact the project had on industry collaborators' knowledge and attitudes (to both the project and to their value chain), and economic dimensions.

The elements of the objectives that have been evaluated are listed in Table 15, together with the approach taken to evaluate them. The first element in Table 15 centres on the outcome greater understanding of the value chain obtain by the two LRG's during the project. The second and third elements focus on the development and application of a modelling framework. While there are clearly outputs associated these elements, which are well documented in this report, the impact of the elements will be delivered through (1) changes in attitudes to the elements and (2) actions that result from them. Changes in actions are captured in Elements 4 (through identification of benefits and attractiveness of the ventures) and 5 (planned changes to the value chain that arise from the project and future applications of the modelling framework).

Table 15. Plan for evaluating the achievement of the overall objectives and outcomes of the project, and the questions used in the surveys of the groups addressing these elements.

Element of the project to be evaluated	Output or outcome	Evaluation approach	Question/s (Table 16)
1. Industry groups and researchers to collaboratively gain a systems view of the value chain and identify possible diversification ventures	Outcome	Survey of participants perception of changes in their understanding of the value chain in their region and possible means to diversify it	6, 2
2. A value chain modelling framework developed to explore the value chain consequences of adopting these ventures in a mill region	Output	Documentation of (1) modelling framework.	
	Outcome	Survey of participants perception of the usefulness of the modelling framework	1, 3
3. Application of this methodology piloted with industry partners in the Burdekin and Maryborough regions	Output	Documentation of modelling applications.	
	Outcome	Survey of participants perception assessment of the usefulness of the modelling analyses	1, 2
4. Industry partners identify benefits of the ventures and determine the attractiveness of the venture to the region.	Outcome	Survey of participants perception of success of the project	5
	Outcome	Economic evaluation of the project	
5. Plans developed for improving regional values chains and further application of the value chain modelling developments.	Outcome	Documentation of plans to change the value chain Documentation of plans for further applications of the framework	

Outputs from the project are listed in *Section 9.1*, and will not be considered further here. The impacts the project had on industry collaborators' knowledge and attitudes (to both the project and to their value chain) were assessed from a survey of the perceptions of LRG members conducted at the conclusion of the project. This survey and its results are described in the following section. An economic evaluation of the project was undertaken and is described in Section 8.3. Finally, plans for improving the value chain in the region or post-project application of the value chain framework are considered in *Section 9.2.*

8.2 Survey of perceptions

8.2.1 Details

As part of the project's evaluation, members of the two LRG's were surveyed at the conclusion of the final workshop (Table 3) in the project to determine the impact the project had on their knowledge and attitudes to both the project and to their value chain. The surveys consisted of six questions (Table 16) that were linked to the elements identified in the evaluation framework (Table 15). Participants were asked to respond to the question on a scale of 1 (not at all) to 5 (completely/very), and encouraged write comments to each question. There were 10 and 11 LRG members present at the final workshop (Table 3) in the Maryborough and Burdekin regions, respectively, and all completed in the survey. The surveys were completed anonymously.

The Maryborough LRG was surveyed first and, based on their feedback (discussed below), Question 4 (Table 16) was not included in the Burdekin survey. In the Burdekin this question was replaced with one on how many (of the seven) project workshops had been attended by the workshop participant, i.e. the final members of the LRG. It was thought important to obtain this information because of the changes in membership of the Burdekin LRG in response to regional issues (described above).

Survey scores were collated and expressed as a percentage of responses within the five possible answer categories (1 to 5). Comments made by respondents on each question were transcribed from the survey forms and analysed.

8.2.2 Survey scores

Results of the evaluation survey were generally very positive (Table 17), although more so in Maryborough than the Burdekin. All LRG members surveyed in Maryborough thought the outcomes/results of the project were positive, as was their participation. Only one member of the Burdekin LRG responded negatively to either of these issues. Average scores (on a scale of 1 to 5) ranged from 3.3 to 4.5, with the average score for each question again being generally lower for the Burdekin than Maryborough LRG.

The number of workshops attended by the final members of the Burdekin LRG ranged from one (36% of respondents) to all seven (9%). There was a significant positive correlation between the number of workshops attended and responses to Question 2 (*participation useful*; $P = 0.09$) and, particularly, Question 3 (*project achieved aims*; $P = 0.04$). Often such a result might be caused by people leaving the group because of lack of interest, etc., and so the survey results are biased by the scores of keen participant who followed the process to completion. That is unlikely to be the case in this study, because those participating in fewer workshops had joined the LRG later in the project's life, and so did not have low participation because of waning interest. Thus the results more likely suggest that a true appreciation of the project's achievements and the value to the industry participant was hindered by the inconsistent representation in the Burdekin region.

To further explore the impact of workshop attendance on attitude to the project, the average scores to the survey questions were partitioned into those who attended majority of the seven workshops and those who attended fewer. Those who attended the majority of workshops scored markedly higher in five of the six questions (Table 17): Their scores were much closer to those of the Maryborough LRG, and even higher for Question 3 (*project achieved aims*).

Table 16. Questions asked in the final evaluation survey and the written comments supplied by the Maryborough and Burdekin groups.

Maryborough	**Burdekin**
1. Were the outcomes/results from the project useful in your view?	
• We would not have looked at many of those aspects • Prevent us going down unprofitable track • Finally proved that a co-gen plant using trash as a fuel is not viable • Thorough detail in model • Disappointing for co-gen as I see it • Co-gen not viable unless government helps a lot • Didn't know what outcomes could be – expected when commented – a good result!	• Yes, in particular harvesting hauling and transport – also, the co-gen scenarios and comparisons • Improved models available for other purposes • Data may need fine tuning • I would have to be more certain that the figures were actual • Still uncertainty about model assumptions • The harvesting costs issue doesn't satisfy me • More goundtruthing required on harvesting
2. Was your participation in the project useful from your perspective?	
• Give an understanding of the whole value chain • Good understanding of results in model and good to have ability to comment on content of models etc • New way of looking at things – new processes / We could be involved as much as you would like to be • We need more work on our business decisions • Information I would not have got other than coming here • New member – only had 2 meetings • Good to have input from a grower level • models available	• Yes, it has enabled me to clarify different things • I haven't been a participant of the other workshops • Have only attended the last two meetings • Have only attended this meeting
3. Did the project achieve what it set out to do in your opinion?	
• Found trash blanket very beneficial • Models can be used in future projects eg. trash and tops • Good outcomes • No because I expected co-gen would have been a goer • Didn't know what to expect when project started	• Hampered by regional politics • Showed what the models are capable of producing (outputs) • Concern about life of the model – can others use it? • Still too many assumptions • Data accuracy and sources • The harvesting costs do not match reality. I can clearly show examples. • Left more questions than answers
4. Did the project meet your expectations?	
• Worked out the option we have to keep Maryborough industry going • Gathered information that I would not have • Perhaps some meetings could have been held with a larger number of growers • Model produced as flexible and results provided • Didn't know what to expect when project started	
5. Was the project successful in your view?	
• Successful – but end result will be no co-gen plant • Yes, ran out of time to keep adjusting model. By the time results were presented the scenarios changed • We have to look at other value for our product and of trash top • General valuable information and help from studies	• Hampered by regional politics, weren't able to reach potential • Yes, from the modelling perspective and the trash co-gen – certainly has defined the issues and scenarios • Efficiencies in Mill transport of product was good to see • Not sure at this stage
6. Do you believe your understanding of value chain analysis has been improved by your participation in this project?	
• There was a lot of information on VC that I didn't think about before • Good to look at it on a regional basis and how decisions effect other sectors • Greater appreciation of looking at the whole picture – not just one section • On the milling side of value chain • Interpretation of some information can be wrong. Looks good on paper but to do it on farm is totally different • Shows that little things can be underestimated in analysis	• Yes, especially feedback and forward • Yes, with caution • In time cane farming will be known as resource production due to endless uses of our plant to produce products • More groundtruthing required

Table 17. Results of the project evaluation survey for each of the two regions. (Questions are given in Table 16).

Question	Q1	Q2	Q3	Q4	Q5	Q6
Percentage of positive (score 4 or 5) responses						
Maryborough	100	100	50	80	90	100
Burdekin	70	60	60	na	60	75
Percentage of negative (score 1 or 2) responses						
Maryborough	0	0	15	0	0	0
Burdekin	0	10	15		15	0
Average score						
Maryborough	4.2	4.2	3.3	4.0	4.0	4.5
Burdekin	3.7	3.5	3.3	na	3.3	3.9
Burdekin ***average score as a function of number of workshops attended***						
Attended 4+	4.0	4.2	4.0	na	3.8	4.0
Attended <4	3.6	3.1	3.0	na	3.1	3.9

8.2.3 Survey comments

Comments made by respondents on each question (Table 16) centre on various themes. As expected, some of these themes supported the conclusions reached from the analysis of the survey scores. For example there were comments that *participants developed a greater understanding of the issues surrounding whole crop harvesting and co-generation*, consistent with the positive responses to Question 6 (Table 17). Comments were also made by the Burdekin LRG (Table 16) that the project was *hampered by regional politics and not able to reach its potential*. These comments supported the conclusion that disruption of the Burdekin LRG membership affected the project's impact.

From the comments it was apparent that some respondents had the view that *the project did not achieve its objectives* (Table 16). This is consistent with the relatively low score to the Question 3 (Table 17). As described above, in the Burdekin the scores to this question were affected by the respondents' previous involvement in the project. However, from the comments (Table 16) it was evident that there were mixed impressions of the projects objectives – some participants clearly thought the objective of the project was a concrete one, to ***make*** *the scenario work*, rather than to analyse the *likely outcomes of the venture* ***before*** *investing* in it. Thus, the results that maximising co-generation was unlikely to be profitable in any of the mills studied were *interpreted* as a lack of project achievement. Clearly, the acceptance by the LRG's that maximising co-generation was not an attractive venture in any of the mill regions reflected in the comments indicates that the project achieved the objective of defining the attractiveness of this venture for the LRG's.

Other comments were positive (Table 16), identifying that through the project members of the LRG's:

- *Were exposed to information, concepts and ideas that they would not have otherwise been*, and
- *Thought the modelling framework developed had wider applicability*.

Negative comments mainly centred on s*cepticism of the modelling results in the absence of practical experience*. Comments on this issue, which were more prevalent in the Burdekin LRG, possibly indicate that some members of the LRG did not understand the abstract process of modelling – that the analyses were not definitive answers, but indicators of the possible outcomes for the assumed scenario, *in the absence* of practical experience. Greater exposure to the modelling process may overcome this outlook.

8.3 Economic evaluation of the project

The project resulted in measurable future benefits for the LRGs conducive to formal cost-benefit analysis. While in the Burdekin the project has mainly confirmed existing plans and contributed to the selection of the best option, the survey of perceptions (described above) suggest its impact in Maryborough was dramatic. The project results played an important part in the decision of Maryborough Sugar Factory and the Maryborough to abandon plans to maximise co-generation. The results of the project showed that this decision is expected to avoid an annual loss of approximately $5.3m to regional stakeholders, compared to a projection of the technological status quo (Table 8). A further, indirect, benefit of the project is the option to use the thus uncommitted biomass byproduct in other, profitable, ways. However, the latter benefits are not included in the cost-benefit analysis, nor are such intangible benefits as increased knowledge about the value chain and its components by stakeholders in the two regions.

The economic benefits of the project can be evaluated under an assumption of the amount of influence the project had on the decision of the Maryborough industry to abandon plans to maximise co-generation. Taking the annual total project costs as stipulated in the contracted budget (Table 18) and a discount rate of 8%, an expected annual benefit of $5.3 over 20 years result in a flow of costs and benefits (Figure 13). Under the *extreme* assumption is that the project was *wholly* responsible for this decision, the measures of project returns are:

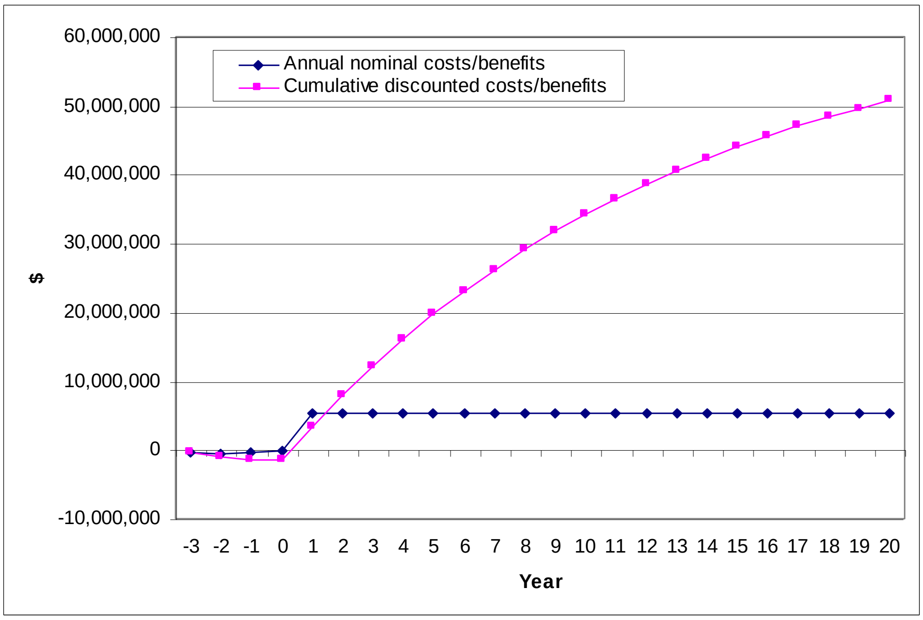
- Internal Rate of return (IRR), 97 %
- Net Present Value (NPV), $50.7M
- Benefit/Cost Ratio (B/C ratio), 34:1

If the project was *partially* responsible for the decision to abandon plans for maximising co-generation, the measures of project returns would obviously be proportionately decreased. For example, even if annual project benefits attributable to the project were one-tenth of those calculated in Figure 13, the project would still have an IRR of 26%, a NPV of $3.7m and a B/C ratio of 3:1. These returns are very high and comparable to those of the most successful cases of agricultural research worldwide (Echeverría 1990) and in Australia (Mullen and Cox 1995).

Table 18. Annual total project costs as documented in the project contract.

Year	2,003	2,004	2,005	2,006
Cost	327,164	596,572	269,407	134,703

Figure 13. Flows of project costs and quantified benefits



These results of the analyses are obviously affected by changes in the price of inputs and products. It is beyond the scope of this section to undertake a full analysis of the sensitivity of estimated project benefits to all these possible changes. However, it is worth considering what the impact of changes in the prices of the major products produced in the scenarios (i.e., sugar and electricity) might be. The price of sugar used in the project ($250) was towards the lower range of historical prices. Given the negative impact whole-crop-harvesting was predicted to have on sugar production in Maryborough higher prices would increase the predicted annual loss, and so increase the project benefits. As pointed out before, REC price is effectively capped at $57 under the current regulatory regime (Figure 7). The Maryborough whole crop harvesting-co-generation scenario has negative returns at that RECs price, with a RECs price over $60 needed for breaking even financially. Thus it is likely that the project benefits would still be substantial under quite a range of prices for these major products.

9 Discussion

9.1 New insights on whole crop harvesting

The piloting of the methods developed for whole-of-value chain analysis in this project has produced new insights on the consequences of whole crop harvesting for maximising co-generation. The predicted impacts of harvesting the whole crop to maximise co-generation differed considerably across the mill regions examined in this project. These differences highlight the complexity of interaction and site-specific nature of factors influencing the costs and revenues associated with power generation from trash in the sugar industry. Obvious differences between the regions included the presence or absence of an existing co-generation plant with spare capacity and the cost effectiveness of bagasse storage. A simpler analysis might have identified these limitations, which were significant for the Maryborough region. As described above however, prior to this study the prime concern of the LRG in each region was the challenge of harvesting and transporting the increased volume of material produced when harvesting the whole crop, suggesting these 'obvious' issues were not so obvious prior to this study.

Many factors contributed to the depth of understanding of whole crop harvesting impacts, and the clarification of the factors determining these impacts. Accessing data from previous detailed sugarcane physiological experiments provided good estimates of the amount of trash associated with a given sugarcane yield. Also, consideration of the changes in total regional cane production, due to (1) agronomic consequences of trash removal from trash blanketed blocks and/or (2) changed cane losses during harvesting the whole crop, further refined estimates of the volume of material produced. These estimates not only underpinned the analysis of the logistics of harvesting and transporting the increased volume of material, they were crucial for determining the size of the co-generation plant (or utilisation of spare capacity in existing plants), which in turn determined bagasse storage needs, capital costs and additional revenues. Information of this detail has not been used in previous assessments of sugar value chain diversification options (e.g., Sutherland 2002; Keating *et al*. 2002), but are crucial for a proper examination of this issue.

In general, the logistical problems of harvesting and transporting the additional volumes of material associated with the trash were not as great as previously imagined by the two LRG's. This was mainly due to two factors: an 'optimistic' assessment of these volumes that existed prior to the project (which also resulted in 'optimistic' assessments of potential revenue from electricity sales) and the identification in the study of possible improvements in the logistical efficiency in harvesting and/or transport. In the Maryborough region, the estimates of trash volumes derived from previous physiological studies have subsequently been verified by mill staff (P. Downs and J. Power, pers comm.). These data have contributed to more accurate assessments of the value of these resources for uses other than electricity co-generation.

As well as providing these insights into whole crop harvesting, this project has clarified the circumstances when whole crop harvesting for maximising fuel for co-generation is most likely to be feasible. These are when:

- There already exists a relatively efficient power generation plant in the region,
- The mill already has efficient (i.e. > 65%) boilers and high pressure and temperature steam supply (i.e. > 40 bar abs, 360°C), and
- Trash has little or no opportunity cost in the region.

The first two points relate to minimising the capital costs associated with such a venture, while the last relates to either potential agronomic impacts of trash removal, that have not been quantified before, or other opportunities for using/selling trash.

9.2 Regional response to results

In both regions, the LRG's decided to not proceed with whole crop harvesting for maximising go-generation based on the results of the value chain modelling (Table 8, 11 and 12). In Maryborough, assuming the region would have moved forward with this venture in the absence of the project, the financial impact of this decision is significant, as indicated by the project's Net Present Value of over $50M (Figure 13). Clearly the project has enhanced mill region profitability in this instance. Apart from the decision against proceeding with whole crop harvesting, there were other impacts and benefits of the project in Maryborough. Possible improvements in transport efficiency were identified within the region. Plans are in place to further develop and implement these improvements within the region (e.g., through the new SRDC project FPP111 aimed at implementing the transport model), leading to ongoing improvements in regional profitability. The definition of the regional value of trash in Maryborough (Table 9) also provides the region with a benchmark for assessing the attractiveness of business cases for alternative use of trash, such as for feedstock or producing more valuable end-products (like liquid biofuels). Clearly, any new vulture that removed trash from the region would need to produce a net benefit of $2.5M just to 'break even' at a regional scale.

The situation is somewhat different in the Burdekin. While the Burdekin LRG did not feel that maximising co-generation was an attractive diversification option during the final workshop, that judgement might change if the value of RECs were to increase substantially in the future, e.g. under different Government Policies on renewable energy or a more active global carbon trading market. Also, there would need to be further analysis and testing of the ways to overcome some of the 'bottle necks' identified in the harvesting and transport sectors before whole crop harvesting could be efficiently implemented in the region. The Burdekin LRG is well informed of that issue now and can pursue feasibility studies if the value of REC start to increase or some form of carbon emission trading is implemented. It may also be valuable for the region to examine whether the efficiency of the current 'coupling' of harvesting and transport systems could be improved. Apart from whole crop harvesting, should the Burdekin region choose to examine business cases for alternative use of trash (as described above), the results from this study will form the definitive source of data for the costs associated with trash recovery. Equally relevant to the alternative uses of trash is the result that collection of trash in the region (for some other use) would be significantly cheaper in done via whole crop harvesting and factory separation compared with post-harvest raking (Table 14).

The possible agronomic benefits of trash were not considered in the Burdekin because widespread burning of trash at harvest by Burdekin farmers at harvest indicates that, generally, trash is considered to have no agronomic value in the region. However, there is community pressure on the Burdekin sugar industry to cease burning trash because of the impacts of the process on the urban community within the region (Small and Windle 2001), a trend that happening across many of the world's sugar industries. Data on regional costs of green cane harvesting-trash blanketing are vital for the industry to be able to assess and communicate its position on the practice of burning in the face of community concerns. This project has provided, for the first time, a methodology for assessing the regional benefits (e.g. Table 9). This advance has been recognised by the Burdekin community, and is the basis for a funding proposal to define the regional triple bottom line impacts of trash blanketing (SRDC Proposal PRPEA012, November 2005)

Thus, apart from the obvious benefit of allowing the LRG's to more accurately determine the viability of maximising co-generation, other benefits flowed to the region from this work. The project has clearly played a part in these regions "*getting better"* and exploring how to "*become different*" (Hamel and Prahad 1994).

9.3 Impact

While the impact of the project was evaluated in the previous section of the project, it is valuable to consider how the impact might have been increased. Interactions with regional groups provided a mechanism for obtaining locally relevant information to inform the value chain modelling process and for continually 'ground-truthing' the modelling results and outputs. It also gave the LRG members an opportunity to gain a more detailed understanding of all sectors of their value chain through assessing results on all sectors of the value chain in their region, and participating in the scrutiny of results of the analyses by members of the different sectors of the chain. The result was an action learning process, by which:

1. The details of the scenarios being represented by the model evolved during the project (as described in Section 5), and
2. The understanding of the regions' value chains increased amongst the industry collaborators (Q6, Table 17) as well as the research team.

These are the outcomes expected from participative action research (PAR) approaches (Gaucher *et al*. 1998). While PAR research techniques are common in agricultural research (Jakku and Thorburn 2006), they are less widely applied in value chain research. Thus the project's design and conduct aimed to maximise impact, but were somewhat novel for whole-of-value chain research.

While industry participants generally thought that the project's results were useful (Q1, Table 17), the project's impact in the Burdekin was likely to have been affected by the disruption to the LRG membership during the project. For example newer members of the Burdekin LRG who attended fewer regional workshops scored lower on the project evaluation survey than those who had been in the LRG since the beginning of the project. Thus, impact of the project would have been increased with more consistent regional representation. This regional stability should be considered before undertaking similar projects in the future.

Another factor that evolved during the project was the ability of participants to separate the abstract aspects of the project's aims and methods, from the concrete reality of getting actual results from investments in new value chain ventures. Models are by definition an abstraction of reality, and so the modelling process necessarily involves simplifications and assumptions. It can be quite difficult for people who have not been involved in modelling to appreciate these issues. Thus, impact of the project might have been enhanced by a fuller discussion of the 'philosophical' approach being employed in the project; its strengths and weaknesses. This may have avoided the situation where the project's objectives were perceived 'to make whole-crop-harvesting work', rather than to provide detailed and relatively sophisticated insights into how likely it was 'to work'.

10 Outputs and outcomes

Outputs from the project include modelling frameworks, results and information, and publications. The modelling frameworks, results and information developed in the project are comprehensively described in the various sections of the report, above. However, it is valuable to summarise the outputs here. Publications arising from the project are also listed.

10.1 Outputs

Outputs from the project include the following:

- A value chain modelling methodology and framework capable of being configured to a wide range of value chain issues.
- A value chain modelling framework (in spreadsheet form) for analysing the whole-of-system impacts of whole crop harvesting for maximising co-generation, trash blanketing, or related issues. This spreadsheet has been supplied to members of the LRG's.
- A road transport capacity planning model to assess the vehicle and trailer requirements (and costs) of the different scenarios explored.
- Simplified, functional models of sugarcane growth (as a function of trash retention) harvesting, transport (road and rail) and milling.
- Definition of the impact of trash blanketing on sugarcane yield in the Maryborough region.
- An empirical model of the amount of trash associated with a sugarcane crop that is widely applicable to the Australian industry.
- Identification of improved efficiency in the transport sector of the Maryborough mill.
- Identification of improved efficiency in the harvesting and haulage sector of the Invicta mill.
- Definition of the cost of trash as a fuel for co-generation, supplied through the harvesting and transport system.
- A new knowledge base of the value chain in each of the two case study regions, which the local industries can build upon when exploring future value chain opportunities.
- A current harvester capital schedule for the Maryborough region.
- Specific advice to the Maryborough and Burdekin LRGs about the expected profitability of a range of investment and technology options.

10.2 Publications arising from the project

Archer A. A., Higgins A. J., Thorburn P. J., Hobson P.A., Antony G. and Andrew W. (2004). Employing participatory methods and agent-based systems modelling to implement agricultural supply chains systems. In proceedings of the 2nd Annual Supply Chain Management Symposium. Toronto, Canada (on CD).

Antony, A., Prestwidge, D., Sandell, G., Archer, A., Thorburn, P. and Higgins, A. (2005). Towards farming-systems change from value-chain optimization in the Australian sugar industry. *Australian Farm Business Management Journal*, 2: 1-9.

Higgins, A.J, 2006. Scheduling of road vehicles in sugarcane transport: A case study at an Australian sugar mill. *European Journal of Operations Research*, 170: 987-1000.

Thorburn, P.J., Archer, A.A., Hobson, P.A., Higgins, A.J., Sandel, G.R., Prestwidge, D.B., Andrew, B**,** Antony, G., McDonald, L.J., Downs, P. and Juffs, R. (2006). Value chain analyses of whole crop harvesting to maximize co-generation. *Proceedings Australian Society Sugar Cane Technologists*, 28: 37-48.

Thorburn, P.J., Archer, A.A., Hobson, P.A., Higgins, A.J., Sandel, G.R., Prestwidge, D.B., Antony, G. (2006). Evaluating diversification options for sugar supply chains: whole crop harvesting to maximize co-generation. Proc. 7th International Conference on Management in AgriFood Chains and Networks, Ede, The Netherlands (in press).

10.3 Outcomes achieved and expected

There have been several outcomes achieved by the project to date, and others expected in the future. Those achieved to date (Table 19) include the regional economic outcomes of preventing investments in unprofitable ventures and moves to adopt more efficient transport schedules in the Maryborough region. These will lead to greater profitability within the region in the future, compared with the situation if this project had not been conducted.

Table 19. Summary of the outcome arising from this project and evidence supporting the outcome.

Outcome	Evidence
Prevention of the Maryborough sugar industry investing in a potentially unprofitable venture	• Results of the evaluation survey and economic evaluation, detailed above.
Maryborough LRG recognise opportunities for increased efficiencies in the road transport sector	• Results of the evaluation survey, detailed above. • Moves to adopt improved transport schedules by MSF. • Development and submission of a SRDC full project proposal (FPP111) to extend implementation of this work. • Results of the evaluation survey, detailed above. • Inclusion of the approach (and project team) in an SRDC EOI on whole of value chain benefits of trash blanketing in the Burdekin (SRDC Proposal PRPEA012, November 2005)
Increased capacity for undertaking quantitative value chain analyses within the sugar industry.	• First detailed whole-of-value chain analysis undertaken – providing an example of how this type of analysis can be done. • New researchers (Archer, Thorburn) involved in value chain R&D.
Maryborough sugar industry exploring additional scenarios for producing animal feed from sugarcane tops.	• After the analysis showed losses to the region for the original co-generation scenario (due to the high milling capital), the local region began to seriously look at opportunities in producing animal feed, which does not require a large milling capital investment. • The transport tools developed in this project were subsequently used to explore detailed scenarios for the purchase of different types of vehicles (that Maryborough Sugar Factory were considering) to transport the cane tops to the mill.

Other outcomes achieved (Table 19) centre on changes in knowledge and attitudes of the LRG's members and increased capacity within the sugar industry to undertake quantitative value chain analyses, especially for the whole value chain.

The Maryborough sugar industry was prevented from investing in a potentially unprofitable venture: The Maryborough Sugar Factory and the Maryborough industry were seriously considering developing a co-generation plant and whole-crop-harvesting venture at the start of the project. The project results showed clearly that this venture would not be profitable, with an indicative annual loss of $5.3M per year (Table 8). Staff of Maryborough Sugar Factory partially attribute abandoning that venture to the results of the project (J. Power and P. Downs, personal communication). This outcome is also supported by the anonymous comments made in the evaluation survey (Table 16): "*Prevent(ed) us going down unprofitable track*"; "*Finally proved that a co-gen plant using trash as a fuel is not viable*". The economic impact of this outcome, evaluated above, was substantial with the accrued benefits attributable to the project to the region being up to $50M (Figure 13).

Understanding of the issues involved in maximising co-generation through whole crop harvesting has increased amongst members of the Local Regional Groups: Responses to the evaluation survey (Table 16) show that members of the Groups now have a better appreciation of the issues involved in this complex value chain diversification venture: "*Certainly has defined the issues and scenario*"; "*Efficiencies in mill transport of product was good to see*"; "*We would not have looked at many of those aspects*".

General understanding of the sugar value chain has increased amongst members of the Local Regional Groups: Responses to the evaluation survey (Table 17, Q6) show that a substantial majority of members of the Groups (all in Maryborough) now have a better understanding of the local sugar value chains through participation in the project. Specific comments include: "*Gave an understanding of the whole value chain*"; "*There was a lot of information on VC that I didn't think about before*"; "*Greater appreciation of looking at the whole picture – not just one section*".

Members of the Local Regional Groups generally accept the value of value chain modelling and the outputs produced: Members of the Groups generally accepted that the application of the value chain model in this project was valuable and that the models could be used for other projects. Responses to the evaluation survey (Table 16) include: "Showed what the models are capable of producing (outputs)"; "Improved models available for other purposes"; "Models can be used in future projects eg. trash and tops". It is worth noting that these responses were made in response to other questions, not to a question specifically aiming to define the Group member's opinions of value chain models. Further evidence for this outcome is that an Expression of Interest for funding from SRDC that included modelling analyses of a value chain issue was submitted by the Burdekin region following completion of the project.

Capacity for undertaking quantitative value chain analyses has increased within the Australian sugar industry: Capacity for undertaking quantitative value chain analyses has increased in three ways. Firstly, this project has demonstrated that whole of value chain analyses can be undertaken in a timely, participatory manner. In doing so, it provides an example to the industry of how this can be done, making future projects in this area simpler. Secondly, this project has introduced new scientists (Archer and Thorburn) into value chain research, increasing the human capacity in research provision. Thirdly, all researchers involved in the project now have a better appreciation of all the sectors of the sugar value chain, not just those in which they previously specialised.

Maryborough sugar industry exploring additional scenarios for producing animal feed from sugarcane tops: After the analysis showed losses to the region for the original co-generation scenario (due to the high milling capital), the local region began to seriously look at opportunities in producing animal feed, which does not require a large milling capital investment. The transport tools developed in this project were subsequently used to explore detailed scenarios for the purchase of different types of vehicles (that Maryborough Sugar Factory were considering) to transport the cane tops to the mill.

Maryborough sugar industry adopting the transport model for transport and harvest scheduling to reduce logistics costs: The road transport scheduling model, partly developed as a component model for the value chain model (and partly through SRDC project CSE005), will be used in 06/07 to improve harvester-transport logistics within the Maryborough region. The participatory action research in CSE010 not only validated the model for the whole-of-crop venture but also as a stand-alone scheduling tool, which now has the local industry support for adoption. This model will be developed further and piloted in 2006 and 2007 through the new "industry-led" SRDC proposal FPP111.

These outcomes will underpin enhanced capacity and capability to improve the profitability of the sugar value chain in the collaborating regions.

11 Future issues

11.1 Post-project action plans

There are a number of post-project actions that have occurred regarding adopting or extending outputs from this project. These were detailed in the section on outcomes. Other post-project opportunities arising from this project centre on communication of the achievements and advances made in this project, and the opportunities for value chain research, development and implementation within the Australian sugar industry.

During the life of this project, Maryborough and the Burdekin focused whole crop harvesting as the main value chain scenario to be addressed. However, the methodology developed within the project can be adapted to address other value chain issues that mill regions across the sugar industry are currently struggling with. It is clear, as recognised by the Industry Reference Panel, that the achievements in this and other sugar industry value chain projects need to be communicated to the broader sugar industry. We plan to undertake this communication in two ways:

Firstly, members of the project team will be involved in a small follow-up project *Increasing the Capacity to Identify and Action Value Chain Integration Opportunities* (CSE013), funded by SRDC and CSIRO. The project aims to develop a review of current and past value chain research in sugar industries (not limited to the Australian sugar industry), and provide learnings/recommendations for the future. This review will be communicated to industry through a workshop and paper at the 2006 conference of the Australian Society of Sugar Cane Technologists.

Second, the specific achievements of this project will also be communicated to industry through a workshop and paper at the 2006 conference of the Australian Society of Sugar Cane Technologists. A paper has been accepted into the conference as listed in the Outputs Section of this report.

11.2 Large-scale implementation of the methodology

This study has highlighted the value that can be derived from combining comprehensive biophysical analyses with more common economic evaluations of diversification options for the sugar value chain. The modelling philosophy developed in the study (Figure 4) could be applied to analyse other value chain issues, such as mill rationalisation. Provided the underlying science and quantification, as embodied in the existing industry models (Figure 4), exists, analyses of the supply chain modelling could be completed quickly. The most time consuming steps would be the specification and refinement of the biophysical system and assumptions. These are ongoing activities that require meaningful input by the local stakeholders through participatory processes. However, they result in co-learning by the stakeholders and the research team and, ultimately, are the real legacy of these types of studies.

11.3 Intellectual Property

The modelling approach and framework developed in this project, depicted in Figure 4, is unlikely to generate any intellectual property (IP). As described in the Outputs section, the approach has been published in the open literature by the project team and specific spreadsheets made available to the LRG's.

In developing the modelling approach, the project team were cognisant that many of the existing industry models needed to describe various parts of the sugar value chain (Figure 4) are subject to IP constraints. The approach provides a means whereby information can be obtained from those models, with the collaboration and/or consent of the IP owners, without infringing IP. Thus we hope that this project will enable the benefit of the sugar industry's investment into process models will be maximised.

11.4 Future Research Needs

Future research needs can include both industry issues and technical developments. Industry issues could include matters such as optimising season length, rationalising mill numbers, assess whole-of-system benefits of different varietal characteristics, etc. While the project team can see the need for research in these, and other, areas, we will confine our comments to research needs on technical developments.

In this project, a multi-agent approach has been taken to link existing sector-specific models for a sugar industry value chain model. The result was a model was built specifically for analysing the impacts of whole crop harvesting in Maryborough and Burdekin. As shown above, analysis of related issues (such as whole-of-system impacts of trash blanketing) were/are able to be undertaken very efficiently. However, analysis of other, less related issues would require assembly of another agent-based model. While this would be done more quickly and efficiently by the project team because of the experience gained in this project, the approach is still limited in its flexibility. The sugar industry may get greater advantages through development of a more flexible tool for analysing value chains. In forestry, which has many logistical and spatial analogies to sugar, modularised value chain models are well developed (Frayret *et al.* 2005) and used within the industry. Strategic investment in such a system would be of great value for the sugar industry.

The priorities identified by the LRG's in this project were generally underpinned by existing industry models, and the existence of these models increased the efficiency of the project. However, there are other value chain issues for which well developed modelling capabilities do not exist. An example is the whole-of-system benefits/disbenefits of higher fibre in sugarcane crops. While fibre is currently selected against by plant breeders, the increasing development of co-generation capacity within the industry may make higher fibre more attractive to the milling sector. High fibre canes may lodge less, yield more and so benefit the farming sector. But this outcome may provide logistical challenges for the harvesting and transport sectors. Many varietal characteristics, such as the relationship between fibre, lodging and yield, are not sufficiently well understood to be quantified and so incorporated into sector or value chain models. This applies to issues within other sector of the value chain as well. There is a need to consider strategic opportunities for improving the value chain within the Australian sugar industry, and invest in the research required to provide the tools to underpin analyses of these opportunities.

12 Recommendations

The feasibility of developing a more generic value chain model should be explored: The value chain model developed in CSE010 was dedicated to the whole-of-crop venture, utilising sub-models that already existed in the industry. Other value chain issues (e.g. season length, mill rationalisation) would require a different value chain model to be developed, with the likely development of some sub-models. Whilst a generic value chain model (that is adaptable) is likely to be more expensive to produce, work is needed to assess the potential benefits of developing such a model versus its likely costs.

A further analysis should be conducted to benchmark the Maryborough case study against the NSW sugar region: The Maryborough case study showed a net loss, whilst the NSW sugar region are rapidly moving ahead in whole-of-crop harvesting with confidence of a region-wide benefit. By applying the value chain model to the NSW region, specific details can be confirmed as to why there are such big differences in benefits between Maryborough and NSW. The wider sugar industry can then learn from this, and will be valuable if other regions move towards whole-of-crop harvesting.

An investment needs to be made in improving the understanding of "cutting edge" value chain research in the Australian sugar industry: The CSE010 was a cutting edge project in terms of the modelling process for whole-of-crop harvesting. It was often difficult for the LRG's to understand the abstract nature of the modelling process or the objectives of the project, particularly in its early stages. This sometimes made it difficult for some members of the LRG's to appreciate the value of the project and drive it forwards. Whilst considerable ground was made during the life of CSE010 to overcome this issue, a continued investment needs to be made to improve understanding, particularly if the industry was to engage in these types of "cutting edge" projects.

Strategies need to be investigated to better manage/accommodate outside influences within such a project: Outside influences have fallen in the following categories (though there are probably others): changes in energy and sugar prices; changes in the LRG; and conflicting regional issues/priorities. The recent rise in sugar price (vs energy) will have an impact on the benefits of whole-of-crop harvest and the regional enthusiasm in such a venture. Membership of the BKN LRG evolved rapidly which impacts the participatory action research process and slows progress. Other issues and priorities within the region (e.g. cane supply contracts, season start activities) often detracts focus away from the project by some members of the LRG, thus slowing it. Whilst outside influences are often difficult to foresee or do much about, it is recommended that ways be sought to lessen their impact.

Future multi-organisational value chain projects should have a funded project manager: The management of the project, involving multiple industry and R&D organisations, was complicated and time consuming. It would benefit significantly from having a specialist project manager, who would free up valuable time for the senior researchers and principal investigators.

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14 APPENDIX 1: Compilation of models relevant to whole-of-value chain research existing amongst the Project Team

15 APPENDIX 2: Detailed description of the value chain modelling approach