NSW DEPARTMENT OF
PRIMARY INDUSTRIES

The Economic, Environmental and Social Benefits to NSW from Investment in the CRC for Beef Genetic Technologies

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Abstract
The Australian cattle and beef industry and the associated RD&E community recently developed a successful proposal for the CRC for Beef Genetic Technologies. The expected benefits from the proposed scientific programs of the renewed CRC were estimated using the DREAM economic modelling framework. A "top-down" assessment philosophy was used that included explicit "with-CRC" and "without-CRC" scenarios. The benefit from the extra investment and consequent research effort due to funding the CRC is estimated to be worth over $1.4b in present value terms. Every $1 of these extra resources brought into the Australian beef industry through funding the new Beef CRC is expected to return around $35 to the industry. The marginal returns to the NSW beef industry from funding the CRC were also assessed. It was estimated that NSW DPI involvement in a refunded CRC will generate an additional $251m in economic benefits to the cattle producers, beef processors and marketers, and beef consumers of NSW, in present value terms. The estimated net cost required to fund this involvement is $3.785m. Estimates were also made of the extra benefits that would flow through to the broader NSW economy, beyond those accruing to the cattle producers, beef processors and marketers, and beef consumers of NSW (some $111m); and of the value for the saved methane output due to adoption of NFI genetics in the NSW beef herd (some $28m).

Keywords: beef; research and development; economic; evaluation; Australia

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Acronyms and Abbreviations Used in the Report

ABARE	Australian Bureau of Agricultural and Resource Economics
Accelerated adoption	Increase in adoption rate and/or adoption ceiling
AE	Adult equivalent
ARC	Australian Research Council
BCA	Benefit cost analysis
BCR	Benefit cost ratio
BEEF CRC	Cooperative Research Centre for Beef Genetic Technologies
BREEDPLAN	Australia's beef genetics evaluation system that estimates breeding values for economically important traits
Consumer surplus	A measure of economic benefit to consumers defined as the difference between willingness-to-pay and price actually paid
Cost-reducing	The impact a new technology has on reducing the cost of production
CPI	Consumer Price Index
Demand-enhancing	The impact a new technology has on increasing demand for the product
DREAM	**D**ynamic **R**esearch **E**valu**A**tion for **M**anagement – a benefit cost analysis software package
Economic welfare	A measure of economic benefit to a market from a change such as the adoption of a new technology
EDM	Equilibrium displacement model
Elasticity	A measure of the responsiveness of producers and consumers to price changes defined as the proportional change in quantity for a 1% change in price
Gene discovery	Refers to finding genes that impact on economically important attributes in cattle and developing diagnostic tests for them
Gene expression	Refers to understanding the function of the genes associated with economically important traits and identifying non-genetic approaches that can be used to influence the expression of these genes
IRR	Internal rate of return
MLA	Meat and Livestock Australia
NPV	Net present value
Producer surplus	Aa measure of economic benefit to producers defined as the difference between willingness-to-accept and price actually received
RD&E	Research, development and extension
ROW	Rest of World
SHEEP CRC	Australian Sheep Industry Cooperative Research Centre
TFP	Total factor productivity
Yield-increasing	The impact a new technology has on increasing the quantity of production

Executive Summary

The Australian cattle and beef industry and the associated RD&E community recently developed a successful proposal for a third Cooperative Research Centre (CRC) related to this industry - the CRC for Beef Genetic Technologies. The proposal contained four major areas of scientific research (high quality beef for global consumers; feed efficiency, maternal productivity and responsible resource use; adaptation and animal welfare; and female reproductive performance), as well as an education and training program including specialists in economics and adoption methods, and a cross-program group of underpinning science, bioinformatics and database specialists. The focus of the CRC is on gene discovery and gene expression, and accelerated adoption. Seven major industry outcomes have been targeted across some 20 individual project areas.

The expected benefits from the proposed scientific programs of the renewed CRC were estimated using the DREAM economic modelling framework. A "top-down" assessment philosophy was used that included explicit "with-CRC" and "without-CRC" scenarios. Differences in assumed investment levels, rates of improvement in meat quality, rates of productivity improvement, probabilities of success and levels and rates of adoption were compared in separate demand and supply analyses that incorporated data on prices, quantities and market elasticity values for each Australian state and the major beef trading countries.

Total estimated benefits from the with-CRC scenarios are in the order of $1.930b. The present value of the full cost of the CRC program is $98m when discounted. This results in a NPV of $1.831b and a BCR of 19.7:1. Total estimated benefits from the without-CRC scenarios are $516m with total costs of $58m. This results in a NPV of $458m and a BCR of 8.9:1. Thus, the benefit from the extra investment and consequent research effort is estimated to be worth over $1.4b in present value terms. Every $1 of these extra resources brought into the Australian beef industry through funding the new Beef CRC is expected to return around $35 to the industry.

The marginal returns to the NSW beef industry from funding the CRC were also estimated. Under the same assumptions as made in the aggregate assessment, it was estimated that NSW DPI involvement in a refunded CRC will generate an additional $251m in economic benefits to the cattle producers, beef processors and marketers, and beef consumers of NSW, in present value terms. The estimated net cost required to fund this involvement is $3.785m. So while the marginal cost to NSW DPI of being involved in the CRC is minimal, the anticipated benefits are substantial. The marginal NPV is $247m and the marginal BCR is 66:1.

Some additional benefits were also enumerated. First, it was estimated that an extra $111m in benefits would flow through to the broader NSW economy, beyond those accruing to the cattle producers, beef processors and marketers, and beef consumers of NSW. Second, net feed intake is a major research area of the new CRC and it is now accepted that selection for more feed efficient cattle will lead to a reduction in greenhouse gas emissions from the beef herd. It was estimated that a minimum value for the saved methane output due to adoption of NFI genetics in the NSW beef herd is in the order of $28m, over the 25 year simulation period. A substantial proportion of that expected benefit could be assigned to the new CRC through further development and adoption of the net feed intake technology. Other social benefits are also discussed although no formal value is placed on these.

1. Introduction

The Australian cattle and beef industry and the associated RD&E community recently developed a successful proposal for a third Cooperative Research Centre (CRC) related to this industry. This proposal was named the CRC for Beef Genetic Technologies. The proposed areas of research were outlined and argued in a "Prospectus" document (CRC for Cattle and Beef Quality 2004). In brief, the proposal contained four major areas of scientific research (high quality beef for global consumers; feed efficiency, maternal productivity and responsible resource use; adaptation and animal welfare; and female reproductive performance), as well as an education and training program including specialists in economics and adoption methods, and a cross-program group of underpinning science, bioinformatics and database specialists. The focus of the CRC is on gene discovery and gene expression, and accelerated adoption[1]. Seven major industry outcomes have been targeted across some 20 individual project areas. Appendix A provides details of the outcome areas and the strategies planned to achieve these outcomes for each of the four science programs and the education and training program.

Two of the four assessment criteria on which the CRC renewal proposal was judged are as follows:

(1) the outcomes will contribute substantially to Australia's industrial, commercial and economic growth; and

(2) the funding sought will generate a return and represents good value for taxpayers.

Both of these criteria imply the need for rigorous economic assessment of the expected impacts of the proposed science programs. Our first objective here is to provide such an assessment for the Australian beef industry. Following some background discussion in Section 2, the methodology used to make these estimates is described and the results generated are reported in Sections 3 to 7.

The New South Wales government, through the NSW Department of Primary Industries (NSW DPI), is a core partner of this CRC. NSW DPI has committed to invest some $9.264m in cash and in-kind contributions, or 10.1 per cent of the total resources (see the Appendix B for details). This commitment makes it the third largest investor in the CRC, just behind QLD DPI (11.0 per cent) and CSIRO (10.4 per cent). Our second objective is to evaluate whether this investment will generate positive returns to the NSW beef industry and to the NSW economy. This question is addressed in Sections 8 to 10.

[1] **Gene discovery** refers to finding genes that impact on economically important attributes in cattle and developing diagnostic tests for them (for example, the GeneSTAR marbling test). **Gene expression** refers to understanding the function of the genes associated with economically important traits and identifying non-genetic approaches that can be used to influence the expression of these genes (for example, growing cattle in feedlots to better express their marbling potential). **Accelerated adoption** refers to reducing the adoption lag and/or raising the adoption ceiling in the beef industry.

2. Background

There have been two previous CRCs researching aspects of the Australian beef industry. From 1993/94 until 2000/01 the CRC for the Cattle and Beef Industry was funded, and then from 1999/00 until 2005/06 the CRC for Cattle and Beef Quality has been funded. Both previous CRCs have been highly regarded by industry, the science community and the CRC Secretariat. Many of the same organisations and personnel have been involved in the two previous CRCs and are involved in the renewed CRC. NSW DPI has been involved in both previous Beef CRCs.

Following a successful Year 5 review of the CRC for Cattle and Beef Quality in mid 2003, planning for a renewal bid commenced. Numerous meetings and workshops were convened by the peak beef industry bodies and a wide range of potential partners, industry leaders and scientists were consulted. The Stage I preliminary case was submitted in March 2004 and the Stage II full business case in July[2]. An interview was held in mid November and the bid team were notified of its success in late December. The CRC for Beef Genetic Technologies was one of 14 successful bids from an initial list of 80 expressions of interest.

There are nine core partners and ten supporting partners of the CRC that have committed more than $90m in cash or in-kind resources to match the Australian Government's $30m contribution. These agencies and their contributions are detailed in Appendix B (in addition, the QLD government provided a separate grant to those successful CRCs that had a strong QLD focus, including this one).

As noted above, NSW DPI is a core partner of this CRC.

[2] Thus the analysis reported here was mostly completed by March 2004, although some minor adjustments were made for submission of the Stage II case. Some new information relevant to the analysis (in particular new estimates of productivity growth in the beef industry) has since been released but has not been incorporated.

3. Methodology

3.1 Assessment Philosophy

The research problem addressed in this evaluation is the measurement of the long-term net benefits from the proposed program of research in the renewed CRC. This requires us to define appropriate "with-research" and "without-research" (or more precisely "with-CRC" and "without-CRC") scenarios. Alston, Norton and Pardey (1995) note that defining the relevant scenarios is potentially one of the most useful parts of the research evaluation process but it is often difficult because many evaluations are concerned with on-going, rather than completely new, research programs.

That is certainly the case here. The proposed CRC research program was not developed, and will not be implemented, in a vacuum. First, there have been significant past RD&E investments, and there are significant current investments, in the general areas covered in the proposed program of research. There have been, and will be in the future, productivity improvements that result from these earlier programs. These will arise because we are assessing RD&E investments in the beef cattle industry and there are very long biological lags involved in this industry.

Second, the nature of the technology under investigation (genetics) means that the impacts of adopting such technologies are spread out over a long time period and the impacts accumulate over time. The benefits of both of these components of future productivity improvement that are based on past R&D programs cannot be claimed to be benefits of research in the proposed CRC. They are the benefits of past investments, even though they form the building blocks of some of the new proposals.

Further, there has been a long history of collaboration achieved by researchers and agencies through involvement in the predecessor CRCs. Also, the research issues making up the renewed CRC program are the result of substantial consultation between industry and potential core partners and are consequently highly valued by them.

Given this context, it is highly probable that in the absence of Commonwealth funding for the proposed CRC, an alternative program of research would have been undertaken by many of the same researchers and many of the same agencies, covering many of the same issues. However, such a research program would certainly be less comprehensive and/or less intensive, as total available funding would be substantially reduced (no CRC cash, less partner in-kind contributions). More importantly though, there would be a crucial lack of discretionary funds for the purchase of new equipment and expensive operating requisities, for the coordination of the RD&E effort across the partner agencies, for the required focus on extension and adoption of the RD&E outcomes, and for the attraction of postgraduate students into the RD&E programs.

Further, there may be some "withering on the vine" effect over time as experienced and cooperating researchers move on to other problems and issues and are replaced by less experienced researchers.

So the benefits of the proposed CRC can be thought of as falling into three possible areas: (1) *genuinely new research outputs*, that would not be possible to generate without the proposed

CRC funding (ie genuinely new technologies); (2) *enhanced research outputs*, that would have significantly greater impact than those outputs generated by an alternate RD&E program undertaken by the same researchers and agencies but without the proposed CRC funding (ie better technologies); and (3) *significantly improved development and extension* of research outcomes based on the findings of past or new research that increases the value of the information available for industry decision-making, beyond what would have been possible without the proposed CRC funding (ie faster and/or more widespread adoption of profitable technologies).

Such an approach to assessing RD&E programs like that proposed in the renewed CRC was recently used to estimate the net benefits of a research program undertaken by the CRC for Weed Management Systems to reduce *vulpia* infestations in Australian temperate pastures (Vere *et al*. 2003). *Vulpia* is an annual grass invader. The change in *vulpia* biomass from current levels was estimated for a with-CRC and a without-CRC scenario, different adoption rates were specified and the benefits from each scenario were calculated. The difference between the simulated benefits of both scenarios therefore represents the benefits from *vulpia* research that can be attributed to the Weeds CRC. The application of this approach to Weeds CRC issues has been extensively peer-reviewed through presentations at conferences and seminars and through journal refereeing processes.

We have adopted this same overall approach to estimating the benefits of the proposed Beef CRC research programs. Thus, we attempt to measure the *marginal* economic benefits of the proposed research programs. Crucially, the measured benefits have to be defined as net of any ongoing benefits derived from past RD&E and net of the expected benefit from any alternative RD&E programs that would most likely be implemented in the absence of CRC funding. However, benefits may include those attributable to enhanced adoption of the results from previous CRCs, or of other available technologies, that are due to Beef CRC activities.

What we are looking to measure is the marginal return to all participants in the Australian cattle and beef industry from the additional investment attributable to the renewed CRC. In the context used here, the Australian beef industry includes cattle breeders through to beef consumers, both domestically and internationally.

3.2 Choice of Broad Approach to the Assessment

We could undertake this measurement task in either of two ways (see The Allen Consulting Group 2003). A "bottom-up" approach would involve examining a range of proposed project areas on a case by case basis, estimating the expected benefits from each of these project areas, and then aggregating the expected benefits over the entire proposed RD&E program. Typically we would use models of relevant farming systems to measure the on-farm impacts on cost or yield, and then use a model of the industry to estimate the aggregate economic impacts given knowledge of expected adoption, etc. Examples of this type of approach are Burrow *et al*. (2003a,b), Farquharson *et al*. (2003) and Griffith *et al*. (2004).

However the nature of the proposed scientific programs in the CRC (Appendix A) are such that there is a lot of interlocking projects, where resources are applied across a number of projects and where outputs from some projects become inputs into other projects. Under these circumstances it is difficult to allocate costs across individual project areas and it is equally as difficult to apportion benefits to individual project areas.

The alternative is a "top-down" approach. Here, the emphasis is on the impact of the whole RD&E package, not the impacts of the individual project areas or programs. Overall rates of productivity improvement are examined and the role of technological change in generating this productivity growth is assessed. Expert opinion is used to disaggregate the shares of potential productivity growth due to the CRC across the various outcome areas, and the benefits from the expected shifts in these various outcomes are then estimated. That is the approach followed here[3].

3.3 Choice of Modelling Framework

The DREAM benefit-cost analysis program (Wood *et al*. 2001) was selected as the modelling framework to undertake the required assessments. This program is based on the economic principles developed in the highly regarded text *Science Under Scarcity* (Alston, Norton and Pardey 1995), and it has been widely used in impact assessment studies over a number of years by many different national and international institutions. It is a modelling system officially supported and promoted by, among other agencies, the International Food Policy Research Institute and the Australian Centre for International Agricultural Research. It has a rigorous theoretical base and a credible history of applications.

DREAM has a number of different sub-models representing different types of market situations. One of these is the "horizontal multi-market" option. This provides a means of assessing the economic impact of a new technology in the context where the product under study is (relatively) freely traded across a number of regions, a situation closely approximated in the Australian beef industry. Northern and Southern Australia, and traditional and potential export markets, can all be defined as separate regions. This facility is considered crucial given that some of the technologies in the renewed CRC will have a particular Northern or Southern Australia focus. Further, given that one of the stated outcomes for the CRC is for Australia to be "...No. 1 supplier of growth in beef demand by developing countries in our region", we need to be able to differentiate both traditional and potential export markets. Unfortunately, selection of one of the market situation options in DREAM precludes joint use of the other options. Choosing to focus on the multi-regional and traded status of the industry means that we cannot simultaneously generate information on the impact of the proposed RD&E in the individual vertical market segments of the industry (such as feedlots, processors, retailers, etc.). Thus, the transactions modelled essentially refer to the farm-gate as the point of exchange and the values we choose reflect this market level.

Two other relevant constraints in DREAM are that (a) we can only analyse one product market at a time (so we cannot jointly examine different types of beef such as grass-fed and grain-fed, or competing products such as lamb, pork or chicken), and (b) we can only analyse a supply shift or a demand shift, but not both.

The Beef Equilibrium Displacement Model (EDM) (Zhao *et al.* 2000, 2001) would be an alternative aggregate beef industry modelling framework to use. It has a well-developed vertical market structure and is also well regarded by industry, but the trade section of that model is relatively weak and it has only limited linkages to the beef markets in the rest of the world.

[3] This approach has also been used recently in the Australian Sheep Industry CRC (Vere *et al*. 2005), and in contributions to rebids by the Sheep and Weeds CRCs (Griffith *et al*. 2006, Jones *et al*. 2006).

In our implementation of the DREAM model for this assessment, we define each Australian state as a separate region (where Western Australia is separated into North and South) and later in the analysis we aggregate these into Northern and Southern Australia. Four separate export markets are defined - the US, Japan, Korea and an aggregate Rest of World. Australian beef is allowed to be available in all possible regional markets and to compete with beef from all possible regional suppliers.

3.4 Data Required

The economic models underlying the DREAM software are equilibrium displacement models just like the EDM, and they require the same basic sets of input data: (1) "equilibrium" prices and quantities, to define the size and structure of the market in each defined region under consideration at a specified point in time; (2) elasticities of supply and demand, to predict how producers and consumers in each defined region will react to new prices generated by the simulated shocks to the market (the impact of the RD&E); and (3) how the proposed RD&E will change either producers' cost structures or consumers' willingness to pay for different quality products in the region(s) where the technology will be adopted (the so-called K shift).

For this study, the year 2001/02 was chosen as the base year for the price and quantity data. This was the most recent year where the full set of required data was available, prior to the disruptions to markets caused by the drought. The analysis uses "real" values based on 2001/02 values. This year is considered to be broadly representative of the peaks and troughs of the world beef market during the coming couple of decades, taking into account the inevitable consequences of the US cattle cycle (Griffith and Alford 2002, 2005) and the increasing risks associated with market disruptions caused by droughts and disease outbreaks.

The base price and quantity data for each region are given in Table 1. Notes explaining calculations relating to these data are given under the table. Although more than two-thirds of Australian beef production is exported, the domestic market remains the largest single market destination.

The base elasticity values are given in Table 2. These are taken mainly from Zhao *et al*. (2000). We note that the domestic demand elasticities given in Zhao *et al*. (2000) have been reduced by 2/3 to reflect the demand at the farm level modelled here rather than demand at the retail level modelled in that study. The demand elasticities are scaled down to reflect the ratio of the approximate farm price of $3/kg divided by the approximate retail price of $10/kg. The demand elasticities for the Northern states have been set lower than those for the Southern states because of fewer possible substitute products available to consumers. Also, the demand elasticities for US, Japan, Korea and the ROW are export demand elasticities for Australian product, and therefore have been set as being moderately to highly elastic because of the existence of many possible substitutes available to consumers and many possible sources of supply of beef.

Table 1. Base Price and Quantity Data, Beef and Veal, 2001/02

Region	Production (ktcw)	Consumption (ktcw)	Beef Exports (ktcw)	(ktsw)	Cattle Exports (ktcw)	(head)	Price ($AU/tonne)
NSW	474	296	204		0.733	3877	3130
VIC	355	171	144		8.464	44785	3223
QLD	978	129	556		28.507	150829	2634
SA	86	54	37		4.571	24184	2714
WA	96	68	21		62.608	331258	2550
TAS	45	17	21		-		2773
NT	1	7	-		50.121	265190	2592
AUSTRALIA	2034	742	1292	984	155.0	820139	
US	11762	12268	(506)				4016
JAPAN	457	1207	(750)				5110
KOREA	190	580	(390)				4295
ROW	35753	35399	354				4016
WORLD	50196	50196	0				

Source: Unless otherwise noted, all data are from *MLA Statistical Review July 2001 - June 2002*
Notes: Consumption in each state is calculated as 35.5 kg/capita times state population for 2001/02 as given in ABS (2003), *Australia at a Glance*, Cat. No.1309.9; live weight of 350kg and an average dressing percentage of 54%. In the model, these equivalents are added to production in each Australian State, to ROW consumption and to both world production and consumption; In the model WA is split into north and south. In the absence of firm data, production is set equal in both halves and demand is set to 50 in the south and to 18 in the north; Domestic prices are for steers 260-300 kg HSCW; NT price is an average of QLD and WA; US price is Australian boneless cow beef, 90%CL, FAS; Japan price is Australian chilled boneless grassfed fullset, FAS; Korea price is unit value of all Australian beef and veal exports to Korea, FOB.

Table 2. Base Supply and Demand Elasticity Values

Region	Supply Elasticity	Demand Elasticity
NSW	1.00	-0.33
VIC	1.00	-0.33
QLD	0.75	-0.27
SA	1.00	-0.33
WA (north/south)	0.75/1.00	-0.27/-0.33
TAS	1.00	-0.33
NT	0.75	-0.27
US	1.00	-3.00
JAPAN	0.70	-2.00
KOREA	0.70	-2.00
ROW	1.00	-5.00

Source: The base values are taken from Zhao *et al.* (2000)

Finally, the supply elasticities for the extensive Northern states have been set lower than those for the Southern states because of less flexibility in enterprise choices and expansion opportunities. The same reasoning holds for Japan and Korea compared to the US and the ROW.

The relevant measures of K are defined in the assessments for each version of the proposed RD&E programs that follow in Section 6. The data in Tables 1 and 2 plus the relevant measures of K allow DREAM to calculate the gross annual benefits from a shift in demand or supply brought about by the proposed RD&E program.

Because DREAM undertakes a rigorous benefit cost analysis, information is also required on the following variables and parameters (Wood *et al*. 2001): costs of the RD&E and the lag before results are available, adoption rates, lags and levels, dis-adoption if relevant, probability of success in producing the expected outputs, the time period over which the RD&E program is to be assessed, the discount rate, the degree to which regions are linked together by prices, and whether the technology is to be available outside the region where the RD&E occurs (for a discussion of these issues see also Marshall and Brennan 2001).

Data on these variables and parameters are discussed in Section 6 below. Before proceeding with the analysis however, it is necessary to test that the modelling framework developed here provides outputs of the same order of magnitude as other types of modelling frameworks.

4. Validation Run of the DREAM Model

Zhao *et al.* (2000) show that a 1 per cent decrease in the cost of supplying weaner cattle in Australia would result in an annual benefit to the whole Australian cattle and beef market of $19.6 million. This was based on 1992-1997 average prices and quantities. In later work Farquharson *et al*. (2003) scaled this annual benefit up to $30 million using changes in the Australian Consumer Price Index (CPI) to reflect 2001 values.

The equations and calculations underlying the DREAM software and the Beef EDM of Zhao *et al*. (2000) are both based on the theory outlined in Alston, Norton and Pardey (1995). Since both models are based on the same theoretical framework, we would expect both to provide equally reliable estimates of the returns to RD&E. However, there are some major differences in the way that the theory is implemented in the two studies. In addition, the data requirements are different in many respects. Thus, we need to test whether both models give simulation results of the same order of magnitude for the same sort of displacement. To do this, following Zhao *et al*. (2000), a 1 per cent decrease in the cost of supplying beef from all Australian states was simulated in the DREAM model developed here.

The estimated annual benefit from this simulation, after full adoption, was $62.4 million. This is about three times that estimated by Zhao *et al*. (2000) and about two times that reported in Farquharson *et al.* (2003). However, the apparent discrepancy can be readily explained. We know that the benefits from RD&E are closely related to the size of the target market for the RD&E, as measured by industry revenue (price*quantity). Compared to the approximately 50 per cent increase in values implied by the CPI indexing as used by Farquharson *et al*. (2003), actual 2001/02 farm level prices for cattle were more than double the 1992-1997 averages given in Zhao *et al*. (2000). In addition, export prices were some 25 per cent higher, and the size of the Australian beef industry was some 12 per cent larger (MLA 2003), than corresponding values used in Zhao *et al*. (2000). These changes in prices and quantities combine to increase industry revenue by almost threefold. 1 per cent of this revenue will be similarly increased by almost threefold - about three times the $19.6 million estimated by Zhao *et al.* (2000), and about double the $30 million used by Farquharson *et al*. (2003).

Thus, the DREAM model as implemented here generates a similar measure of the total benefits from RD&E in the Australian cattle and beef industry as that reported by Zhao *et al*. (2000) for the beef EDM, when the input data are correctly adjusted for the different base years. As such, it is expected to provide a credible basis for assessing the economic benefits of investing in the CRC for Beef Genetic Technologies.

5. A Review of Returns from Investments in Agricultural Research

Two crucial pieces of input data for the analysis of the benefits of the proposed CRC are the underlying rate of productivity improvement in the Australian beef industry and the expected rate of productivity improvement if the CRC proposal was funded. To assist in making some judgements about these inputs, a review of past studies on productivity growth and returns to RD&E investments in the livestock industries was undertaken.

Measured productivity growth in Australian broadacre agriculture between the mid-1970s and the mid-1990s averaged 2.7 per cent per year (Knopke, Strappazon and Mullen 1995). The performance of specialist producers within this broad category has varied from 0.9 per cent for the sheep industry to 1.0-1.5 per cent for the cattle industry to 3.4 per cent for the cropping industry. Since these are measured rates of growth, we can estimate the underlying *potential* rate of productivity improvement available to the beef industry to be in the order of about 5 per cent given anecdotal evidence of low adoption rates in the order of 25 per cent. Using these same data, Mullen and Cox (1995, 1996) and Cox, Mullen and Hu (1997) in a series of papers estimated that the return to Australia from public sector investments in broad-acre agriculture RD&E have been in the range of 15 to 40 per cent, over the period 1953-1994.

This is consistent with international studies of the returns to agricultural research investments. Alston *et al*. (2000) reviewed almost 300 studies of RD&E in agriculture which provided more than 1800 estimates of rates of return. The data period covered 1958 to 1998 and the studies came from a range of universities, government departments and international institutions across both the developed and developing worlds. The rate of return across all studies (with some extreme outliers excluded) ranged from -100 per cent to +910 per cent. The average was 59 per cent. The rate of return for livestock-only studies was not significantly different from this average, but that for research and extension together (47 per cent) was significantly less than for research-only studies. The authors went on to argue that the rate of return may be much lower than those reviewed, and may be closer to 10 per cent, because of measurement problems in many earlier studies.

Table 3. *Ex Ante* Appraisals of Livestock Industries Research and Extension Proposals

Nature of Project	Year	BCR/IRR
Pasture management		5
Pasture establishment		9
Bomoxynil tolerant sub-clover		24
Biological control of Paterson's Curse		38%
National forage conservation network - dairy	1999	6
Wool production from mixed lucerne/perennial grass pastures in Northern NSW	2000	3
Spring v's Autumn lambing in the Central West of NSW	1998	3
Sub-clover breeding		39
Cattle quality in South Africa	2000	11
Whole farm planning	2000	27

Source: Mullen and Vere (2003)

Table 4. *Ex Post* Evaluations of Livestock Industries Research and Extension Projects

Nature of Project	Year	BCR/IRR	
Grafton crossbreeding research	1992	8.5	13.5%
Trangie/Glen Innes growth rate selection in beef	1992	3.2	13.5%
Developing and using BREEDPLAN	2000	9	
Beef cattle genetics (selection and crossbreeding only) in Australia	2002	3.6	19%
Beef cattle genetics (all sources) in Australia	2002	28	
Net feed intake cluster of projects	2003	9.6	14%

Source: see references in the text

Rates of return information for some studies relating to Australian livestock industries are given in Tables 3 and 4. For example, a NSW Agriculture review of returns to the NSW beef industry from investments in selection and crossbreeding RD&E was conducted in 1992 as part of an RD&E program evaluation (Parnell *et al*. 1992). That review estimated that the Grafton crossbreeding program would yield a NPV of approximately $170 million by 2020, a BCR of 8.5:1 and an IRR of 13.5 per cent. Corresponding figures for the Trangie/Glen Innes growth rate selection program were $170 million, 3.2:1 and 13.5 per cent.

Graser and Barwick (2000) estimated a NPV of over $350 million and a BCR of over 9:1 for the genetic improvements from developing and using BREEDPLAN (1985-2005, 8 per cent discount rate).

Farquharson *et al*. (2003) estimated that over all sources of genetic gain, the total return to the Australian beef industry from genetic technologies since 1970 was $9.4bn against a total investment of $340m. The benefit/cost ratio for this investment is 28:1 over the last 30 years. The biggest contribution to this high benefit/cost ratio has been the infusion of better-adapted *Bos indicus* genetic material into the sub-tropical and tropical herd (although a less reliable method was used to estimate this class of benefits). But even if these northern adaptation benefits are ignored, and all costs are attributed to the other sources of value (within-breed selection, southern crossbreeding and changing breed mix in the south), beef genetics RD&E has generated a NPV of $921 million, a BCR of 3.7:1 and an IRR of over 19 per cent. When only the benefits to selection and cross-breeding are included, the rate of return calculated in this study is less than the average of the studies included in the Alston *et al.* (2000) report. However, the rate of return obviously would be much larger than the average if the benefits from the changing breed composition in the Northern herd were also included.

In a follow-up analysis, the economic performance of a terminal crossbreeding system based on Brahman cows and a tropically adapted composite herd were compared to a straight-bred Brahman herd (Burrow *et al*. 2003a). All systems were targeted to meet specifications of the grass-finished Japanese market. The production system modelled represented a typical individual central Queensland integrated breeding/finishing enterprise or a northern Australian vertically integrated enterprise with separate breeding and finishing properties. Due mainly to a reduced age of turnoff of crossbred and composite sale animals and an improved weaning rate in the composite herd, crossbred and composite herds returned a gross margin of $7 and $24 per Adult Equivalent (AE) respectively above that of the Brahman herd. These figures are equivalent to a 4 per cent and a 14 per cent improvement in profitability respectively. The benefits of changing 25 per cent of the existing 85 per cent of Brahmans in the northern Australian herd to either crossbreds or composites over a 10-year period were also examined. With no premium for carcass quality in crossbred and composite sale animals, annual benefits were $16m and $61m for crossbreds and composites in 2013. The cumulative present value of this shift over the 10-year period was $88m and $342m respectively, discounted at a nominal 7 per cent. When a potential 5c per kg premium for carcass quality was included, differences in annual benefits rose to $30m and $75m and cumulative present values to $168m and $421m for crossbreds and composites respectively.

A similar analysis was undertaken for the same crossbred and composite animals targeted at the 120 day grain-finished export market (Burrow *et al*. 2003b). The faster growth rate of the crossbred and composite herds and their improved feed efficiency resulted in a gross margin of $38 per AE respectively above that of the Brahman herd. These figures are equivalent to about a 22 per cent improvement in profitability. The gross margin increases by another $5 per AE if just 15 per cent of steers achieve a higher marbling score (worth 10c/kg) and by another $9 per AE if there were to be a 5c/kg premium for tenderness on an assumed 60 per cent of steers. Again, the benefits of changing 25 per cent of the existing 85 per cent of Brahmans in the northern Australian herd to either crossbreds or composites over a 10-year period were examined. With no tenderness premium in crossbred and composite sale animals, annual benefits were some $108m in 2013. The cumulative present value of this shift over the 10-year period was $600m, discounted at 7 per cent. When a 5c per kg premium for tenderness was included, differences in annual benefits rose to $130m and cumulative present values to $730m for crossbreds and composites.

A recent study examined the return on investments in a cluster of projects associated with net feed intake (Griffith *et al.* 2004). Comparing the benefits to all recipients in southern Australia relative to the costs incurred by all RD&E suppliers resulted in an NPV of $176.7 million, an IRR of 14 per cent and a BCR of 9.6. Again, while the aggregate benefits are of course much smaller, the rates of return match those found for selection and crossbreeding in the Farquharson *et al*. (2003) study.

In other industries, during 1991/92 the Grains Research and Development Corporation commissioned an independent economic analysis of 16 selected grains RD&E projects undertaken over the previous 15 years (GRDC 1992). Using a 10 per cent discount rate, the benefit cost ratios ranged from 3:1 to 297:1, the rates of return ranged from 34 per cent to 561 per cent, and the aggregate present values of the benefits exceeded the aggregate present values of the costs by just over $1 billion.

In summary, we estimate that the underlying potential rate of productivity improvement available to the beef industry is in the order of about 5 per cent pa. Evaluations of specific livestock sector RD&E projects undertaken in Australia and overseas suggest IRRs in the range 10-20 per cent and BCRs in the range 3-10. Beef genetics studies have generally fallen within the suggested ranges, excluding the very high rates of return estimated from first the Brahman infusion into Northern Australia and then the potential shift into composite breeds. These two areas of RD&E suggest rates of productivity improvement in the order of 25-30 per cent, but the first at least has been and gone.

6. Defining the With-CRC and Without-CRC Scenarios

Given the "top-down" approach to the analysis discussed earlier, we discussed the potential outcomes with a wide range of people involved in the CRC renewal process and most of the assumptions made below are based on the consensus views from these discussions.

6.1 Resource Availability

We take the total cost for the CRC to be $110m over the seven year life of the CRC, made up of $30m in CRC funding, $5m in private sector cash contributions, and $75m in in-kind contributions[4].

If the CRC was not funded, our estimate of the total cost of an alternative seven year RD&E program is $65m, made up of $5m in private sector cash contributions (essentially MLA funding) and $60m in in-kind contributions from the currently cooperating agencies involved in beef industry RD&E. Staff in industry organisations and in specified programs of some agencies such as State Departments would mostly continue to be involved in beef industry RD&E irrespective of the existence of a renewed CRC, as would other in-kind resources such as cattle and land. However, staff in other agencies like CSIRO or universities or foreign partners would have greater flexibility to change direction and undertake RD&E in other industries. Our assessment is that some 80 per cent of in-kind resources would still be involved in beef industry RD&E activities if the CRC for Beef Genetic Technologies was not funded.

6.2 Rates of Productivity Improvement

As noted above, we estimate that the underlying potential rate of productivity improvement available to the beef industry is in the order of about 5 per cent pa. This is based on documented measured rates of productivity improvement of 1.0-1.5 per cent pa and low rates of adoption of new technologies by the beef industry in the order of 25 per cent (MLA, pers. com. 2004).

We estimate the aggregate impact of the renewed CRC on the Australian cattle and beef industry to be an additional 4 per cent in the potential annual rate of productivity improvement. This would occur after maximum adoption of the research outcomes of the CRC. Such a figure reflects recent estimates of the benefits of specific genetic technologies (for example Burrow *et al*. 2003, Farquharson *et al*. 2003, Griffith *et al*. 2004), the strong expectations by the scientists involved that CRC funding would provide the resources necessary to repeat these types of successes in the future, and the estimates by Manson and Black (2004) that 95 per cent of the measured rates of productivity improvement in the Australian beef industry are attributable to RD&E investment (see also Wilson 2006). For example, the huge benefit captured by the Northern Australian beef industry from infusing *Bos indicus* genes (some $8.1 billion in present value terms over the past 30 years or so), was based on an improvement in herd gross margin of some 50 per cent (Farquharson *et al*. 2003, p26). This converts into an implied productivity improvement of about 16 per cent for that production system. Similarly, the potential huge benefit of moving into composite cattle in the

[4] These were the confirmed contributions as at March 2004, valued in 2004 dollars (not discounted). New partners that have committed since then have increased the total cost to over $121m (see Appendix B).

Northern herd is based on improvements in herd gross margins of 14 per cent for grass-finishing and 22 per cent for grain-finishing. These figures imply an improvement in productivity of between 5 and 8 per cent for that production system. Taking account of the high expectations of the scientists involved, the risks involved in achieving such high payoff outcomes again, and the Davidson and Martin (1965) rule that experimental outcomes be discounted by a third when applied in commercial farming systems, a conservative estimate of a 4 per cent addition to the potential annual rate of productivity improvement, was selected[5].

6.3 Distribution of the Overall Rates of Productivity Improvement

The wide range of participants in the renewal process reached some consensus on the relative contributions of each of the seven major outcome areas to the success of the new CRC. We use these consensus estimates to allocate the selected overall potential rate of productivity improvement across different types of impacts based on the RD&E activities in the various proposed programs of research. These shares are shown in the central column of Table 5, that is, 20 per cent of the total productivity impact from the beef quality improvement outcome, 10 per cent from the reduced feed cost outcome, etc. We take these overall allocations to relate to the whole Australian industry. Based on the material provided for each of the science programs in the Prospectus document (CRC for Cattle and Beef Quality 2004), we have further allocated these impacts as cost-saving (C), yield-increasing (Y) or demand-enhancing (D), and as applying to either the Northern industry, the Southern industry, or to both. These allocations are shown on the left-hand-side of Table 5.

Therefore, due to the expected impacts of the proposed CRC, on the left-hand side of the table we are assuming an overall 9 per cent potential rate of growth in productivity in the Australian cattle and beef industry, or an increase of 4 percentage points on the estimated underlying rate of potential productivity growth. This 9 per cent figure is then allocated across the various impact areas according to the proportions shown in the centre column. Thus, in the first data row of the table, 20 per cent of the 9 per cent overall figure, or 1.8 per cent, is estimated to be due to increased beef quality (Program 1). Half of this 1.8 per cent is assumed to directly influence consumer demand[6]; the other half is assumed to be reflected in reduced transactions costs throughout the marketing chain. These costs are further assumed to be split 50:50 between the north and the south, and with cattle numbers assumed to be approximately 50:50 between the north and the south over the simulation period, each region has the same cost saving of 0.9 per cent. The impact areas of increased yield, increased reproduction rates and

[5] Although a 9 per cent rate of potential productivity improvement seems large, when this rate is multiplied by the expected adoption level of 35 per cent it is noteworthy that the implied actual or measured rate of productivity improvement is only just over 3 per cent. The Australian grains industry exceeded 3 per cent annual productivity growth long ago, and according to the latest ABARE data, the northern Australian beef industry is close to 3 per cent already.

[6] MLA (2002) argue that the recent increase in domestic beef quality has slowed the decline in per capita beef consumption in Australia.

Table 5. Specific Assumptions about RD&E Impacts

With-CRC (9% potential productivity improvement)			Component of Growth	Without-CRC (5% potential productivity improvement)		
North C or Y	**South C or Y**	**Demand D**	**(aggregate share of each component in brackets)**	**Demand D**	**North C or Y**	**South C or Y**
C (0.9)	C (0.9)	D (0.9)	Increased beef quality (0.2)	D (0.5)	C (0.4)	C (0.4)
C (0.45)	C (1.35)		Reduced feed cost (0.1)		C(0.2)	C (0.8)
C (1.8)	C (0)		Reduced parasite input costs (0.1)		C (0)	
		D (0.9)	Increased market access (0.1)	D (0.5)		
Y (0.9)	Y (0.9)		Increased meat yield (0.1)		Y (0.6)	Y (0.9)
Y (2.7)	Y (2.7)		Increased reproduction rate (0.3)		Y (2.0)	Y (1.0)
C (0.9)	C (0.9)		Misc. enhanced management (0.1)		C (0.9)	C (0.9)

Note: as the details of the operational plans for the various programs have been developed, it is clear that some of the initial allocations of impact across regions in particular will need to be revised. For example, the meat science RD&E in Program 1 is now targeted much more in the south than the north, while the female reproduction RD&E in Program 4 is now targeted much more in the north than in the south.

miscellaneous management are treated in the same way. Reduced input costs are assumed to have an impact only in the north, so the impact there has to be twice as large as the aggregate national impact of 0.9 per cent. Conversely, reduced feed costs (Program 2) are assumed to have differential impacts in the north and south, but mainly in the south, so their impacts have to average out at 0.9 per cent. Increased market access only impacts on demand.

To summarise, in the with-CRC scenario, the components of the 9 per cent potential productivity growth that go into the DREAM model include:

- a 1.8 per cent increase in demand for Australian beef in the domestic market and in Australia's share of high value export markets (Japan and Korea),
- a 4.05 per cent decrease in the cost of producing Australian beef in the North,
- a 3.15 per cent decrease in the cost of producing Australian beef in the South,
- additionally, a 3.6 per cent increase in output in the North, and
- additionally, a 3.6 per cent increase in output in the South.

In the absence of any funding from the Commonwealth CRC program from 2006 onwards, we have assumed that some of the planned RD&E would still be done, some would be partially done and some would never be done. Our estimate is that the current underlying rate of potential productivity gain would be just maintained, that is, at around 5 per cent. Further, based on discussions with several groups of the scientists involved in the process, our estimates of the expected changes in the various components of the overall program are given on the right-hand-side of Table 5.

Without CRC funding, on the right-hand side of the table we are assuming a continuation of the current overall 5 per cent potential rate of growth in productivity in the Australian cattle and beef industry. In a similar way as described above, this 5 per cent figure is then allocated across the various impact or outcome areas according to the proportions shown in the centre column. Thus, 20 per cent of the 5 per cent overall figure, or 1.0 per cent, is estimated to be due to increased beef quality. Half of this is assumed to directly influence consumer demand, and the other half is assumed to be reflected in reduced transactions costs throughout the marketing chain. However, this is an area of RD&E that would suffer proportionally more from the lack of funds and the impact on costs would not be 0.5. There is a similar expected reduction in impact in the area of reduced parasite input costs. Both of these areas rely heavily on the gene expression and gene discovery infrastructure proposed in the new CRC. These areas are offset by assumed greater than proportional impacts in increased meat yield, in reduced feed costs in the South (as the NFI work progresses) and in cost savings due to miscellaneous enhanced management (traditional areas of RD&E by State Departments that would continue without CRC funding).

To summarise, due to the expected impacts of an alternative RD&E program that would go ahead if the proposed CRC was not funded, we are assuming:

- a 1.0 per cent increase in demand for Australian beef in the domestic market and in Australia's share of high value export markets (Japan and Korea),
- a 1.5 per cent decrease in the cost of producing Australian beef in the North,
- a 2.1 per cent decrease in the cost of producing Australian beef in the South,
- additionally. a 2.6 per cent increase in output in the North, and
- additionally, a 1.9 per cent increase in output in the South.

6.4 Adoption Profiles

It is well known that beef cattle genetic technologies take a long time to produce measurable change. By their nature they have very small initial impacts that slowly accumulate in the population over time. For example, Farquharson *et al*. (2003) examined changes in BREEDPLAN genetic parameters between 1985 and 2000 and found only small changes in weight measures. There were no measurable changes in carcase quality traits by 2000, even though the R&D on these had commenced at least a decade earlier. Griffith *et al.* (2004) calculated that after 25 years of adopting net feed intake technology, the improvement in the net feed intake of a typical southern Australian herd was only 6.9 per cent.

However, here we are allowing CRC commercialization and adoption strategies, and to a lesser extent the commercialization and adoption strategies in an alternate RD&E program, to also contribute to the adoption of existing pipeline stocks of technologies produced from previous CRCs or elsewhere. Thus it is expected that there would be some measurable change in adoption of new technologies, attributable to CRC activity, in the short to medium term.

So in the without-CRC scenario, we assume that adoption rates and adoption levels will continue on from current levels in a similar way that the current underlying rate of potential productivity improvement will continue. Although there is no published evidence on these parameters, based on discussions with research and extension staff we assume a 7-year R&D lag, a maximum adoption level of 25 per cent, and a 5-year lag till that level is reached. That is, the maximum annual benefit is achieved in 2017/18.

In the with-CRC scenario, there is an explicit focus on accelerated adoption methodologies and industry take-up of the outcomes generated (in particular, a continuous improvement and innovation cycle), and the RD&E itself will be more coordinated and intense. Because of these factors, there are expected to be shorter lags in achieving results and in industry adopting them, and an overall higher level of industry adoption (see Vere *et al*. 2003 for similar assumptions in relation to Weeds CRC activities). Thus, we assume a 5-year R&D lag, a maximum adoption level of 35 per cent, and a 2-year lag till that level is reached. That is, the maximum annual benefit is achieved in 2012/13.

With the lack of specific resources for equipment, etc, we are also assuming that the overall quality of the R&D would be slightly diminished, with slightly lower probabilities of successful outputs, in the without-CRC scenario.

One factor not able to be taken into account is the risk associated with the different approaches to commercialization and adoption. There is an argument that because the continuous improvement and innovation approach is an inclusive, participatory technique, and it allows producers to decide on their own course of action, they may not decide to adopt any CRC technologies (see Murray 2000). This suggests a higher risk of non-achievement of the specified adoption outcomes. However, we believe that this risk has been minimized by the inclusion of many different agencies in the commercialization and adoption program of the CRC and the overall design of the strategy to be followed.

The adoption assumptions, and common assumptions across all assessments, are given in Table 6.

Table 6. Common Assumptions for the Benefit Cost Analysis

Item	**Without-CRC**	**With-CRC**
Base year	2006	2006
Simulation period (years)	25	25
Real discount rate (%)	4.00	4.00
Probability of success (%)	70	80
RD&E lag (years)	7	5
Adoption lag (years)	5	2
Maximum adoption level (%)	25	35
Dis-adoption lag (years)	None	None
Price linkages (L) between regions (0<L<1)	Imperfect (L around 0.8)	Imperfect (L around 0.8)
Technology spillovers (S) between regions (0<S<1)	Allowed within Australia but not between Australia and other countries	Allowed within Australia but not between Australia and other countries

7. Aggregate Benefits and Costs

The DREAM modelling framework described and tested above was simulated under four separate scenarios, that is, the with- and without-CRC scenarios for each of the demand and supply shifts. As noted above, in the DREAM framework it is not possible to jointly model more than one type of shift, one type of product, or one type of market environment. These results are reported in Table 7 and 8 for the with-CRC and without-CRC scenarios, respectively.

7.1 The With-CRC Scenario

In the with-CRC scenario, the total benefits from the demand-enhancing components of the portfolio have a present value of about $593m when summed over the 25-year period of the simulation. More than half of these benefits accrue to consumers in export markets because of the greater size of these markets and the higher prices that consumers in these markets are willing to pay for higher quality, compared to Australian consumers. Producers in our export markets, and in competing supply regions, also gain from this investment since the overall demand for beef is increased and they are large suppliers to these markets. Domestic producers and consumers gain about $125m from these impact areas. The annual benefit of this set of impacts is $55m after reaching maximum adoption levels, with about $12m accruing in Australia.

Table 7. Results for the With-CRC Scenarios, 2006-2030, PV ($M)

Shift	**Region**	**Producer Benefits**	**Consumer Benefits**	**Total Benefits**
Demand	Northern Australia	5	21	26
	Southern Australia	5	95	100
	Export markets	152	315	467
	All markets	162	431	593
Supply	Northern Australia	691	1	692
	Southern Australia	628	5	633
	Export markets	-299	311	12
	All markets	1020	317	1337
TOTAL		1182	748	1930

The total benefits from the cost-reducing and yield-increasing components of the portfolio have a present value of about $1.337b when summed over the 25-year period of the simulation. The great majority of these benefits accrue to cattle producers in Australia because they have direct access to the new technologies. Consumers in our export markets are also beneficiaries as they have access to more beef at lower prices. However, producers in competing supply regions lose from the research program since they suffer the consequence of an overall fall in prices but do not have the cost savings from the technologies to compensate. The annual benefit of this set of impacts is about $124m after reaching maximum adoption levels, with almost all of this accruing in Australia.

Total estimated benefits from the with-CRC scenarios therefore are in the order of $1.930b. The present value of the full costs of the CRC program (nominally $110m) is $98m when discounted. This results in a NPV of $1.831b ($1.930b - $98m) and a BCR of 19.65:1 ($1.930b/$98m). Thus the proposed research portfolio of the CRC for Beef Genetic Technologies is expected to return around $20 to the Australian beef industry for every $1 invested from all sources.

Since the demand-side and supply-side simulations have to be run separately, we are not able to calculate an IRR for the whole RD&E portfolio. However, if all of the $98m in costs were set against the cost-saving and yield-increasing impact areas, this would generate a BCR of 13.6:1 and an IRR of 47.8 per cent.

7.2 The Without-CRC Scenario

In the without-CRC scenarios, the pattern of benefits is much the same as in the with-CRC scenarios although the magnitudes are of course lower. Total benefits from the demand-enhancing components of the portfolio have a present value of around $156m when summed

Table 8. Results for the Without-CRC Scenarios, 2006-2030, PV ($M)

Shift	Region	Producer Benefits	Consumer Benefits	Total Benefits
Demand	Northern Australia	1	6	7
	Southern Australia	1	25	26
	Export markets	40	83	123
	All markets	43	114	156
Supply	Northern Australia	177	0	177
	Southern Australia	177	1	179
	Export markets	-81	84	3
	All markets	273	86	359
TOTAL		316	200	516

over the 25-year period of the simulation, but most of these accrue to foreign producers and consumers and only $33m accrues to the domestic industry. The annual benefit reaches $19m at maximum adoption levels, $4m of which accrues to the domestic industry. Total benefits from the cost-reducing and yield-increasing components of the portfolio have a present value of almost $360m, with an annual benefit at full adoption of around $44m. Almost all of this accrues to the domestic industry.

With total estimated benefits of $516m and total costs of $58m, the NPV is $458m and the BCR is 8.9:1. If the CRC were not funded and an alternative RD&E program was developed along the lines as that assumed here, with funding restricted to some $65m over seven years, it is estimated that this program would only return about $9 for every $1 invested. Again, we are not able to calculate an IRR for the whole RD&E portfolio, but if we assume all of the $58m in costs were set against the cost-saving and yield-increasing impact areas, this would generate a BCR of 6.2:1 and an IRR of 22.4 per cent.

7.3 The Marginal Returns

We are primarily interested in the differences between these two scenarios, that is, the marginal returns from the marginal investment. These are shown in Table 9.

Table 9. Differences Between the With-CRC and Without-CRC Scenarios, PV and NPV ($m)

Scenario	Region	Producer Benefits	Consumer Benefits	Total Benefits	Total Cost	NPV	BCR
With-CRC	Total Market	1182	748	1930	98	1832	20
Without-CRC	Total Market	316	200	516	58	458	9
Difference		**865**	**548**	**1414**	**40**	**1374**	**35**

Under the assumptions made in this assessment, investing $30m of taxpayer funds into the CRC for Beef Genetic Technologies will leverage another $15m of in-kind contributions from research providers (see Section 6.1). This is relative to a scenario where an alternative, lower cost research program into the Australian cattle and beef industry is implemented. These extra resources have a discounted value of about $40m over the period of the analysis undertaken here. These resources are sufficient to allow some new research components to be added to the portfolio, some existing components to produce better outcomes, and a more targeted approach to development and extension that speeds up and increases the adoption of the new technologies that are generated by the research program.

As shown in Table 9 the benefit from this extra investment and consequent research effort is estimated to be worth over $1.4b in present value terms, far in excess of the marginal investment of $40m. Thus every $1 of these extra resources brought into the Australian beef industry through funding the CRC for Beef Genetic Technologies is expected to return around $35 to the industry. Recall that in the context used here, the Australian beef industry includes cattle breeders through to beef consumers, both domestically and internationally.

It is useful to reflect on how these results fit into what is already known about the returns from beef cattle genetics programs. Some of the data reported in Tables 3 and 4, and in other reports mentioned above, are summarised in Table 10. It is apparent that both the with-CRC and without-CRC results fit comfortably in the ranges of outcomes covered in the table. In particular, the BCR and IRR calculated for the with-CRC scenarios are of similar orders of magnitude to other large programs of RD&E such as all previous beef cattle genetics R&D, all broad-acre agriculture, and all ARC projects.

Table 10. Comparison with Previous Research Evaluations

Project	**Year**	**BCR**	**IRR (%)**
Grafton crossbreeding research	1992	8.5	13.5
Trangie/Glen Innes growth rate selection in beef	1992	3.2	13.5
Developing and using BREEDPLAN	2000	9	
Beef cattle genetics (selection and crossbreeding			
only) in Australia	2002	3.6	19
Beef cattle genetics (all sources) in Australia	2002	28	
Net feed intake cluster of projects	2003	9.6	14
Composite grass-fed in the North	2003	Profit increased 14%	
Composite grain-fed in the North	2003	Profit increased 22%	
All broad-acre agriculture	1995		42
All ARC projects	2003		39 and 50
CRC for Beef Genetic Technologies	**2004**	**20**	**47.8 (supply shift only)**

Note: see the text for appropriate references

8. Benefits to the New South Wales Beef Industry

New South Wales is defined as a separate region in the DREAM analysis (Tables 1 and 2), and therefore there are consumer and producer benefits calculated separately for it. These values provide the first part of the information needed to evaluate whether investment in the CRC for Beef Genetic Technologies will generate positive returns to the NSW beef industry (including cattle breeders through to beef consumers), and to the NSW economy.

8.1 The With-CRC Scenario

In the with-CRC scenario, the benefits to the NSW beef industry from the demand-enhancing components of the portfolio have a present value of about $51m when summed over the 25-year period of the simulation (see Table 11). The great majority of these benefits accrue to consumers (about $49m). The annual benefit of this set of impacts to the NSW industry is about $4.7m after reaching maximum adoption levels.

Table 11. Results for the With-CRC Scenarios, NSW, 2006-2030, PV ($M)

Shift	**Region**	**Producer Benefits**	**Consumer Benefits**	**Total Benefits**
Demand	NSW	2	49	51
	All Australia	10	116	126
Supply	NSW	296	3	299
	All Australia	1319	6	1325
TOTAL	NSW	298	52	350
	All Australia	1329	122	1451

The benefits to the NSW beef industry from the cost-reducing and yield-increasing components of the portfolio have a present value of about $299m. The great majority of these benefits accrue to cattle producers in NSW. The annual benefit of this set of impacts is about $28m after reaching maximum adoption levels.

Therefore, the total estimated benefits to the NSW industry from the with-CRC scenarios are in the order of $350m in present value terms, or about $33m annually once full adoption is achieved. These benefits represent some 24 per cent of the benefits accruing to all Australian beef producers and consumers. The NSW consumer share is considerably higher than this (40 per cent), reflecting the relatively high NSW population, while the NSW producer share is a little lower than this (23 per cent), closely approximating the share of beef produced in NSW (Table 1).

8.2 The Without-CRC Scenario

In the without-CRC scenarios, the pattern of benefits to the NSW beef industry is much the same as in the with-CRC scenarios although the magnitudes are again lower (see Table 12).

Total benefits to the NSW beef industry from the demand-enhancing components of the portfolio have a present value of around $13.5m with an annual return of just over $1.5m, while the benefits to NSW from the cost-reducing and yield-increasing components of the portfolio have a present value of $84.5m, with an annual benefit at full adoption of around $10.2m. The total benefits to the NSW industry from the without-CRC scenario are $99m with an annual return of about $11.7m.

Table 12. Results for the Without-CRC Scenarios, NSW, 2006-2030, PV ($M)

Shift	Region	Producer Benefits	Consumer Benefits	Total Benefits
Demand	NSW	1	13	14
	All Australia	3	30	33
Supply	NSW	84	1	85
	All Australia	354	2	356
TOTAL	NSW	85	14	99
	All Australia	357	32	389

In the without-CRC case, NSW has a slightly higher share of the benefits (25 per cent) accruing to all Australian beef producers and consumers because the Northern Australian industry has a stronger focus in the with-CRC scenario than in the without.

8.3 The Marginal Returns

The marginal returns to the NSW beef industry from funding the CRC are shown in Table 13. Under the assumptions made in this assessment, investing $30m of taxpayer funds into the CRC for Beef Genetic Technologies and leveraging another $15m of in-kind contributions from research providers will generate an additional $251m in economic benefits to the cattle producers, beef processors and marketers, and beef consumers of NSW, in present value terms. This translates to an additional $21m per annum after full adoption is reached.

Table 13. Differences Between the With-CRC and Without-CRC Scenarios, NSW, PV and NPV ($m)

Scenario	Region	Producer Benefits	Consumer Benefits	Total Benefits
With-CRC	NSW	298	52	350
Without-CRC	NSW	85	14	99
Difference	**NSW**	**213**	**38**	**251**

The 25,200 commercial beef producers in NSW in 2001/02 (that is, those who met the ABS criteria of greater than $5,000 in gross value of production from beef cattle) would therefore gain about $700 each per annum on average from NSW DPI investment in the CRC, after full adoption is reached, or about $8,500 in total over the 25 year evaluation period.

The 6.5m people who lived in NSW in 2001/02 would gain about $0.50 each per annum on average from their beef consumption activity, after full adoption, or about $5.85 in total over the 25 year evaluation period.

9. The Cost to New South Wales of Being a Core Partner in the Beef CRC

9.1 The With-CRC Scenario

The cash and in-kind resources contributed by each of the 19 core and supporting partners in the CRC are detailed in Appendix B (CRC for Cattle and Beef Quality 2004). Table 1A provides these details for each of the four research programs, while Table 1B provides the details for the education, commercialisation and administration components of the portfolio, as well as the overall totals.

According to the data in these tables:

- Program 1 accounts for 21.7 per cent of participants in-kind & cash resources and is assumed to receive a total budget of $6.8m;
- Program 2 accounts for 26.3 per cent of participants in-kind & cash resources and is assumed to receive a total budget of $6.3m;
- Program 3 accounts for 16.2 per cent of participants in-kind & cash resources and is assumed to receive a total budget of $5.8m;
- Program 4 accounts for 20.8 per cent of participants in-kind & cash resources and is assumed to receive a total budget of $7.2m;
- Education accounts for 3.7 per cent of participants in-kind & cash resources and is assumed to receive a total budget of $3.1m;
- Commercialisation accounts for 9.7 per cent of participants in-kind & cash resources and is assumed to receive a total budget of $8.2m, and
- Administration accounts for 1.7 per cent of participants in-kind & cash resources and is assumed to receive a total budget of $4.1m.

NSW DPI is the third largest investor in the CRC, contributing 10.1 per cent of the total resources, only marginally behind QLD DPI (11.0 per cent) and CSIRO (10.4 per cent). This is made up of $38,000 in cash and $9.226m in in-kind contributions. NSW DPI's in-kind contribution is based on the value of 4.7 FTE/year (3.7 research FTE, 1.0 extension FTE), plus half the value of AGBU's contribution of 3 FTE/year. This sums to 6.2 FTE over 7 years, or 43.4 FTE in total. While research staff, extension staff and technical staff are valued differently in such calculations, the average is in the order of $212,000 per FTE per year.

NSW DPI's major investment is $5.135m in Program 2. This represents 55 per cent of the total NSW DPI contribution and 25 per cent of the total in-kind investment in this Program. NSW DPI has a lesser role in Program 1 ($1.497m, or 8.2 per cent of the total in-kind investment in this Program) and in Commercialisation ($1.670m, but 25 per cent of the in-kind investment in this program) and only very minor roles in Program 3 ($111,000) and in Program 4 ($851,000).

The in-kind resources and their shares contributed by each of the 19 core and supporting partners in the CRC, and the expected distribution of CRC and participant cash contributions, are detailed in Appendix Table 2A for each of the four research programs. Table 2B provides these details for the research programs in total, the commercialisation program, as well as the overall totals.

If it is assumed (as in these Tables) that funds are allocated on the basis of shares of in-kind contributions, NSW DPI is expected to receive up to $556,000 of the available operating funds for Program 1, up to $1.571m of the available operating funds for Program 2, up to $2.066m of the available operating funds for the Commercialisation program, and about $400,000 for the other programs. Overall, NSW DPI will provide 12.2 per cent of the total in-kind investment across the four research programs and the Commercialisation program, and is expected to receive up to $4.591m (13.4 per cent) of the available operating funds for these programs. These available operating funds include the $30m Commonwealth investment plus the $11.452m cash contributions from core and supporting partners (Table 1B).

Thus, in the with-CRC scenario, NSW DPI is contributing $9.264m to the CRC for Beef Genetic Technologies over its seven year term, and is expecting to receive $4.591m from the CRC to undertake the specified RD&E projects. Therefore, there is a total expenditure of $13.855m by NSW DPI from its involvement in the CRC for Beef Genetic Technologies.

Given the benefit flowing to the NSW beef industry from the with-CRC scenario is $350m (Table 10), this results in a NPV of $336m and a BCR of just over 25.0:1.

9.2 The Without-CRC Scenario

As outlined in section 6.1, if the CRC was not funded, we estimated the total cost of an alternative seven year RD&E program to be $65m, made up of $5m in private sector cash contributions (essentially MLA funding) and $60m in in-kind contributions from the currently cooperating agencies involved in beef industry. Our assessment was that some 80 per cent of in-kind resources would still be involved in beef industry RD&E activities, on average across all of the agencies involved, if the CRC for Beef Genetic Technologies was not funded.

Applying these assumptions to the NSW DPI contributions (probably a very conservative assumption), we expect that in the without-CRC scenario, NSW DPI would contribute $7.380m over the seven year term of an alternate RD&E program (80 per cent of the $9.226m of in-kind contributions to the CRC), and would receive about $2.690m to undertake the specified RD&E projects (essentially MLA cash contributions to Program 2 RD&E - where NSW DPI is a world leader - and a quarter share of the MLA contributions to the CRC's commercialisation program). There is therefore an estimated expenditure of $10.070m by NSW DPI from its expected involvement in an alternate RD&E program that would have been put in place if the CRC for Beef Genetic Technologies was not funded.

Given the benefit flowing to the NSW beef industry from the without-CRC scenario is $99m (Table 11), this results in a NPV of $89m and a BCR of just under 9.9:1.

9.3 The Marginal Returns

From Table 12 there is a net return to the NSW beef industry of $251m from CRC programs, and from the information provided above there is a net cost of $3.785m required to fund the involvement of NSW DPI as a core partner. So while the marginal cost to NSW DPI of being involved in the CRC is minimal, the anticipated benefits are substantial. The marginal NPV is $247m and the marginal BCR is 66:1. This is a consequence of the cooperative nature of CRC investments and programs, where much greater outcomes can be achieved jointly than individually.

10. Discussion

From section 8.3, the marginal return to the NSW beef industry from funding the CRC is an additional $251m in economic benefits to the cattle producers, beef processors and marketers, and beef consumers of this state, in present value terms. This translates to an additional $21m per annum after full adoption is reached. From section 9.2 above, the extra cost of being a partner in the CRC is $3.785m. The marginal NPV is therefore $247m and the marginal BCR is 66:1.

The NSW BCRs from the with-CRC scenario, the without-CRC scenario and the marginal analysis are broadly in line, although a little bit higher, with those from the aggregate analysis reported in section 7, while the NSW NPVs are broadly in line with the NSW share of the total Australian beef production.

However, there are other sets of benefits that are not yet counted, and these are described in the following sub-sections.

10.1 Benefits to the Broader NSW Economy

The estimated aggregate annual benefits *to the Australian cattle and beef industry* from the without-CRC scenario (section 7.2) are based on an underlying 5 per cent productivity improvement, and these equal $44m annually at a 25 per cent adoption rate. Results from simulations with the updated MONASH model of the national economy (Wittwer 2003) show that a 5 per cent productivity improvement in the beef cattle industry generates an annual benefit to the national economy of $133m, and a 5 per cent productivity improvement in the beef processing industry generates an annual benefit to the national economy of $122m. Summing these two areas of impact and dividing by the same adoption rate as assumed in the without-CRC analysis (25 per cent) gives a benefit to the national economy of $64m annually. Thus, from a 5 per cent potential productivity shock adopted by 25 per cent of the beef industry, there is a benefit of $44m pa accruing to the beef industry (from the DREAM analysis reported here), and an additional benefit of $20m pa accruing to other sectors of the Australian economy (from the MONASH simulations). That is, a multiplier of about 45 per cent.

There is no reason to believe that a multiplier of a similar magnitude cannot be applied to a productivity shock of 9 per cent as in the with-CRC case, or to the net benefits between the two scenarios. For the marginal investment by the Commonwealth (with-CRC case minus without-CRC case), this would imply an extra $600m in benefits to the Australian economy, in present value terms, above and beyond those benefits accruing to the broader cattle and beef industry.

For the marginal return to the NSW beef industry from funding the CRC of $247m, this would imply an extra $111m in benefits to the NSW economy, beyond those accruing to the cattle producers, beef processors and marketers, and beef consumers of NSW, in present value terms.

10.2 Environmental Benefits

As described in Appendix A, there are a number of environmental outcomes expected from the Beef CRC. In Program 2, there is an explicit focus on net feed intake (NFI) in the breeding herd, and on decreasing methane emissions from beef cattle. In Program 3, there is an explicit focus on reduced parasite control costs and on improvements in animal welfare.

There are now well-established theoretical and experimental links between selection for improved NFI and a significant reduction in methane emissions per day and per unit of liveweight gained (Griffith *et al*. 2004). The experimental work showed that steers eating less feed produced less methane, and that steers that were low methane producers on one occasion were, in most cases, low methane producers subsequently when tested on the same diet.

So if a cattle producer purchases NFI superior genetics, then over time the herd will require less feed to maintain the same herd size and farm income. As explained in Griffith *et al*. (2004), for a sustainability-oriented producer, this would result in a lower stocking rate and may provide some environmental benefits to the farm in terms of better ground cover, greater water-holding capability and less grazing pressure on preferred pasture species. Superior NFI cattle will also produce less manure and urea and more easily cope with drought conditions.

Alternatively, a profit-maximising producer may wish to increase the size of the herd and increase farm income (Alford *et al*. 2004). The pasture base may be no worse off than before the NFI genetics were introduced, but some of the other environmental indicators may be compromised by the higher stocking rate, such as soil compaction.

In more recent work, Alford *et al*. (2006) developed a geneflow model to simulate the spread of improved NFI genes through a breeding herd over 25 years. Based on the estimated geneflow, the voluntary feed intakes were revised annually for all beef classes in the model using livestock populations within Australia's National Greenhouse Gas Inventory. Changes in emissions (kg methane/animal/year) associated with the reduction in feed intake were then calculated. Annual enteric methane emission from both the individual and national herd were calculated by multiplying the livestock numbers in each beef class by the revised estimates of emissions per animal. For the national herd, differential lags and limits to adoption were assumed for Northern and Southern Australia. The cumulative reduction in national emissions was calculated to be 568.1 Gigagrams (Gg) of methane over 25 years, with the annual emission in year 25 being 3.1 per cent lower than in year 1. It was concluded that selection for improved NFI will lead to substantial and lasting methane abatement and this is largely a consequence of its implementation as a breeding objective for the grazing herd.

It is possible to estimate an economic value for this reduction in methane emissions. The estimated 568.1Gg of methane equals 568,100 tonnes of methane, and there are 21 tonnes of CO2 for every 1 tonne of methane. According to the NSW Independent Pricing and Regulatory Tribunal (2005), under the NSW Greenhouse Gas Abatement Scheme the current penalty for NSW power generators exceeding their target level of CO2 emissions is $10.50 per tonne of CO2. Thus a minimum value for the saved methane output due to adoption of NFI genetics in the national beef herd is a little over $125m. In more mature carbon markets such as in Europe, the price of CO2 has recently hit 20 Euros per tonne. At this price and at current exchange rates, the value of the reduction in methane emissions due to the adoption of NFI could be as high as $375m across the national herd over a 25 year period. Even at the lower CO2 price, the share of this benefit accruing to the NSW beef industry is in the order of $28m, over the 25 year simulation period. A substantial portion of this value could be assigned to the new CRC given its explicit focus on further development of the NFI technology and on accelerated adoption.

Some economic benefits from the Program 3 focus on reduced parasite control costs through genetic selection have already been included in the modelling described above, but there would be additional environmental outcomes from the reduced use of chemical control measures for parasites. While most of this benefit would accrue to northern Australia, there would be some spill-over benefits to the north coast of NSW.

10.3 Social Benefits

Social outcomes from the RD&E in this area of work are very difficult to identify and to quantify. There is likely to be minimal change to farming practices when adopting Beef CRC technologies and there is even less change likely to regional incomes or to regional communities, over and above those changes to cattle producers and beef consumers.

One potential social impact is that because most of the technology is being developed in Australia, the cattle industry will not have to rely as much on imported genetics and there may be a more vibrant set of breed societies and industry organisations because of this. This may also result in greater export opportunities. Further, there is a strong focus on adaptability which means that cattle selected for these traits can cope more readily with dry conditions, management can be more flexible and the beef industry would not be as adversely affected by droughts. This may provide some social benefits during such times. In addition, given an emphasis on focus groups and capacity building as part of the accelerated adoption focus, it would be expected that NSW beef producers would gain better management and marketing skills, and that the focus groups might provide for more cohesive local communities. Finally, since NSW Department of Primary Industries staff members are world leaders in some of these areas of work, there is some broader social benefit from knowing that NSW Department of Primary Industries staff are being well trained, are engaged in path-breaking research and are effectively contributing to industry and community outcomes. These outcomes (especially those related to net feed intake and greenhouse gas emissions) relate not only to NSW but also to other parts of the southern Australian beef industry, and to a lesser extent, the northern Australian beef industry as well. However, it is very difficult to judge what share of these benefits can be assigned to the funding of the new Beef CRC.

On a broad scale, some winners and losers can be identified, as with any RD&E that has a particular geographic focus. Thus producers in the NSW beef industry who adopt the relevant technologies will face increased profits, while those producers who do not adopt (and producers in other beef producing countries) will face decreased profits. These producers will suffer the consequences of the expected fall in beef prices that will result from the widespread adoption of the targeted genetic technologies, but will not be compensated for by having access to the technology.

In the above discussion of the outcomes from this RD&E program, a range of industry goods and public goods have been identified. We cannot place quantitative values on all of these public and private outcomes, but we suggest that the expected outcomes from the Beef CRC RD&E are a fairly even mix of industry goods and public goods.

11. Conclusions

Under the assumptions made in this assessment, investing $30m of taxpayer funds into the proposed CRC for Beef Genetic Technologies will leverage another $15m of in-kind contributions from research providers, and these $45m in extra funds will generate an expected benefit of just over $2b to the Australian economy (about $1.4b to the beef industry and about $600m to the broader economy). There is no doubt that there is a sound economic argument for funding the CRC for Beef Genetic Technologies, and in terms of the formal criteria that had to be satisfied: (1) outcomes will contribute substantially to Australia's industrial, commercial and economic growth; and (2) the funding sought will generate a return that represents good value for the taxpayer.

The marginal returns to the NSW beef industry from funding the CRC were also estimated. Under the same assumptions made in the aggregate assessment, it was estimated that NSW DPI involvement in a refunded CRC will generate an additional $251m in economic benefits to the cattle producers, beef processors and marketers, and beef consumers of NSW, in present value terms. The estimated net cost required to fund this involvement is $3.785m. So while the marginal cost to NSW DPI of being involved in the CRC is minimal, the anticipated benefits are substantial. The marginal NPV is $247m and the marginal BCR is 66:1.

Some additional benefits were also enumerated. First, it was estimated that an extra $111m in benefits would flow through to the broader NSW economy, beyond those accruing to the cattle producers, beef processors and marketers, and beef consumers of NSW. Second, net feed intake is a major research area of the new CRC and it is now accepted that selection for more feed efficient cattle will lead to a reduction in greenhouse gas emissions from the beef herd. It was estimated that a minimum value for the saved methane output due to adoption of NFI genetics in the NSW beef herd is in the order of $28m, over a 25 year simulation period. A substantial proportion of that expected benefit could be assigned to the new CRC through further development and adoption of the net feed intake technology. Other social benefits are also discussed although no formal value is placed on these.

One of the interesting implications is that the extra funds brought into beef RD&E by the renewed CRC funding are crucial to achieve outcomes and impact in the larger payoff components of the proposed portfolio, such as increased reproduction rates. This obviously relates to the expensive-to-fund gene discovery and gene expression research.

The distribution of the benefits of the proposed research portfolio adds to the argument for renewed funding the CRC. Almost one third of the benefits accrue to consumers in export markets, and much of this goes to consumers in the ROW region. This result confirms that because of CRC funding, Australia has the potential to be a major beneficiary of the future growth in regional beef demand that is forecast to occur under the Livestock Revolution (Delgardo *et al*. 1999, 2002).

Further, the more that the scientific outcomes can be restricted to Australian producers, or at least protected by IP measures, the more competitive Australian producers will be relative to producers in other exporting countries. Under the assumption made here of no-spillovers of CRC technology outside Australia, producers in other countries lose from the proposed research portfolio.

Over the seven years that the CRC for Beef Genetic Technologies will be funded, the economic modeling framework developed in this analysis will be regularly revised and updated to monitor progress towards achieving the outcome targets that have now been specified in the Commonwealth agreement.

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Appendix A. CRC for Beef Genetic Technologies: An Overview of the Science Programs (as at June 2005)

Program 1 – High quality beef for global consumers

Outcome 1.1 ~ From 2012, 10% of Australian beef sires will be evaluated for multiple DNA tests that account for 50% of the genetic differences in carcase yield, marbling and beef tenderness, increasing annual gross revenues in the Australian beef industry by $43 million for improved beef quality and a further $15.5 million for increased retail beef yield.

Our objective is to identify new gene (DNA) tests for carcase and meat quality and obtain an understanding of the genetic processes that contribute to these economically important traits. We will build upon the innovations of the CRC for Cattle and Beef Quality and increase the rate of gene discovery and commercialisation. To do this, we will use cattle populations that were assembled in the previous beef CRCs, as well as some new populations that will be used for industry validation (see strategy 1.2). We will significantly increase the rate of gene discovery by using information from the recently released, publicly-available bovine genome sequence and new gene mapping tools such as whole genome screens of high densities of single nucleotide polymorphisms (SNP). In addition, new traits such as fat distribution (intramuscular fat *vs.* carcase fat) and total carcase fatness will be examined using the existing CRC databases. DNA tests derived from international sources will also be tested in Australian cattle to determine their value to Australian cattle breeders. The large number of DNA tests will be genotyped on animals that are in BREEDPLAN to aid the integration of molecular information into conventional breed evaluation. This approach is one of several ways in which the new genetic information will be used by breeders or by enterprises along the supply chain.

This strategy will also deliver proof of concept to demonstrate the production systems that will be required to optimise expression of genes for carcase and beef quality and to quantify the profit delivered by the DNA test suite in specific cattle populations and production systems. The plan is to take a timed approach to the various traits in the order of tenderness, marbling and fat distribution and finally retail beef yield. This sequence will be overlapping and is designed to capture the maturity (or availability) of gene markers for the different traits. For the tenderness research in the first 2 years, the goal is to understand co-dependencies amongst the genes and proteins known to be associated with tenderness and toughness. Is connective tissue toughness really independent of myofibrillar toughness? Does the LOX polymorphism have impacts on the structure of muscle, or the enzymic profile of muscle including the calpain/calpastatin ratios. We will address these questions by establishing two herds of cattle with known genetic variance in the currently identified gene markers. Depending on our predicted phenotypic differences, we may also apply a hormonal growth promotant treatment, since this is known to influence both causal mechanisms of toughness. There will be a classical ‘meat science’ and MSA workup of the slaughter cattle. However importantly there will be a biochemical and molecular workup of the major tenderness proteins and genes to underpin biological understanding of expression.

Outcome 1.2 ~ By 2012, the compliance rate for cattle achieving market specifications will be increased by 20% with concomitant improvements in profitability due to improved operational, environmental and production efficiencies and increased throughput across the supply chain.

This strategy aims to develop a series of phenotypic models to predict animal outcomes in terms of meeting market specifications, carcase eating quality and carcase yield. Data will be sourced from previous Beef CRCs to build and further develop these models and, with the new tools developed within this CRC, further enhance the ability and accuracy of the prediction at an individual animal level. These phenotypic models will be linked to genetic indices and selection tools enabling a continuum of selection direction at both the genetic and phenotypic level. Year 1 will also see the further development of an animal growth model (composition of gain model combining genotype and growth path effects), to enhance the prediction of carcase composition and hence the ability to better meet market specifications.

The commercialisation component of this project will start in 2005/2006 and in many ways, it will underpin commercialisation of Program 1 globally. Initially we will establish links with co-operating supply chain networks across Australia (initially one in each of NSW, Western Australia, Queensland and New Zealand). The cooperating supply chains will need to have sophisticated technologies for retail beef yield measurement (actual bone outs, VIAScan or similar), be grading MSA cattle, have relationships between both domestic and export 'longer fed' markets and be willing for the CRC to communicate with their producer/feedlot base. Once the relationships are in place and the technologies established, yield and MSA grading data together with meat science and DNA samples will be collected. The data will be used in (i) benchmarking exercises (ii) industry validation of DNA markers discovered in Strategy 1.1.1/1.1.2 and (iii) validating and refining the phenotypic prediction models.

Outcome 1.3 ~ By 2012, palatability prediction models, customised for international markets, will be developed and used by at least two of our key trading partners.

Australia has developed a unique grading scheme called Meat Standards Australia (MSA) to predict the palatability of beef. The MSA scheme uses a total quality management approach where critical control points from the production, processing and value adding sectors have been combined into a model to predict palatability of individual beef muscles in the carcase. The accuracy of the scheme has attracted international attention with several countries expressing interest in evaluating the MSA scheme to allow customisation and application in overseas markets. This has provided Australia with a unique opportunity to take the lead in development of a beef grading model to develop palatability as an international descriptor of beef quality. Ultimately it would be intended that palatability be used as another beef descriptor for trading purposes. In collaboration with international researchers, this program will quantify differences between Australian and international consumers in their palatability perceptions to beef. In the first instance, the research will focus on consumers in Korea and the Irish Republic. Application of MSA to different international markets will require quantification of critical control points (CCP) for these production/processing systems. Also as DNA markers for eating quality are commercialized in Program 1.1 there is an opportunity to quantify the magnitude of these markers in terms of MSA palatability scores and for these markers to be incorporated into the MSA model, both domestically and internationally.

Program 2 – Feed efficiency, maternal productivity and responsible resource use

The focus of Program 2 is to work with pharmaceutical and biotechnology companies and seedstock and specialist beef producers to develop technologies that will lead to increased efficiency of beef production by decreasing feed intake and methane loss per unit of high quality beef produced. The program comprises multi-disciplinary, multi-organisational teams, committed to achieving the ambitious outcomes described below.

Outcome 2.1: From 2012, feed costs for the national beef herd will be reduced by $15.5M p.a. without impacting on cattle weight gain, through genetic improvement of feed efficiency in seed stock cattle.

This will be achieved by developing a suite of DNA tests (gene discovery) that explain genetic variation in feed efficiency. Work on gene expression will provide the dual role of aiding the gene discovery work and developing systems for managing specific genotypes to maximise efficiency and profitability. Accompanying the tests will be a comprehensive information package, including include information on correlated effects and guidance to implementation in breeding programs. Industry delivery of products such as commercially available DNA tests will be through partnering with a commercial specialist for delivering genetic testing to the beef industry. In addition, breed societies are important partners who will be engaged throughout the CRC by working with groups of breeders.

The Trangie feed efficiency selection lines are the best cattle feed efficiency resource in the world and a third generation of calves will be generated over the next three years. The calves will have DNA extracted for gene mapping as well as serial tissues sampled for gene expression studies. Gene expression will be examined both as animals age (i.e. comparing young and mature animals) as well as nutritional regime (under conditions of high and low feed availability).

Outcome 2.2: From 2012, breeding herd efficiency (kg calf/MJ energy per cow and calf unit) will be improved on average by 0.5% per annum in at least 50% of specialist beef enterprises in temperate Australia.

Maternal productivity is a function of fertility, dystocia, milking ability and calf growth. A starting point for this work will be mining BREEDPLAN databases to quantify genetic relationships between maternal productivity, feed efficiency and body composition traits. BREEDPLAN data sets will be aided by additional measurements (primarily cow body composition) recorded in progeny test herds and commercial properties. This will involve ultrasound measurements on a large number of heifers/cows in selected BREEDPLAN herds.

In addition to work in cooperator herds, a comprehensive evaluation of breeding herd efficiency differences between divergent genotypes for NFI and fatness under various nutritional regimes will be conducted. This will involve 120 heifers from each genotype for four joinings at Struan (SA) and Vasse (WA) research stations.

Products from this research will be EBV's, information packages and management strategies relevant to beef producers in temperate Australia. Commercialisation will involve establishing breeder groups from both the seedstock sector and commercial groups as focus groups to achieve adoption of these technologies. The commercial groups will be accessed through the MLA More Beef from Pastures program. Tools such as "Beef-N-omics" that aid whole-farm planning will provide a conduit for communication between CRC researchers and specialist beef producers. Phenotypic prediction models will also be developed in collaboration with Program 1 to aid management decisions for specialist beef producers.

Outcome 2.3: By 2012, commercial products and management strategies developed by the CRC will be used by 50% of feedlots and 20% of grazing enterprises to decrease methane emissions from beef cattle by 20% and increase the dietary energy captured for production by 5-10%.

A starting point for this work is developing an understanding of the genes involved in methanogenesis, regulatory processes and alternative pathways for hydrogen utilisation. Ruminal methanogens are phylogenetically diverse, but have gene products that are highly conserved across species. Identifying the genes involved will provide targets to develop novel classes of methanogen inhibitors. Identifying bioactive materials that minimise methanogenesis is part of the strategy. The other approach is to identify the microbiology underpinning hydrogen utilisation, with a focus on microbes that utilise hydrogen without producing methane. Commercial partners will be sought for products such as probiotics that have potential for increasing efficiency and decreasing methane production.

A crucial link between the microbial and whole animal studies in Program 2 is the work on links between methane production and feed efficiency. Methane production will be measured in the Trangie selection line calves grazed on both pasture and grain. In addition to methane production, characterisation of microbial populations will be undertaken. Knowledge of the genes involved in methanogenesis will be helpful for this work, thus further linking activities across strategies within the program.

Products that may arise from this work include inoculants, bioactive agents and supplements. As for gene markers, the commercialisation strategy is to partner with an appropriate company with a track record of delivering products to industry. In addition, use of the products and likely impacts on profitability will be communicated through the commercial producer network developed as part of this program and through alliances developed in Program 1.

Program 3 ~ Adaptation and Cattle Welfare

Outcome 3.1 ~ From 2012, the combined effects of reduced parasite control costs and improved productivity from use of well adapted cattle and improvements in animal welfare will increase the gross annual revenue of the Australian beef industry by $43 million p.a.

Strategy 1 – Gene Discovery

This focuses on the physical mapping of genes controlling tick resistance. This includes a PhD project to reanalyse existing whole genome scan data for all available traits, taking a multiple trait and false discovery rate approach to obtain better estimates of the distribution of gene effects. A new whole genome scan is proposed in the Belmont AXBX population where data and DNA are already available, to increase the number of Quantitative Trait Loci (QTL) available for further study and to confirm existing QTL. Higher density tests will be developed and applied to QTL of particular promise to undertake fine mapping using a combined linkage association and linkage disequilibrium approach, with the aim of developing diagnostic DNA tests for use by cattle breeders in tropical and sub-tropical environments.

Strategy 2 – Mechanisms of resistance of cattle to ticks

This involves the study of gene expression patterns and other biological parameters of individual tick resistance QTL to assist gene discovery, while also contributing to understanding the mechanisms of resistance of cattle to ticks. Several different approaches will be used to develop this understanding. In the first, gene expression studies and biological assays will be undertaken before and following attachment of ticks on tropically adapted composite animals with known genotype status for key tick resistance QTL. Pathways of gene expression will be identified that can be related to the inheritance of individual QTL allowing inference of causative genes that are both positional and functional candidates for the QTL.

Another approach will assess the power of microarrays to predict later life phenotype and genetic merit for tick resistance and related traits. A further approach involves study of the gene expression and immunology of tick resistant versus susceptible populations of cattle and is divided into gene expression and immunological components. Initially, small numbers of *Bos indicus* (resistant) and *Bos taurus* (susceptible) animals will be subject to controlled tick infestation and tissue and blood samples collected for gene expression and immune response assays in a time series, pre- and post-infestation. A subsequent study will compare resistant and non-adapted *Bos taurus* animals. Gene expression patterns will be related to inheritance of individual QTL identified in Strategy 1. Data will be analysed to provide assessment of pathway-driven predictors of QTL and to determine whether gene expression patterns early in life correspond to correlates of resistance observed post-infection.

Strategy 2 will also validate candidate genes and pathways for tick resistance using different approaches such as an *in vitro* cell culture system for targeted gene knockdown using RNAi. Candidate genes will be developed in the QTL mapping and host gene expression research, along with *in silico* analyses of QTL regions for potential regulatory elements. RNAi delivery cassettes will be developed for the highest priority gene candidates, and gene expression pre- and post-delivery of RNAi assayed to validate the predicted pathways of control for the candidate genes.

A further possibility being examined with commercial partners is an option to discover targets for new vaccines and therapeutics against ticks. This research will proceed only if a commercial partner agrees to co-invest and fully develop and commercialise the research outputs from an early stage of development. If the research proceeds, it will initially undertake a comparative *in silico* data mining and interpretation of existing tick genome and EST sequences jointly with ILRI to identify putative candidate targets for anti-tick vaccines or therapeutics. cDNA subtraction and gene expression assay will be used to identify novel genes associated with larval and adult tick attachment. Candidate genes will be validated using RNAi knockdown in tick primary cell culture and in live ticks, monitoring impacts on gene expression and in the case of live ticks, on survival, growth and reproduction.

The final area within Strategy 2 will develop rapid diagnostics for acaricide resistance. A PhD student will sequence strong candidate genes for acaricide resistance mechanisms, identified in other tick or insect species, searching for putative functional polymorphisms. Comparative *in silico* analysis of tick sequence data will be used to identify other potential resistance mechanisms for possible sequencing. Where causative polymorphisms are identified, they will be validated in live tick trials and PCR-based diagnostics developed to allow rapid appraisal of resistance in field samples.

Strategy 3 ~ Cattle Welfare

The development of approaches to deliver the cattle welfare strategy was delayed to ensure full harmonisation with MLA's welfare strategy. Workshops were held in June 2005 and it was agreed at both MLA and CRC workshops that CRC activities should include the application of genomic technologies to understand and potentially assess cattle welfare. The following activities were provisionally identified:

Poll / horn and African horn genes: Late dehorning of cattle was recently identified as one of the top three welfare issues that needed to be addressed by the northern Australian beef industry. The polled gene causes a dominant loss of horns and has been mapped to within 1 Mb by groups in USA and Europe. A consortium is being put together to identify the causal mutation. Even if the causal mutation cannot be found, a tight haplotype could be discovered to provide a diagnostic test for the polled gene. Use of homozygote (two copies of the poll gene) bulls would ensure that all offspring were polled. A potential complicating factor in Australia is the possible presence of the African horn gene, particularly in *Bos indicus* and composites derived from such cattle. The mode of inheritance of the African horn gene is not clear, but it is hypothesised to interact and wholly or partially override the effect of the polled gene. If this is true and if the African horn gene is present in Australian cattle, a genetic assay will also be required for this gene to allow effective genetic selection for lack of horns. The CRC could potentially contribute to development of a diagnostic DNA test for the poll and African horn genes to speed dissemination of polled cattle in northern Australia to overcome growing welfare concerns about dehorning practises. Decisions on the feasibility of this approach depend on the findings of an MLA-commissioned review due for submission to MLA in July 2005.

QTL for behaviour and welfare traits: Previous research has not investigated the use of QTL for behaviour and welfare traits, beyond the fact that some adaptation traits such as tick resistance, have both production and welfare implications. An opportunity exists to map QTL for behaviour (flight time) and welfare (heat tolerance as indicated by rectal temperature) in an existing data set on the Belmont CBX cattle at no additional cost to the CRC. The data for this population will be reanalysed in Strategy 3.1 to identify new QTL and estimate correlated effects of the QTL. Flight time and rectal temperature will be included among the traits not previously analysed. If substantial QTL are identified, the potential value of such QTL will then be explored in consultation with industry.

Emotional, physiological and gene expression responses to chronic fear and rest deprivation in cattle: Fear is known to be a potent stressor and when the occurrence of aversive stimuli is unpredictable and uncontrollable by the animal, it induces an enhanced or chronic stress response. The aim of this approach is to develop a challenge model that facilitates the development of chronic fear response in cattle in a field context. In the first two years, the primary focus will be on developing the challenge models and measurement methodologies and generating the cattle resource required for the challenge studies. The major stress challenge studies will be conducted in years 3 and 4. The most informative measures from this stage will then be validated under industry conditions during year 5.

Strategy 4 ~ Commercialisation
Commercial outputs from adaptation research in Program 3 will include DNA tests with known gene function and gene pathways; tests for tick susceptibility or resistance independent of marker assisted breeding programs (e.g. immune biomarker or MHC based typing tests); potential tick therapies for use in developing a vaccine or treatments to control ticks and molecular acaricide resistance assays for regulatory and similar purposes. As well, new management strategies will be developed to allow cattle to better cope with environmental stressors.

The main output from the welfare strategy will be acceptable, scientifically defensible measures of cattle welfare for use by the Australian beef industry. It is most likely these outputs will augment and build on the current MLA on-farm QA programs or be applied through direct on-farm monitoring or welfare audit systems. The welfare audit systems may provide only a rudimentary indication of the welfare status of animals but they will provide a good foundation on which new knowledge and research outputs from the CRC and MLA could be built.

Program 4 – Female Reproductive Performance

Outcome 4.1 ~ Every year from 2012 an improvement of $46.5 million will be achieved in the gross annual revenue of the Australian beef industry due to improved reproductive performance of the beef breeding herd with no impact on breeder herd mortalities due to younger age of joining and with cows rearing their calves to normal weaning age of 6-9 months.

This program comprises gene discovery, gene expression and quantitative genetics research focussed on female traits (post-partum re-conception, age at puberty, lifetime reproductive performance) and male traits (eg sperm morphology) as indicators of female reproductive performance.

Discovery of genes associated with postpartum re-conception and age at puberty
Reproductive rate is a key driver of profitability in the Australian beef cattle industry. The number of calves produced by breeding cows over their reproductive lifetime can be affected by many environmental factors including management and husbandry practices and nutrition and seasonal effects. Individual components of reproductive performance are also affected by genetics, with a large amount of genetic variation for reproduction existing in the Australian cattle population. Research in this strategy aims to identify diagnostic DNA tests for traits that directly impact on reproductive rate. The female reproductive data collected in the CRC II northern beef cattle herd will be used as the primary data for this purpose. Animals within this population have been, and will continue to be measured for a number of phenotypes indicative of reproductive rate. DNA from these animals will be typed using thousands of DNA markers situated throughout the entire bovine genome. Analysis of these genotypes (DNA types) and phenotypic measurements will identify which genes have an impact on reproductive rate. Diagnostic tests will be established for these genes, and in combination with programs such as BREEDPLAN, will enable the identification of genetically superior breeding stock for reproductive traits.

Expression of genes associated with postpartum re-conception

The ability to re-conceive within a defined mating period after calving is regarded by industry as the major factor limiting annual calving and overall female reproductive performance in beef cattle, particularly extensively managed Brahman and Brahman cross genotypes in northern Australia. Reproductive function is controlled by interactions, mainly through hormone signalling, between the brain, anterior pituitary gland and ovaries. These interactions within the reproductive system do not occur in isolation but are influenced by nutrition, metabolic status and general wellbeing. In Program 4 we have concluded that the time taken to resume fertile ovulations after calving is the primary determinant of when re-conception occurs postpartum. Other factors including fertilisation and embryonic development are clearly involved in the establishment of pregnancy but these are considered to be of lesser importance than the resumption of fertile ovulations, particularly in determining the interval between calving and re-conception. The growth of ovarian follicles, which contain an unfertilised egg (oocyte), and the ovulation of follicles to release the oocyte, are under the control of hormones secreted from the brain and anterior pituitary gland. The mechanisms that regulate the secretion of reproductive hormones from the brain and anterior pituitary are complex and the challenge is to understand and describe changes in gene expression in these tissues that are temporally associated with the resumption of ovulation postpartum. Temporal changes in gene expression in the liver postpartum will also be monitored to better understand the links between the metabolic and reproductive systems. In addition, we will look for biomarkers in the blood that are reflective of changes in gene expression that are related to ovarian function and ovulation. Candidate genes and biomarkers will be evaluated in genetic and non-genetic models and the findings will be further tested with industry in order to develop genetic and non-genetic strategies to increase postpartum re- conception within defined mating periods.

Early-life predictors of lifetime female reproductive performance

Although lifetime female reproductive performance is a major factor determining the profitability of beef cattle enterprises, there is a lack of data on the genetics of this trait and its relationship with other economically important productive and reproductive traits. The aim of this strategy is to identify early life predictors of lifetime cow reproductive performance. The current CRC II female cattle populations being maintained at research stations throughout Queensland will be utilised to record lifetime reproductive performance and longevity. Phenotypic data such as mating and calving information, mortality records, weights, body composition and linear type traits and physiological indicators like IGF1 will be collected and analysed to identify early life predictors of lifetime cow reproductive performance. The information will also be useful in determining the genetic relationships between the DNA tests for postpartum re-conception and age at puberty and lifetime cow reproductive performance. Statistical models will be developed to include these traits in genetic evaluation software such as BREEDPLAN and BREEDOBJECT.

Male indicator traits to improve female reproductive performance

Early life predictors of reproductive performance would greatly improve the efficiency of selection of sires for both male and female reproductive performance in beef herds. Research in this strategy will develop early life predictors of bull fertility at the phenotypic level (his calf output) and at the genetic level (the reproductive performance of his female and male progeny). If this strategy can identify, at 12 months-of age, bulls that sire more fertile daughters, then the identification of gene markers could be explored as an additional approach to commercialise this application. Except for scrotal size, there is little existing information on the degree of genetic variation in male reproductive traits and their association with female reproductive performance. Traits such as sperm morphology have been related to calf output in multiple-sire matings in extensive herds. However there is a lack of information on the heritabilities of, and genetic correlations between, such traits and this strategy will rectify this deficiency. Identifying early life predictors of an individual bull's fertility would substantially reduce the number of bulls required for breeding across Australia, allowing much greater selection emphasis on genetic superiority for the overall breeding objective. This will provide new opportunities to increase rates of genetic improvement for all traits and significantly increase the impact of using genetically superior bulls in commercial herds.

Commercialisation and adoption
Improving the genetics of female reproductive performance will benefit the gross annual revenue of the Australian beef industry by $46.5 million per annum by 2012. In northern Australia alone, the number of calves is expected to increase by an extra 400,000 calves per annum. This will then provide increased opportunities to apply management strategies to improve market specifications and improvements in genetic selection strategies as a result of the higher reproduction rates. In addition to the benefit of higher production and improved financial efficiency for individual businesses, this outcome will effectively support the increased demand for meat protein from neighbouring Asian countries. Program 4 research results will be packaged into integrated information delivery systems for producers in the first instance to create awareness of these results and ultimately, the adoption of these tools into their beef businesses.

Program 5 ~ Education and Training

Undergraduate, post-graduate and vocational education
There is a shortfall of tertiary trained students with technical and research skills in both the traditional basic sciences and the science of effective innovation, commercialization and adoption in all sectors of the beef industry. To address this shortfall, the CRC for Beef Genetic Technologies will support at least 35 postgraduate students to undertake higher degree training in the sciences that underpin Programs 1 to 5. Scholarships will be offered at PhD and Masters level to Australian and overseas students associated with our international participating partners. To ensure students have the personnel and management skills required when they enter the workforce, an annual professional development workshop will be held each year in conjunction with the CRC's postgraduate conference.

The success of plans to accelerate adoption of new technologies in the beef industry depends on the level of education in areas that underpin the new technologies and adoption strategies. Avenues to increase the level of education include delivery of undergraduate and vocational courses to both current and future participants in the beef supply chain.

Support for undergraduate studies includes course development in genetic technologies, meat science, feedlot management and the science of adoption and innovation. Another mechanism to increase the flow of postgraduate students into science areas relevant to the Beef CRC is the use of summer scholarships to students undertaking their honours year.

The running of specialized workshops or short courses presents an opportunity to continue the producer education initiative that was part of earlier Beef CRCs.

As government extension services to the beef industry are scaled down, their role is being taken up to some degree by private consultants, including veterinary practitioners. The role of private practitioners in delivery of new technologies to the beef industry would be more effective if there refresher courses were available to upgrade their skills in specific areas.

Agricultural Colleges and TAFEs provide an important and effective means of training beef industry personnel. Much of the material developed for other sectors can be re-formatted into material suitable for incorporation into current and future courses to be delivered by Agricultural Colleges and TAFEs. The syllabus for secondary schools is placing increasing emphasis on small projects in the final year of high school. Many schools find it difficult to provide projects on beef cattle due to the expense and difficulty of accessing relevant data for project areas. A library of potential projects with data and relevant resources would ensure a larger number of students are given an introduction into beef sciences.

Accelerated adoption
A number of different approaches are being used to achieve accelerated adoption of CRC technologies and return on investment in the CRC by the Australian and global beef industries. They include:

Livestock Library: There is a large volume of animal production research and extension that has been published over the past 50 years. Whilst this information is still highly relevant to today's livestock industries and is generally held in the public domain, the material is often difficult to access. In conjunction with the Sheep CRC, the Beef CRC will deliver an electronic library on the web that provides 'free to air' access for a range of users to previously published scientific, technical and extension articles relevant to the Australian and New Zealand livestock industries. The library has a search engine based on article content, type, author and publication. On-line access to this information will assist producers, technology transfer specialists, students or researchers gain additional skills and knowledge and to make more informed decisions.

Beef CRC website: The web is an important communication tool for on-going activities and programs within the Beef CRC. The website needs to be user-friendly and easily accessible. Information for external users contained on the site includes organizational structure, program details and promotional material for Beef CRC events. Information for staff and scientists contained on the site includes information on organizational financial reports, teaching and presentation resources and details on operational and progress reporting. The web site will also contain a staff directory with address, phone and email contacts. In addition the Beef CRC Web site will provide one of the many access points for the Livestock Library

Integrating Delivery Strategies: This strategy will fully equip a team of extension staff with the outputs from CRC I and II and the capability to customize information into integrated packages, collect important benchmark information and share skills and resources to attain maximum adoption levels through beef industry sectors. The case for the new CRC was based around achieving higher levels of adoption and decreasing the time from when research is completed and the technology is applied by industry. Furthermore the success of the new CRC will be measured directly against improvements in industry from the utilization and uptake of new CRC technologies.

The scale of these improvements and the manner in which the beef industry assesses new technology demands a holistic approach in the commercialization and adoption of CRC outputs. Whilst each of the research programs (Programs 1-4) have extension officers embedded within them to enable a full understanding of the program's activities and outputs, it is essential they also liaise as a team with other extension staff to achieve a shared understanding of how their program's outputs fit into an overall production or processing system. It will only be through integration of technologies across the whole supply chain that maximum utilization and adoption of CRC outputs will be achieved.

Capacity building for accelerated adoption: A number of strategies will be used to achieve accelerated adoption by industry partners within the research programs. One approach will take the form of regular workshops and the formation of specialist teams with the necessary tools, skills and support. A second strategy will provide quantification and research on new methods to accelerate adoption of technologies and practices relevant to achieving CRC outcomes. Research in the area of accelerated adoption is needed because whilst there is a relatively large amount of literature based on surveys about 'constraints' to adoption there is little research on methods to achieve accelerated adoption, particularly in the context of the targeted outcomes of each of Programs 1 to 4. The research will produce scientifically validated methods, practices and tools that accelerate adoption. The research design will ensure improvements in adoption and returns are achieved during the research. This strategy will provide professional, high quality capacity building programs tailored to the needs of the CRC and, through action and outcome-based R&D, will develop new methods, tools, processes and systems and the capacity to implement these through all of the CRC's programs.

Monitoring and evaluation: Each of the CRC's research programs has targeted outcomes described in economic terms and requiring economic analysis for their achievement. Further, over all the programs, there is an explicit reliance on accelerated adoption as a mechanism to achieve these outcomes. Implicit in this is the notion that monitoring and evaluation processes must be established to enable the improvement to be measured and the outcomes to be achieved. This strategy sets up these monitoring and evaluation processes *within* each of the research programs using well-tested methodologies. The monitoring will be done primarily within Programs, to set up case study focus groups specific to each network. However, a co-ordinated network of case studies across the major production environments of Australia and New Zealand will also be developed. Finally there will be development of capacity building packages in impact assessment and the integration of domestic monitoring activities with existing beef industry models.

The outputs will comprise specialist monitoring advice and guidance, along with case study networks specific to each Program. The strategy will also provide capacity building packages in impact assessment procedures and practices for integration with existing beef industry models to evaluate progress of CRC outcomes.

Appendix B: Analysis of NSW DPI Financial Position in the CRC for Beef Genetic Technologies

Table 1A. Cash and in-kind contributions by organisation to the four research programs ($'000)

Organisation	Program 1			Program 2			Program 3			Program 4		
	Cash	InKind	Total	Cash	InKind	Total	Cash	InKind	Total	Cash	InKind	Total
ALFA	250		250	250		250						
CSIRO	38	1,287	1,325					4,507	4,507		3,669	3,669
Ag WA		507	507		3,060	3,060						
Qld DPI	38		38		1,103	1,103		2,505	2,505		3,781	3,781
QLD Govt	50		50	50		50	50		50	50		50
Vic DPI		624	624		1,979	1,979		954	954		828	828
Genetic Solutions		114	114		114	114		97	97		97	97
MLA	940		940	2,340		2,340	940		940	940		940
Meat & Wool NZ	400		400	400		400	400		400	400		400
Murdoch Univ		2,588	2,588		1,533	1,533		1,846	1,846			
NLRI, Korea	14	3,516	3,530	14		14	14		14	14		14
Northern Pastoral											1,500	1,500
NSW DPI	38	1,459	1,497		5,135	5,135		111	111		851	851
Sastek P/L												

Table 1A (cont). Cash and in-kind contributions by organisation to the four research programs ($'000)

Organisation	Program 1			Program 2			Program 3			Program 4		
	Cash	InKind	Total	Cash	InKind	Total	Cash	InKind	Total	Cash	InKind	Total
SARDI		817	817		3,255	3,255						
Sygen International				264		264						
Ohio State Univ					812	812					2,742	2,742
Univ Adelaide	100	3,203	3,303	100	1,490	1,590	100		100	100		100
UNE	38	2,779	2,817		1,180	1,180		1,100	1,100		967	967
Univ QLD	50	919	969		919	919		2,190	2,190		3,074	3,074
Total Non-CRC	1,956	17,813	19,769	3,418	20,580	23,998	1,504	13,310	14,814	1,504	17,509	19,013
% of overall	17.1	22.3	21.7	29.8	25.8	26.3	13.1	16.7	16.2	13.1	21.9	20.8
CRC $	4,832		4,832	2,880		2,880	4,261		4,261	5,680		5,680
% of overall	16.1		16.1	9.6		9.6	14.2		14.2	18.9		18.9
Total	6,788	17,813	24,601	6,298	20,580	26,878	5,765	13,310	19,075	7,184	17,509	24,693
% of overall	16.4	22.3	20.3	15.2	25.8	22.2	13.9	16.7	15.7	17.3	21.9	20.4

Table 1B. Cash and in-kind contributions by organisation to the education, commercialisation and administration programs ($'000)

Organisation	Education			Commercialisation			Administration			Total		
	Cash	InKind	Total	Cash	InKind	Total	Cash	InKind	Total	Cash	InKind	Total (and % of total)
ALFA	120		120	220		220				840		840 (0.9)
CSIRO										38	9,463	9,501 (10.4)
Ag WA					374	374					3,941	3,941 (4.3)
Qld DPI					2,626	2,626				38	10,015	10,053 (11.0)
QLD Govt	50		50	50		50				300		300 (0.3)
Vic DPI					247	247					4,632	4,632 (5.1)
Genetic Solutions					691	691					1,113	1,113 (1.2)
MLA	440		440	1,400		1,400				7,000		7,000 (7.7)
Meat & Wool NZ	51		51	400	252	652				2,051	252	2,303 (2.5)
Murdoch Univ											5,967	5,967 (6.5)
NLRI, Korea	13		13	13		13	13		13	95	3,516	3,611 (4.0)

Table 1B (cont). Cash and in-kind contributions by organisation to the education, commercialisation and administration programs ($’000)

Organisation	Education			Commercialisation			Administration			Total		
	Cash	InKind	Total	Cash	InKind	Total	Cash	InKind	Total	Cash	InKind	Total (and % of total)
Northern Pastoral											1,500	1,500 (1.6)
NSW DPI					1,670	1,670					9,226	9,264 (10.1)
Sastek P/L					140	140					140	140 (0.2)
SARDI					471	471					4,543	4,543 (5.0)
Sygen International										264		264 (0.3)
Ohio State Univ											3,554	3,554 (3.9)
Univ Adelaide	100	596	696	100		100	100		100	700	5,289	5,989 (6.6)
UNE		1,518	1,518		182	182		1,400	1,400	38	9,126	9,164 (10.0)
Univ QLD		459	459							50	7,561	7,611 (8.3)
Total Non-CRC	774	2,573	3,347	2,183	6,653	8,836	113	1,400	1,513	11,452	79,838	91,290
% of overall	6.8	3.2	3.7	19.1	8.3	9.7	1.0	1.8	1.7	100	100	100
CRC $	2,298		2,298	6,047		6,047	4,002		4,002	30,000		30,000
% of overall	7.7		7.7	20.2		20.2	13.3		13.3	100		100
Total	3,072	2,573	5,645	8,230	6,653	14,883	4,115	1,400	5,515	41,452	79,838	121,290
% of overall	7.4	3.2	4.7	19.9	8.3	12.3	9.9	1.8	4.5	100	100	100

Table 2A. Potential share of CRC and partner cash across organisations for the four research programs ($'000)

	Program 1			Program 2			Program 3			Program 4		
Organisation	**In-Kind**	**%**	**Cash share**	**In-Kind**	**%**	**Cash share**	**In-Kind**	**%**	**Cash share**	**In-Kind**	**%**	**Cash share**
ALFA												
CSIRO	1,287	7.2	490				4,507	33.9	1,952	3,669	21.0	1,505
Ag WA	507	2.8	193	3,060	14.9	936						
Qld DPI				1,103	5.4	338	2,505	18.8	1,085	3,781	21.6	1,551
QLD Govt												
Vic DPI	624	3.5	238	1,979	9.6	606	954	7.2	413	828	4.7	340
Genetic Solutions	114	0.6	43	114	0.6	35	97	0.7	42	97	0.6	40
MLA												
Meat & Wool NZ												
Murdoch Univ	2,588	14.5	986	1,533	7.4	469	1,846	13.9	800			
NLRI, Korea	3,516	19.7	1,340									
Northern Pastoral										1,500	8.6	615
NSW DPI	1,459	8.2	556	5,135	25.0	1,571	111	0.8	48	851	4.9	349
Sastek P/L												

Table 2A (cont). Potential share of CRC and partner cash across organisations for the four research programs ($'000)

	Program 1			Program 2			Program 3			Program 4		
Organisation	**In-Kind**	**%**	**Cash share**	**In-Kind**	**%**	**Cash share**	**In-Kind**	**%**	**Cash share**	**In-Kind**	**%**	**Cash share**
SARDI	817	4.6	311	3,255	15.8	996						
Sygen International												
Ohio State Univ				812	3.9	248				2,742	15.7	1,125
Univ Adelaide	3,203	18.0	1,221	1,490	7.2	456						
UNE	2,779	15.6	1,059	1,180	5.7	361	1,100	8.3	476	967	5.5	397
Univ QLD	919	5.2	350	919	4.5	281	2,190	16.5	949	3,074	17.6	1,261
Totals	17,813		6,788	20,580		6,298	13,310		5,765	17,509		7,184
			24,601			26,878			19,075			24,693

Table 2B. Potential share of CRC and partner cash across organisations for the research and commercialisation programs ($'000)

	All research programs				Commercialisation program			All research and commercialisation programs			
Organisation	**In-Kind**	**%**	**Cash Share**	**Cash Share %**	**In-Kind**	**%**	**Cash share**	**In-Kind**	**%**	**Cash share**	**Cash Share %**
ALFA											
CSIRO	9,463	13.7	3,948	15.2				9,463	12.5	3,948	11.5
Ag WA	3,567	5.2	1,130	4.3	374	5.6	463	3,941	5.2	1,592	4.6
Qld DPI	7,389	10.7	2,974	11.4	2,626	39.5	3,248	10,015	13.2	6,222	18.2
QLD Govt											
Vic DPI	4,385	6.3	1,596	6.1	247	3.7	306	4,632	6.1	1,902	5.6
Genetic Solutions	422	0.6	160	0.6	691	10.4	855	1,113	1.5	1,015	3.0
MLA											
Meat & Wool NZ					252	3.8	312	252	0.3	312	
Murdoch Univ	5,967	8.6	2,255	8.7				5,967	7.9	2,255	6.6
NLRI, Korea	3,516	5.1	1,340	5.1				3,516	4.6	1,340	3.9
Northern Pastoral	1,500	2.2	615	2.4				1,500	2.0	615	1.8
NSW DPI	7,556	10.9	2,525	9.7	1,670	25.1	2,066	9,226	12.2	4,591	13.4
Sastek P/L					140	2.1	173	140	0.2	173	0.5

Table 2B (cont). Potential share of CRC and partner cash across organisations for the research and commercialisation programs ($'000)

	All research programs				Commercialisation program			All research and commercialisation programs			
Organisation	**In-Kind**	**%**	**Cash Share**	**Cash Share %**	**In-Kind**	**%**	**Cash share**	**In-Kind**	**%**	**Cash share**	**Cash Share %**
SARDI	4,072	5.9	1,307	5.0	471	7.1	583	4,543	6.0	1,890	5.5
Sygen International											
Ohio State Univ	3,554	5.1	1,374	5.3				3,554	4.7	1,374	4.0
Univ Adelaide	4,693	6.8	1,677	6.4				4,693	6.2	1,677	4.9
UNE	6,026	8.7	2,293	8.8	182	2.7	225	6,208	8.2	2,518	7.3
Univ QLD	7,102	10.3	2,841	10.9				7,102	9.4	2,841	8.3
Totals	69,212		26,035		6,653		8,230	75,865		34,265	
			95,247				14,883			110,130	

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