final report

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Prepared by: David Campbell
ACIL Tasman Pty Ltd

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Meat and Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

An economic analysis, using real options methodologies, of the RELRP program funded by MLA

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Executive summary

Purpose

ACIL Tasman was commissioned by Meat and Livestock Australia (MLA) to undertake an economic assessment of its Reducing Emissions from Livestock Research Program (RELRP).

We are viewing the RELRP as a strategic investment in risk management for the livestock, in the context of evolving greenhouse gas policy regimes in Australia and elsewhere. Irrespective of their overall merits, these developments pose substantial challenges for traditional livestock production systems while also opening up opportunities for the Australian livestock sector to mitigate damage through tapping into a new revenue stream, and in doing so to help limit the costs for the Australian economy as a whole.

The study is fundamentally about the value added by the RELRP, not about the economics of methane abatement – though of course the two are closely linked. A key emphasis in the work has been probing of the additional value that might be attributed to the RELRP over and above that will in any case emerge from the substantial volume of work of work already done in this field, and expected to be done in countries around the world in coming years. This backdrop of research work – the 'counterfactual' is of crucial importance if a credible assessment of the value of investing in the RELRP is to be made.

Rationale

While the RELRP has been running for several years, the rationale for its continued operation can now be viewed as tied strongly into two recent developments:

- Passage of legislation that should see a rising carbon price from 1 July, initially though a carbon tax but from 2015 emerging from a cap and trade mechanism with widening regulated upper and lower bounds on price.
  - From the perspective of the RELRP and the Australian livestock industries, the initial rate of carbon tax is almost irrelevant to methane strategy; plausible prices beyond 2020 and even well beyond 2030 are key drivers of the case for now investing in technologies that will take years, and even decades, to deliver their full impacts.
  - Treasury projections involve the carbon price rising faster than inflation over some decades, with an indicator nominal value in 2030 of about $90.
    - … While these figures are plausible, we suspect they will prove to be somewhat higher than actual outcomes for a range of reasons,

including possible policy shifts, relative to the Treasury assumptions, in Australia and overseas.

… Nonetheless, plausible carbon costs as high as this constitute both a serious commercial threat and an opportunity that could justify significant investment in methane reduction across the sector.

- While the current legislation excludes agriculture from direct and compulsory participation in the market, agriculture will be affected, indirectly but substantially, by flow through effects to the costs of major inputs to production and processing.

- Establishment of the Carbon Farming Initiative within which livestock producers will be able, and actively encouraged, to find cost competitive ways of delivering credible offsets to the emissions trading market, or parallel voluntary markets.

With an opposition deeply opposed to the carbon pricing arrangements, there are no guarantees that these policies will last – though unravelling the legislation is likely to be hard. Furthermore, the Opposition is committed to a policy of direct action to reduce emissions – a policy that could be expected to result in a willingness to 'buy' methane emissions reductions from suitable certified farm practices. In assessing the RELRP and the livestock sector's methane strategies, it is appropriate to factor in some chance that the carbon market policies could be fully or partially unwound, but with a much smaller chance of eliminating the proposed market for offsets from methane reductions.

Equally though, it is relevant to recognise that international progress in developing stronger carbon policies, and even the success of the Australian policies in reducing non-agricultural emissions (thus increasingly highlighting the significance of agricultural emissions) could also lead to strengthening of the policy settings over the next couple of decades. These are all part of the risk environment within which an assessment needs to be set.

Also included in this risk environment are wider, if more traditional, uncertainties regarding forward prices of major livestock products (including new potential to attach a premium to product that could be certified to come from a low emission production system) and major inputs to production – such as fuel prices and water. There are also possibilities of emerging food security policy.

Even without the RELRP, there were clear indicators that farming systems could, technically if not necessarily cost effectively, be modified to lower the emissions intensity of production. There were strong indicators of scope for genetic selection (across animals, pastures and rumen microbiology), of modification to feed regimes and of increased use of feedlots to contribute to reduction in methane production relative to production of livestock products.

The challenge and rationale for the RELRP lies largely in the recognised value of a suite of practically implementable behaviour changes that could, collectively, deliver capabilities that could be tapped to the benefit of the sector under plausible future circumstances. A key ingredient in allowing these options to be tapped to the benefit of sector lies in the need for the ability to demonstrate performance to the satisfaction of offset accreditation systems – placing further emphasis on credible monitoring and accountability systems.

The rationale for Australian livestock producers contributing to such work lies in expectations that greater value is likely to emerge with the RELRP than without it – as is discussed in more detail below. At least statistically, the RELRP could be expected to bring forward the mean time till valuable technologies are available or could allow those technologies to be better, including more rapidly, 'optimised' to Australian conditions. This could include tapping into the local capability, built up and maintained via the RELRP, to allow faster adaptation of technologies emerging elsewhere as well as exploiting the specific information gained about the methane production system across the sector in Australia.

The presence of a sound rationale does not establish that the RELRP investment is delivering good value for money – but it does provide a logical focus for looking at how value might be delivered, how much more might be available as a result of the RELRP's activities over and above the counterfactual and whether this additional value is likely to exceed the costs of the RELRP investments.

Emissions intensity: production vs production efficiency

We have heard the view expressed that the RELRP is primarily concerned with delivering reduced emissions while at least maintaining production of traditional livestock products. In reality, we consider it highly likely that, in the future, production of major livestock products is likely to rise, even with a carbon pricing regime. However, we do not believe that setting maintenance of production as an objective is appropriate, nor in the best interests of the livestock sector investors in the RELRP.

As flagged above, under the emerging policy settings, livestock producers in the future are likely to plan in terms of an expanded product range – in which carbon market offsets are a legitimate product. If the carbon price is high enough, then a point could be reached where limiting traditional production is a sensible strategy because of the expanded options to sell carbon offsets. In the same vein, a rising price for sheep meat relative to wool can result in reduced wool production as enterprises restructure to market reality.

The CFI and the carbon market will expose livestock producers to a cost on emissions. They will be progressively able to derive revenue from demonstrated reduced emissions – so that failure to reduce emissions will entail an *opportunity cost*, as will any enterprise expansion that results in increased emissions. It follows from this that increasing emissions efficiency – emissions per unit of production – will be rewarded and logical. It does not necessarily follow that reducing emissions will be logical. If livestock production can effectively utilise rights to emit more efficiently than other sectors – a proposition to be market tested by the creation of rights to sell emission reduction – then expanded production of emissions may well make sense. The key point is that the expanded production needs to be justified, inclusive of the resultant costs to the rest of the economy as a result of the failure to reduce these emissions and deliver offsets.

By the same logic, contraction in production of livestock products could make sense, at a high enough carbon price, if the value of these emissions to marginal livestock production is less than their value in other sectors of the economy. We would see it as unnecessarily restrictive to commence with a production objective as opposed to an efficiency and commercial objective for the sector – and more generally in relation to the land base used by the livestock sector.

Overview of the portfolio

The RELRP involves several themes and these align closely with work being done elsewhere. They focus on the major prospective methane 'levers' – genetic selection (animals, pastures and rumen microbes/chemistry), feed supplementation and waste management – and on improved monitoring technologies, both to support increasingly refined research and to support the accreditation processes needed to access the offsets market.

Our approach, of focussing on the portfolio of options being fostered for the sector, emphasises the important ways in which this RELRP portfolio needs to be viewed holistically, and not as a collection of largely independent activities. However, as the results of our modelling show, the range of the option value of the individual themes each presents a compelling case for continuation of the scale of the current investment with any aggregation, should it prove credible, increasing the case for investment.

Sound and credible monitoring technologies could be viewed as a key 'enabler' for the rest of the portfolio. Successful delivery of a low cost, credible technology that can be applied in field could be expected to add greatly to the value of a wide range of other developments across the portfolio – and elsewhere. It is the interaction between the ability to reduce emissions and the ability to demonstrate this that will deliver value.

Similarly, there are likely to be significant interactions – positive and negative – between the various themes. Animal breeding for lower emissions intensity may reduce the benefits from some feed/supplementation strategies. Conversely, breeding to allow animals to take better advantage of some supplements is logically possible. Moving animals in feedlots alters the energy equation fundamentally and can be expected to interact with other approaches.

The other interaction of great interest is that between emissions reduction and production of traditional products. One argument is that emissions of methane are pointers to wasted energy – so that technologies to lower emissions might reasonably result in more efficient energy use and result in improved production — suggesting a possible 'win-win'.

There is evidence in favour of this in some areas – but only up to a point. If technologies are pushed too far it appears probable that the reverse will be true – than marginal reductions in emissions will, past a point, be accompanied by marginal reductions in traditional production. For reasons outlined above, this may be efficient, if the cost of the methane emissions is high enough, but it does mean there is a hard trade-off to be addressed.

Further research may well push out the point at which this trade-off arises. However, the reality is that the livestock sector can expect to have to deal with a range of trade-offs in working towards the best enterprise structure – and this will need to be done in the continuing presence of substantial uncertainty in respect of key prices. Of course, the sector has long had to operate in such a world – what is changing is the carbon price, that will initially emerge from a fairly immature and potentially volatile market and these evolving technologies for catering for the new market in emissions reductions.

These considerations place a strong emphasis on robustness of options and will favour caution amongst producers in making high cost changes that could prove, under plausible future developments, to be costly. On the other hand, investments that are low cost while delivering expanded access to emissions market, or that are capable of being self-funding based on relatively near-term, carbon prices, are likely to be a lot more attractive.

Indicators of cost and value

Ultimately, we need to address the question of the value for money offered by RELRP moving forward. Costs to date have been modest in relation to the perceived risks/possibilities but that in itself does not mean the investment has been sound. The opportunity costs of enteric methane emissions in total are large as can be seen in Table 1.

Table 1 **Scale of methane emissions opportunity costs and possible value (and some early upper bound estimates of some technologies emerging)**

	PV at 10%	Annual value by 2025
	(Billion)	**(Billion)**
Low carbon price (CER modified)	$8	
Mid carbon price	$15	
High (Treasury modelling)	$ 21	$ 3,901

Data source: ACIL Tasman modelling based on parameters from Treasury and ABARE, and indicator assumptions regarding impacts on emissions.

As a general proposition, the table includes indicators of value that are large relative to the recent costs of the RELRP but quite small relative to the size of the sectors emissions, valued at the assumed carbon prices

The reality is that the big potential lies well in the future; the main driver of the investment should be seen as possibilities well beyond 2030. If carbon prices reach the heights modelled by the Treasury – noting that this modelling includes a rising real trend well beyond 2030 – then a wide range of technologies to boost emissions efficiency would appear likely to be attractive. Indeed, some ability to tap into these possibilities and sell offsets might be an important contributor to sector sustainability. Realistically, animal breeding will take through to 2030 – and some decades beyond – to deliver on its potential.

An important feature of the RELRP seems to lie in the way it aligns its biggest returns with those circumstances in which pressures from the carbon market are greatest.

The counterfactual

Based largely on the recent scientific review of the RELRP, and the gaps analysis, the portfolio appears well structured, focused on the key prospective 'levers' for modifying emissions patterns. None of this would be convincing if the efforts within the RELRP program were going to make very little difference to the flow of options to the Australian livestock sector, allowing better adaptation to the evolving carbon policy regime and market. The sector could, instead, look to saving the costs of RELRP while 'free riding' on the work going on elsewhere – or could focus on a program designed to optimise our exploitation of options emerging from overseas.

While the program appears well founded in its science objectives, there is little that has come through to us to suggest it is doing a better job than the collection of overseas activities. Furthermore, there is little to suggest that it is crowding out overseas work.

A definitive scripting of what would happen without the RELRP is virtually impossible (as is scripting what will happen with it). What we can say is:

- The collection of international and Australian research is yielding strong pointers to future possibilities for the sector that would be both technically feasible and commercially attractive at plausible carbon prices – over an extended period.
- Lead times till maturity with some of the science remains reasonably long, while lead times in rolling out some of the more promising strategies are certainly long:
  - These lead times are a major constraint on the value offered by the research, but at the same time they underscore the case for bring enough critical mass to bear on the possibilities to 'do justice to their potential'.
- Australian researchers, through the RELRP, do add to this critical mass with quality research that almost certainly is reducing the mean time till key technical breakthroughs occur:
  - In saying this, we are not arguing that the Australian research is inherently better, but that the expanded effort in research that needs to trawl through many possibilities to find the most promising does alter the shape of the forward statistical distribution of outcomes – that it can be worth having an 'extra iron in the fire'.
    - … It skews the distribution to the left, in favour of earlier progress.
    - … This would be true even if there were nothing peculiarly 'Australian' about the RELRP research – and even if, under the most likely scenario, the Australian research would have little impact on the overall rollout – its can still deliver high value insurance against plausible possibilities that the counterfactual would otherwise deliver much more slowly.
- Importantly though, the RELRP efforts are peculiarly Australian:
  - There are trawling through Australian genetics, feeds, climatic and soil conditions and farming systems
  - They are building and cultivating Australian capability relevant to the rollout of technologies wherever they emerge, including both the technical rollout and early creation of certification for application within Australian conditions.

- In relation to effective in-field monitoring capabilities, we understand that RELRP work is at the leading edge – supported by a patent application.
  - We do not know the details of the technology, and are sceptical that the Australian work has brought forward availability by a long time period, but this does lend support to the view that the RELRP is bringing forward the statistical boundary on technology delivery
  - Given the portfolio role of such a technology, as an enabler to other technologies tapping the offsets market, demonstrated success here would certainly support a robust assessment of value.

Any assessment of the magnitude of these effects must be heavily subjective at this stage. However, given the long lead times involved, even a modest advancement in access to these possibilities has potentially very high value, as suggested by Table 1. Note that the last row attaches a value to bringing forward Australian access to an overseas breakthrough. This could be because RELRP cracks a problem earlier, or because of the ability to apply the breakthrough sooner in Australia because of the knowledge of the Australian sector, its genetics etc. A 5-year (effectively one breeding cycle) advancement in a 10 per cent reduction in enteric emissions is indicatively valued at over $400m.

It is this combination of effects – of additional irons in the fire and of complementary access to scope for earlier rollout in Australia, that we see as characterising the world with RELRP v's a world without.

A final element in the counterfactual relates to the policy environment, with and without RELRP. Outcomes from the RELRP may well influence what is feasible politically – and could alter policy settings. Of particular importance though is the fact that some of emerging prospects might be capable of delivering more value, more cost effectively, if institutional arrangements were to be modified to deal with features of these strategies, including farm-level volatility and costs of verification. Some investment in engagement with the policy processes, to ensure that the costs and risks of current settings, and feasible alternatives, are understood could result in a substantial boost to the value of the RELRP outcomes. This is an issue we will address further in the next stage of the study.

Results of our analysis

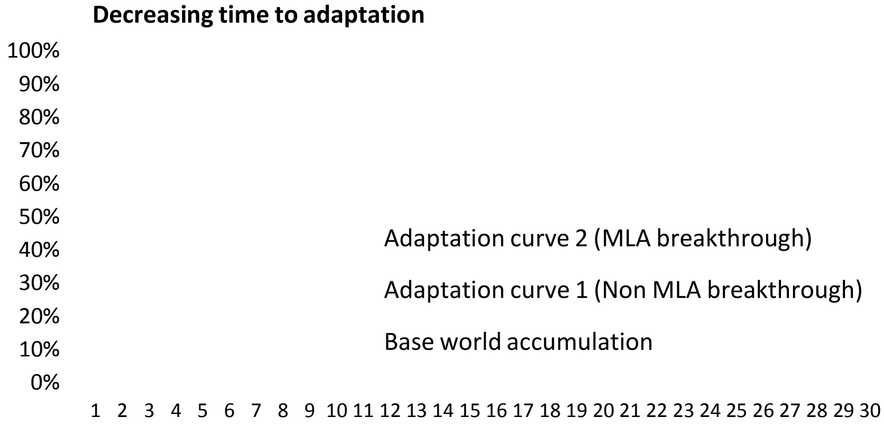
We have applied an options base methodology to test how and under what conditions the RELRP captures a portion of the significant opportunity costs of the enteric methane emissions. In summary the methodology models three ways in which the RELRP adds value for Australian livestock producers to the international research effort under way:

1. By adding an iron(s) in the fire, where the probability of a scientific breakthrough is increased due to the additional effort of the MLA funded work in Australia:
   a) This is sensitive to, but not dependant on, the likelihood of success of the RELRP research compared to the likelihood of success of international research
   b) The relativity of likelihood of success is based on a number of typical factors influencing the probability of research success including:
      i The quality of the research and the prioritisation of the various specific parts of the research portfolio
      ii The extent to which the RELRP research if filling gaps in the international research effort, particularly in areas that are more likely to be relevant to Australian production systems
2. By maintaining research capacity working in Australia MLA is reducing the time it would take to adapt international breakthrough to Australian conditions. The key variable is the extent to which the technology is able to be adopted by Australian producers.
3. Adoption rate of new technology by Australian producers are likely to be quicker and higher if it comes through an MLA research, development and extension program.

The model begins with the establishment of the base case (counterfactual where the rest of the world is investing in the enteric methane reductions (ROW)) which is then modified to determine how the probability of scientific success and time to adaption and adoption changes in a world where MLA invests in the RELRP.

The green line in Chart 1 represents the base case, the purple line the shift in the base case where the RELRP brings forward the time to adaptation of a breakthrough occurring in the ROW, and the blue line is where the RELRP increases the probability of a breakthrough and reduces the time to adapt the innovation.

Chart 1 **Conceptual basis of the RELRP value creation model (probability x year)**



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The model was applied to three key themes of the RELRP; genetics, rumen intervention, and supplements. We believe that the measurement, information management, farming systems themes, while having some value in their own right, are largely enabling investments.

The results of our modelling are shown in tables 2 to 4 below. The results of the modelling show how the characteristics of each of the themes translate into a series of options values overlaid with three carbon price scenarios. There is considerable conservatism built into the modelling and each of the results should be viewed as a lower bound range of potential value.

Under the lowest carbon price regime, the scale of the current investment could be questioned. However, the nature of the investment is that it creates the option, but not the obligation to continue to invest in the program. Therefore, if carbon prices appear to be on a trajectory over following the low carbon price scenario, this review exercise can be repeated to determine if the then current scale of investment is warranted. These results show that the upside potential is significant with limited downside risks, which are potentially covered by the significant spillover production benefits that are likely to result from this investment in addition to the potential methane reductions.

The results should provide some confidence that under all but the lowest carbon price scenario, the key themes demonstrate significant risk management value. The modelling has shown the proportion of the methane emissions reduction options that has been created by individual themes within the portfolio is large with considerable upside potential.

At this stage it is not possible to determine to what extent the modelling results are additive as this depends on the extent to which each of the themes are converging on the same suite of methane reduction technologies but using different pathways.

However, taken individually each present a sound case for continuation of the current scale of the program with some potential reshaping to exploit some of the complementary features of the themes and optimise the option value of the program as a whole.

Table 2 **RELRP genetics option value (low capacity to adapt international innovation)**

	Non-MLA innovation	MLA innovation
Low carbon price (modified CER)	$7m	$18m
Mid carbon price	$17m	$44m
High carbon price (Treasury)	$26m	$68m

Table 3 **RELRP rumen intervention option value**

	Non-MLA innovation	MLA innovation
Low carbon price (modified CER)	$10m	$125m
Mid carbon price	$25m	$304m
High carbon price (Treasury)	$38m	$470m

Table 4 **RELRP supplements option value**

	Non-MLA innovation	MLA innovation
Low carbon price (modified CER)	$6m	$72m
Mid carbon price	$14m	$175m
High carbon price (Treasury)	$21m	$264m

The modelling results were then assemble into a decision tree analysis using the carbon price, time to breakthrough and research costs as the key variables. The summary decision trees are present in the following figures.

The decision trees have been assembled base on individual themes and no interaction has been taken into account. However, there would be interaction between the themes. The interaction is dependent on the extent to which the science underpinning each is common and converging, or where the themes are complementary. The higher the convergence, the greater the interaction between themes. For example; if the genetically derived methane emission is similar or the same as those that are likely to be derived by current rumen intervention technologies, then a rumen breakthrough could supersede the genetics technology.

However, selecting for genetic variance is less risky and therefore acts as insurance against the more risky rumen intervention theme. Supplements play a similar role to both the genetics and rumen theme. Both the genetics and supplements themes also have a much higher probability of achieving some verifiable emissions reductions in the short term that is in addition to their insurance value.

Figure 1 Summary genetics decision tree analysis

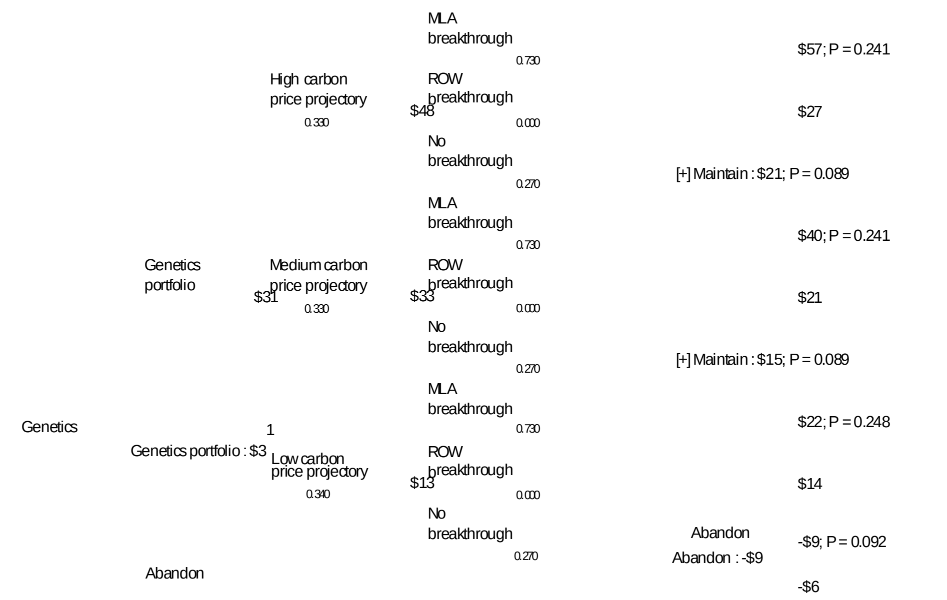


Figure 2 Summary rumen intervention decision tree analysis

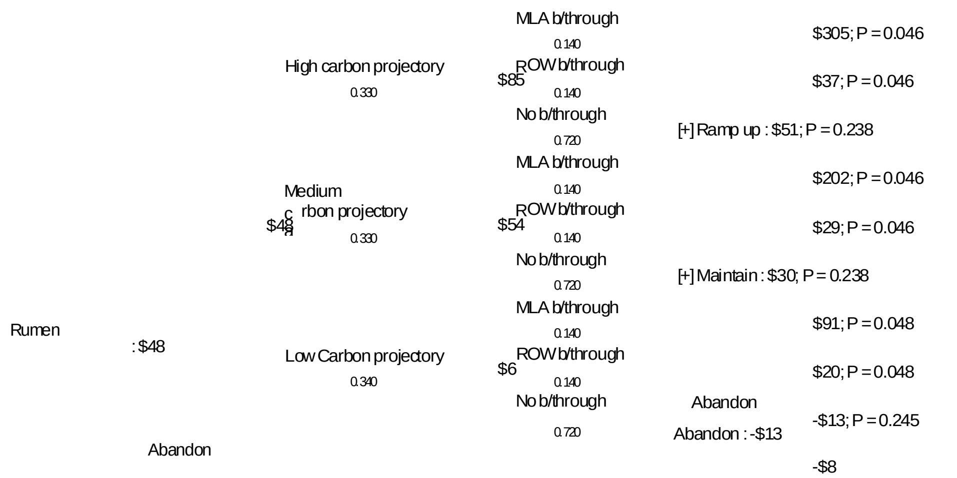
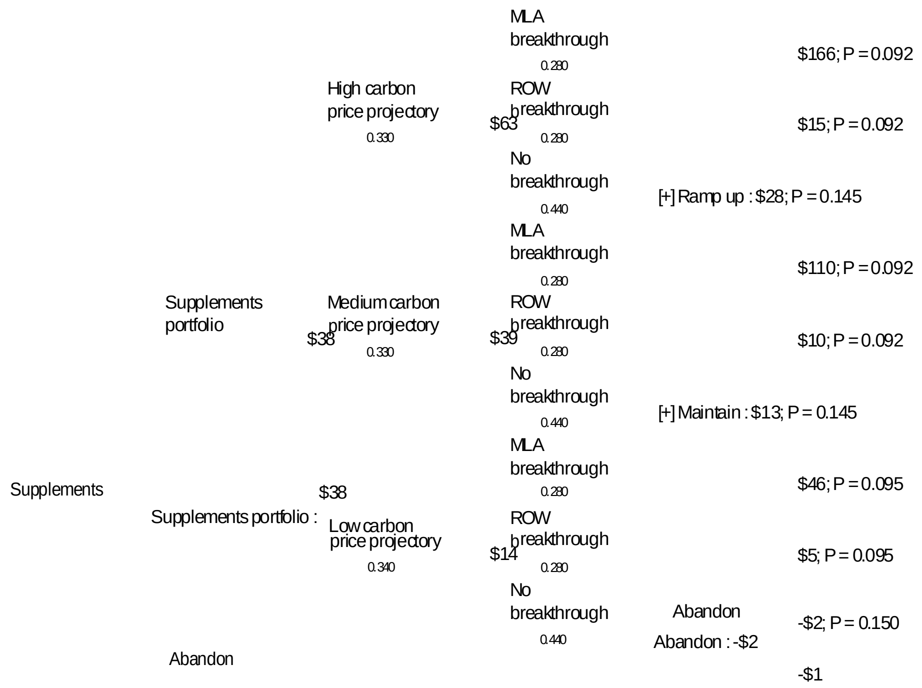


Figure 3 **Summary supplements decision tree analysis**



The consistent message of the decision trees is that under the assumptions we have used maintain investments in the program produces a positive result.

Against the above background, our initial impressions can be summarised as:

- The case for an Australian-focused program of this broad type appears strong, even after factoring in overseas efforts.
  - This case is strongly reinforced by the likely long lead times in achieving penetration with some technologies – and the contribution to these lead times associated with delivering appropriateness to local conditions that can translate into verifiable impacts.
- Early results substantiate a number of claims that Australian livestock industries appear likely to be able (with suitable verification procedures) to offer cost effective emissions reductions, even at modest early carbon prices, with sound prospects for some early practical 'products'.
  - Early products include supplements and genetically selected low emitting animals – both of which may lend themselves to aggregation as a way of limiting monitoring and other transaction costs.
- Identified prospective methane emission reductions being researched appear capable of meeting CFI criteria as they are credibly verifiable, additional and permanent, but may be discounted for leakage – especially if the incentives to deliver carbon offsets, as a new revenue stream, are

strong enough to favour some contraction in traditional production from some enterprises.

  - Careful consideration of leakage risks may be helpful in guiding the balance of effort across the RELRP portfolio.

- There appear to be strong prospects for MLA to use this research program's findings to influence institutional arrangements to gain greater recognition of the abatement options available from livestock – and to limit any perverse effects from the form of those institutional arrangements.

Discussion of our impressions

With passage of the carbon market legislation, and credible forward carbon prices, the stakes are big – big enough to justify substantial investment in insurance against emerging risks as demonstrated by the results of our modelling. Planning should be based around likely medium to longer term carbon prices – with any early sales of offsets being seen more as cost offsets than the purpose of the exercise.

These developments could also justify investment that brings forward the mean time till significant options for such abatement become available from other sources – a relevant perspective, given the scope and quality of work being done outside of the RELRP. There are good reasons to expect that the RELRP would help bring forward such benefits, linked into:

- adding to the prospects for an earlier breakthrough ('extra irons in the fire' argument)
- building and maintaining local expertise for adaptation and extension of both locally and overseas developed strategies
- the likely interactions of the science with local conditions and genes that suggests adaptation starting from scratch after overseas demonstration could entail long lead times to practical implementation, potentially with associated large costs
- possible benefits, including further risk management, from the control of some elements of IP, including in relation to measurement and reporting.

The RELRP appears, based on the science review and subject to the suggestions in the gaps analysis, to involve generally high quality, appropriate science attacking increasingly prospective technical opportunities. Results to date, coupled with experience outside the RELRP, do support the view that significant emissions abatement is likely to prove feasible with relatively modest adverse impacts, if any, on productivity as measured traditionally.

If abatement is verifiable, additional and permanent, the evidence points to substantial value in offsets markets – and at least some of the more promising technologies appear suited to delivering this abatement at a fairly modest 'operating cost', including a number of 'aggregation' prospects in relation to both supplements and breeding (animal and pasture varieties).

There is already a range of measures that could be implemented, with strong prospects for cost effective emissions abatement across the range of these measures; having such initiatives accredited for purposes of selling offsets is likely to take longer.

A powerful feature of the options being developed within the RELRP lies in the way that they will offer the greatest value precisely when and if the adverse wider consequences of the carbon markets for livestock sector costs are greatest. It should be attractive to exercise more of the options precisely if and when carbon prices, and their adverse flow-through impacts along the production chain, rise. In an important sense, RELRP offers some insurance against the more severe plausible ways in which the carbon markets might evolve over time – in terms both of their price outcomes and possible changes to the policy settings.

We do not see permanence as posing a major problem with most of the emerging methane abatement prospects – much less so than, for example, in relation to other areas such as soil carbon. Verification is also likely to be addressed by the development of low cost measurement technologies offering reasonable precision. We understand these may emerge fairly quickly based on work to date and they could open up a range of opportunities for innovation in offsets markets.

However, there appear to be real issues in relation to leakage of benefits if optimal responses by some enterprises entail a reduction in traditional output of meat and wool – meat and wool markets could be expected to 'compensate' by encouraging increased output (and emissions) from enterprises not supplying into the GHG offsets market. Such production-reducing options could have growing appeal as carbon prices rise.

Excessive leakage could translate into discounting of the market value of the offsets, reducing the value of the abatement options and possibly bringing pressure to bear on the exclusion of agriculture from the market. The ability of some firms to 'opt out' of participation is a key factor underpinning these leakage concerns. For this and other reasons we are exploring whether there might be a case for RELRP placing stronger emphasis on 2-way interaction with the emerging institutional arrangements – essentially some research into impediments to sound behaviour change and ways of tweaking the institutional arrangements to address those impediments.

Essentially, this would involve introducing complementary options into the portfolio, to allow greater value to be derived by both the livestock sector and the Australian economy from the prospects now being pursued.

Implications for forward strategy

Based on the work to date, we have certainly found nothing to suggest the current level of investment in these challenging technologies is excessive, or that balance across areas of research is particularly poor.

With increasing indications of real prospects for abatement through several technologies, and with apparently growing confidence that in-the-paddock monitoring with reasonable precision is likely to become possible, and accepted, in the reasonably near term, the portfolio appears to offer growing value. These trends would, if anything, favour some ramping up of efforts, given the growing prospects for early deployment of the options. Passage of the carbon legislation and the CFI both appear to strengthen the case for this type of investment and for seeking to accelerate access to abatement options that could be implemented at modest cost.

However, some considerations raised here do raise challenges for the detail of the portfolio balance and will need to be given greater attention in the next stage. Included here are:

- The leakage issue that is likely to make some forms of farm-level abatement more commercially attractive than others – and that may need to be addressed with a portfolio skewed towards these possibilities and/or complementary measures directed at limiting the incentives and scope for leakage.
- The indications of high volatility in achieved outcomes from some measures is both a problem in its own right and a challenge to harness smarter ways of working with high volatility:
  - Possibilities here include the certification of diversified portfolios of behaviour changes, across farms, regions, systems etc to deliver lower volatility packages for certification.
  - A longer term alternative would be to pursue change in international rules to remove what could be a costly bias in the incentives for abatement.
  - In both cases there are challenges for the balance of the RELRP portfolio and for its engagement with policy processes.
- Some consideration should be given to the extent to which the genetic, rumen intervention and to a lesser extent, the supplements themes are converging on the same technology and scientific explanation. The lower risk but long adoption lead time of the genetics program suggests that it is useful insurance against the higher risk rumen research. However, its

option value could be enhanced considerably if the genetic selection was skewed to providing methane reductions that operated under different pathways than the rumen interventions. A similar review should be applied to the supplements investments as well

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1 Introduction

ACIL Tasman was commissioned to undertake an analysis of the Meat and Livestock Australia (MLA) research program Reducing Emissions from Livestock Research Program (RELRP). The program is a joint initiative of the Department of Agriculture Fisheries and Forestry (DAFF) and MLA.

The project was undertaken between December 2011 and March 2012. It has relied on information provided by MLA on the project and independent scientific peer review of the research conducted to date.

2 The task

The first objective of this project is to determine what, if any, net economic impact the suite of methane emissions reduction research investments undertaken by MLA in the RELRP program have had. The second objective is to document insights into the types of further activity likely to deliver value for money, and prioritising some of the prospects highlighted by the 2011 science review of the program.

MLA is funded by a mixture of levies collected from Australian sheep and cattle producers and matching Australian Government funding up to 0.5 per cent of the gross value of production. Therefore it will be important to also look at how the benefits of the research are distributed between levy payers and the Government.

The MLA levy payers will be interested what benefits may accrue from the research to their individual businesses and what future risks are being better manager due to this investment. The Australian Government will be interested in the additional contribution livestock enterprises may make to meeting Australia's overall emissions reductions targets as a result of this research by offering cost effective abatement opportunities through the Carbon Farming Initiative (CFI) in the first instance, and potentially through inclusion in the carbon trading system proposed after 2015.

3 Context and opportunities

In late 2011 the Australian Government passed legislation to implement a tax on greenhouse gas emissions. The tax will come into effect on 1 July 2012. To an extent, the terminology 'tax' is a misnomer in terms of defining the policy. The tax is really just a transitional instrument to allow a carbon market to be introduced with greater certainty as to costs in the early years than would be possible were the market to be introduced from day 1.

The implied carbon price is set to start at $23 per tonne, rising by 2.5 per cent per year until 2015 where a carbon trading system will take over to determine the price. Market forces, driven by the size of evolving aggregate emissions entitlement pool and by technological and behavioural changes flowing from the policy, will then largely determine the price. There are, however, provisions to include a cap and floor on price (with the initial tax being an extreme version where the cap and floor are set to be equal) to contain the rate of price movement and potential for volatility – these will rise, and the gap between them will widen, over time.

The arrangements are to apply directly only to deemed large emitters – estimated to be about 500 firms across Australia. Agriculture has been explicitly excluded from the direct and compulsory application of the tax (and the subsequent quantitative constraints of the trading scheme) to its emissions, though it will still face a range of indirect impacts via the application of these arrangements to key inputs to its production and later transport, handling and processing. It is also the direct focus of the parallel CFI.

The purpose of the carbon tax evolving to an emissions trading scheme is to contribute (along with other policies, including the CFI) to limiting, in a credibly demonstrable and predictable way, Australia's *aggregate* emissions of GHGs. A tax delivers price certainty, but cannot guarantee that emissions will be reduced below target levels; an unfettered market with a quota on aggregate emissions can deliver certainty in meeting targets but with substantial uncertainty as to the carbon price. The proposed arrangements seek to effect a gradual transition between these two approaches, that ensures that targets can be achieved over time.

Importantly though, the policy is not designed to limit the emissions of each individual firm. Instead, the adoption of an approach based on tradable emissions rights clearly implies the intent to ensure that increasingly 'scarce' rights to emit are concentrated in applications where the remaining emissions allow the creation of greatest value. This will be areas of activity where the opportunity cost to the economy of further limiting emissions will be greatest. Some sectors may actually increase their emissions under the policy – but in order to do so will have to have justified the opportunity cost associated with using up the associated emission rights and restricting activity in other sectors. Proposals for limited use of international trading further frees up opportunities for sectors that can deliver high value in relation to emissions to be able to do so.

An immediate consequence of the policy has been to *increase the value of technologies* that might previously have been uncommercial but that offer opportunities to increase greenhouse gas efficiency in production systems at modest cost – at costs that could prove competitive against the market price of emissions rights. In turn, this has increased the value of R&D initiatives that show promise of delivering such 'competitive' opportunities to improve emissions efficiency.

It is important, for the purposes of this assessment of RELRP, to recognise that this value increase has already largely occurred – driven by the increased likelihood of such technologies being deployable, given passage of the legislation and the CFI, and given realistic prospects for carbon prices rising well above initial levels. Reflecting the broad approach taken in our assessment below, we note that the *value of options to deploy* more carbon efficient technologies, and of options to develop more carbon efficient technologies, has risen strongly as a result of these recent developments. This is true even of prospects that are not yet proven.

Importantly, under the CFI, agriculture will be allowed to provide offsetting emissions reductions – to trade emissions reductions into the national scheme, under certain circumstances, as discussed in more detail in section 6. Agriculture also has the potential to provide/sell offsets into voluntary commercial GHG reductions schemes. Voluntary reduction schemes are generally established by companies seeking to develop a commercial advantage by associating environmental responsibility with their products or services.

To date voluntary schemes have generally offered only low offset prices and have experienced limited adoption by Australian primary producers. The introduction of the 'carbon tax' will offer much higher carbon offset prices for compliant activities – though in general the requirements to demonstrate compliance are expected to be quite stringent and in some cases costly.

These opportunities to provide offsets will confront the livestock producer with an *opportunity cost on the emissions they produce*, raising questions as to whether it might be feasible and commercially attractive to avoid or reduce emissions through changes to production processes. This means that livestock producers will have another potential source of revenue for their livestock enterprises – a new 'product line', in the form of *verified emissions reductions*.

This product line will not, in general, be costless to 'produce'. However if, as expected, the opportunity cost of the emissions, as seen by the farmers, rises over time, it may prove attractive to adapt the farm model to allow increased 'production' of verified emissions reductions. This may even be true if it comes at the expense of some reduction in traditional production (of meat, wool etc.) Farmers have long faced trade-offs across the range of products they produce – looking to develop the best product mix given technical possibilities and input and output prices.

With the introduction of the carbon tax and the ability of farming to offer offsets, when making decisions about their enterprises, producers will seek to maximise net revenue based on the multiple revenue streams that the enterprises can produce. For example a beef producer will decide what mix of beef production and emissions reductions will maximise enterprise profitability. Similarly, a sheep producer will decide what mix of wool, sheep meat, lamb and emissions reductions offsets will maximise marginal revenue.

The scope of the offsets available to livestock producers will be determined by what will be a recognised offset under the CFI (see section 6 for more details on the CFI).

Therefore for sheep and cattle producers the value of the RELRP will ultimately be determined to a large extent by the net improvement it delivers in profitability of beef and sheep production, inclusive of the ability to produce and sell offset activities.

However, looking forward, the value of the RELRP should be seen as lying both in this prospective value, given plausible ways in which the carbon trading regime may evolve to deliver a market price on emissions reductions, *and* in the way that the program can help to limit risks to the livestock sector that might otherwise emerge as a result of an escalating price on emissions and/or plausible future changes in the institutional and market arrangements. Logically, this includes possible future inclusion of agriculture within the carbon market and possible emergence of significant premiums on products that can demonstrate low embedded emissions.

It is important to recognise that, even ahead of the introduction of the tax and its evolution to a trading market, the RELRP has delivered value (though not necessarily value for money) by expanding the available set of promising lines of development to tap into these future opportunities. To the extent that the underlying science is better understood than would otherwise have been the case, and that there are promising ways in which farm activities might be adapted over time to deliver emissions reductions (or, more importantly, reduced emissions intensity in livestock production), that as a result of this work have prospects for early progression into practical production options, value will have been delivered already to the livestock sector.

The value of the program for the Australian Government will be the additional reduction the research will make to the national costs of delivering on abatement targets. In this case additional means that any abatement produced by the research is additional to what the sheep and cattle industries would have produced in the absence of the RERLP. This includes cost reductions that can be achieved earlier than would otherwise have occurred.

The contribution the research makes to reducing national abatement costs means to what extent will this research lead to marginal offset opportunities in the livestock industries that are competitive with the next cheapest source. By creating lower cost marginal abatement opportunities, the RELRP should reduce the net cost to the economy as a whole of reducing greenhouse gas emissions, assist Australia meet international abatement obligations (should binding obligations be entered into by the Australia Government), and ultimately forestall dangerous global warming to that extent that reductions in cuts to anthropogenic emissions can.

Of course, ultimately, these values need to be justified relative to the costs of the RELRP and the costs of implementing the farm changes needed to tap into these opportunities.

3.1 Structural uncertainties and the carbon price

Given that the value of the RELRP – and indeed the level and form of the RELRP that will be cost justifiable – will be heavily dependent on future carbon prices, it is important to recognise the remaining institutional uncertainties that will largely shape the price over time. These uncertainties apply in Australia and internationally.

Within Australia, the Opposition is strongly opposed to the proposed carbon market. Furthermore, the prospects are substantial for a change of Government, at the next election – following an Opposition campaign based on a policy platform that includes undoing the carbon market arrangements. This in itself does not guarantee they will be unravelled. Such a change is likely to fail in the Upper House and could require a double dissolution if it is to succeed. This would certainly take time and meat and livestock sector planning would sensibly include a real prospect of the arrangements remaining, even with a change of Government.

It is also important to recognise that the Opposition is also committed to constraining emissions – proposing instead a 'direct action' policy that would entail the Government 'buying' emissions reductions. Indeed, its proposed policy includes a form of market that would bid to supply emissions reductions for a price – with the costs to come from tax revenues. The overall effect of such a policy will also be to post a carbon price, and to do so in a way that could create attractive opportunities for livestock producers able to lower their emissions and demonstrate this lowering, at modest cost.

From the point of view of the RELRP and its value, the major distinguishing feature of the two policy approaches is likely to be the level of restraint on emissions delivered over time – and possibly the acceptability of some forms of emissions reductions where there remain some concerns as to permanence (notably some forms of capture of carbon in soils).

There is likely also to be variance in the willingness to deliver reductions through purchase of overseas credits. Greatly widened access to overseas credits could deliver a substantially lower carbon price than that suggested by the current Government price forecasts.

Overseas developments will play a key role in shaping the Australian carbon price, irrespective of the Government of the day. Government forecasts are heavily driven by assumptions regarding the rate at which the rest of the world moves to pricing carbon and how this is done. Large uncertainties in this area that have not been greatly reduced by outcomes from Copenhagen and Durbin remain important elements in forward price uncertainty.

We discuss in section 1 below possible price scenarios that we have then used in weighing the value of the RELRP and in drawing out strategy insights.

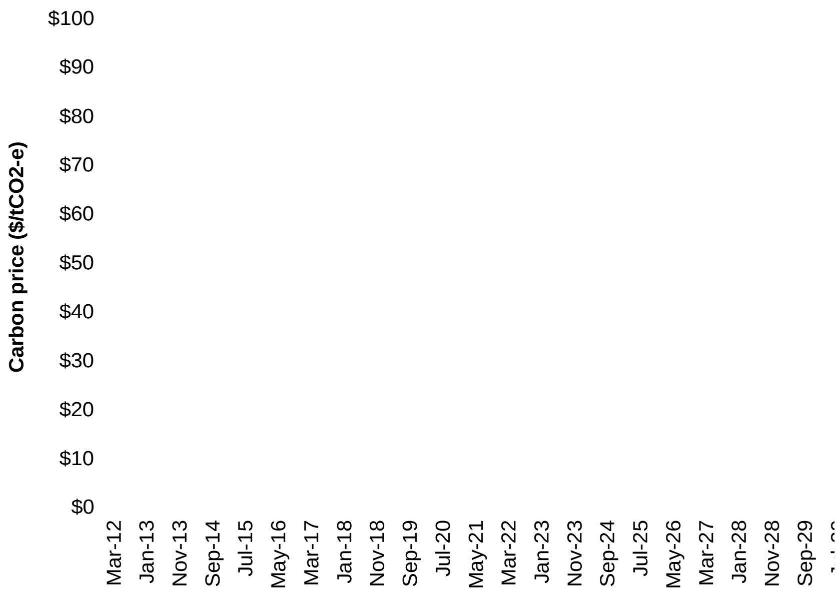
3.2 Creating value in the RELRP

The way that MLA creates value for producers and the Government through the RELRP is by identifying, funding and overseeing the extension of research into reducing livestock methane emissions and/or lowering the methane intensity of livestock production activities. Therefore MLA's performance will be determined by:

- How well it can prioritise and oversee individual methane emissions projects, and
- Combine a number of projects into a portfolio (and manage that portfolio), which produces a higher risk weighted return than one or more individual projects would if conducted in isolation

It would be a potentially costly mistake to view the *purpose* of the RELRP as being to lower emissions from the livestock sector – even though that seems a plausible outcome. We have taken the view that the RELRP, as a livestock sector-driven initiative, is fundamentally a program whose purpose is to *lower risks faced by the sector*, especially in the context of probable input cost increases flowing from wider emissions policy settings in Australia and overseas. We view the RELRP as being directed at *cultivating an expanding set of options* for livestock producers to *respond, better than they otherwise could, to the threats and opportunities* likely to be opened up by the proposed GHG policy environment, and by plausible developments in that environment over time.

Chart 2 **Projected nominal carbon price (based on the medium international response scenario)**



Data source: Australian Treasury modelling conducted for the Clean Energy Future policy

In particular, we note:

- The forward market cost of GHG emissions is quite uncertain, after the tax is phased out, but based on modelling to date will probably rise substantially (see Chart 2) , and plausibly very substantially, as the level of permissible emissions is reduced. Current projections show the carbon price increasing by 8.25 per cent per annum between 2012 and 2030
  - Rising prices can be expected to entail rising input costs for agriculture and the processing and transport of agricultural products.
  - The original modelling was of real prices, to which inflation assumptions were later added. That modelling points to an approximate doubling of the real price between 2012 and 2030, with a significant upwards trend continuing beyond 2030.
  - At the same time, rising prices for verified emissions reductions can be expected to increase the value of options to deliver offsets to this market – so these options are likely to have greatest value if and when

they are needed most, to compensate for the rising cost of inputs to livestock production.

  - This suggests a potentially valuable role for the RELRP in delivering to the livestock sector a *hedge strategy* to deal especially with plausible 'high price trajectory' evolution of the carbon markets
    - … This could attach value even to abatement possibilities that are unlikely to make economic sense under more moderate and even most likely price trajectories – highlighting 'insurance value' that might be delivered by the RELRP.
    - … There are parallels here with the substantial investments being made by governments in carbon capture and storage technologies, even ones that would require very high carbon prices to break even.
- In any case, rising market prices on emissions (and firming expectations of future rises) can be expected to flow through to rising value in options to create and sell offsets, and the livestock sector would benefit from access to a wider range of strategies to allow it to generate offsets cost effectively under plausible forward price scenarios.
  - Effectively, this entails management of the risks that the sector could otherwise find itself unnecessarily constrained in its capacity to benefit from these emerging opportunities.
- While agriculture has been excluded from the direct effects of the planned carbon market, this status is not certain running forward indefinitely.
  - For example, were international developments to favour Australia moving to an even more aggressive emissions target in the longer term – extending well beyond the current 50 per cent reduction by 2050, then current emissions from agriculture could emerge as a major constraint driving the costs of compliance. Ultimately the exemption, without other effective mechanisms to lower agricultural emissions, places a ceiling on the level of emissions reduction that is even technically achievable in Australia.
  - Were other economies to move aggressively against agricultural emissions, in ways that could affect their sectors' costs and competitiveness, then the case for maintaining the exemption in Australia may well be seen to have weakened, especially if the effective cost of the exemption is rising rapidly
  - While the major political parties have given no indications that they would consider removal of the exemption, it would seem sensible for the livestock sector to include in its planning strategies to have it better placed, in the medium to longer term, to accommodate a shift in this exclusion policy towards a strategy that more explicitly targets agricultural emissions.

MLA's investments options extend from investing all of the funds dedicated to reducing emissions into one project based on a single avenue of research assessed as having a high probability of success, through to a very large number of much smaller projects.

If investing in one large project, MLA would need to take into account the heterogeneity of its levy payers' emissions reductions requirements as the herd and flock is spread over different breeds, and different production systems, operated in a wide range of climatic zones and soil types. To address this MLA would sensibly look to invest in research that, if successful, would have universal, or at least very wide, application but this would narrow the research possibilities dramatically. Therefore MLA has strong incentives, by the nature of the character of its constituents' needs, to develop portfolios of investments. However, the case for looking at developing a diverse portfolio of options is in fact much stronger than this.

By adding projects to its portfolios of related research (of which methane reduction is one) the risk of not producing a successful innovation is reduced. The extent of the reduction of risk brought about by the additional of each project to the portfolio is dependent, in part, on the extent of the correlation between projects. High correlations reduce the risk reduction effects of each addition and *vice versa*.

3.3 Plausible price futures

Chart 2 sets out one version of plausible carbon prices out to 2030, based on current Government policy and a range of assumptions about international and technological developments – and inflation rates. Given the institutional uncertainties set out in Section 3.1, it would be sensible for any assessment of the value and future direction of RELRP to allow for significant departure from these estimates.

Our view is that the price trends shown in Chart 2, while feasible, are more likely than not on the high side. The estimates were based on assumptions, especially in relation to international action, that appear now less likely. To help in working with the uncertainty, we have considered three alternative scenarios.

Our first approach has been to use the Treasury Core Policy scenario carbon price trajectory which assumed medium global action to nominally limit aggregate emissions by 2100 to 550 ppm (which is consistent with the upper bound for the stated aim of limiting temperature increases compared with the preindustrial period to 2 degrees Celsius - although with substantial associated uncertainty.

This price path assumes OECD countries join the global efforts by 2015 and the large non-OECD emitters (incl India, China and Brazil) by 2020. This objective now appears aggressive particularly since Copenhagen and Durban. Nonetheless, it is relevant to note that the Treasury modelling included upper level price scenarios that again doubled the carbon price by 2030 (to over $180 per tonne nominal and $120 per tonne real). While our view is that this Core Policy is now likely to prove high, it is not a worst case scenario – and this is relevant for the value of RELRP, viewed as a form of insurance against high carbon price outcomes.

Our second approach looks to the European market, with a view to too severe a divergence over time being likely to erode the political attraction of the Australian arrangements. The current European price is about 4 Euros this year and escalating at a cost of carry of around 7.3% per annum.

This is very low and is affected by a number of structural factors depressing prices including low European economic growth causing lower emissions and hence demand for permits, the heavy grandfathering of free permits and significant changes to the eligibility of CDM based permits leading to a rush to sell them prior to the change. Permit liquidity falls dramatically over time with almost zero liquidity after 2016. Prices are posted to 2020 on the InterContinental Exchange which is one of the major trading exchanges for carbon in Europe. Prices after 2020 have been escalated at the same cost of carry. They have been converted to AUD by allowing a gradual depreciation of the Australian Dollar against the Euro such that in 2020 it is 0.6 Euro to the AUD.

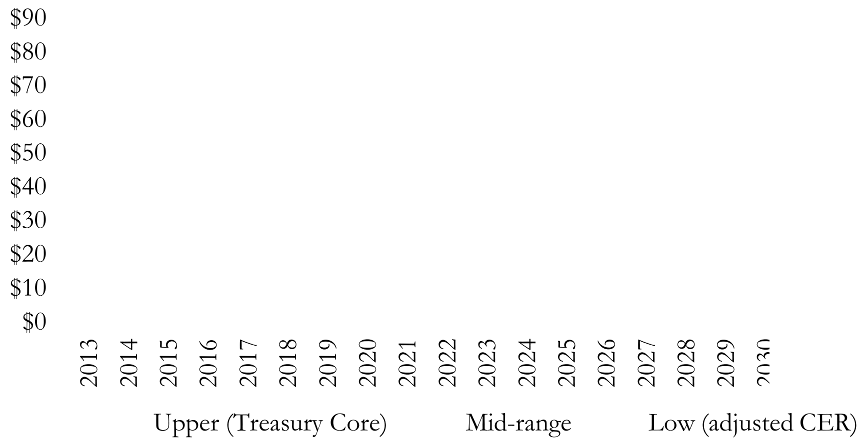
We have then adjusted this series to reflect the legislated Australian tax rates for the first three years. We assume the current legislation lasts for at least this period, but that after that it might be replaced by an alternative that delivers a price outcome closely linked to this European CDM permit based price outcome. This approach implies a substantial drop in price after the first there years, though strong recovery in Europe and/or policy change in Europe could push the prices higher.

The European curve, and its adjusted version, are well on the low side. The adjusted curve might reasonably be viewed as showing a lower bound price, even in the context of a shift in Australia to direct action – where the European price might be seen as setting a logical floor on how aggressively the policy is pushed in Australia.

The third approach is a mid-point estimate. It has three years of fixed prices and then implements a price based on the average of the European and Treasury figures, but constrained to not allow the price to fall below the third year tax rate. It is not overly scientific but Treasury looks high and Europe low (based on underlying factors in each case) and hence the mid-point might be seen as a more plausible indicator, recognising that this includes uncertainty about policy change in Australia as well as wider trends. Notionally, it might be seen as transition to a pragmatic policy that allows increased use of international trading to constrain the gap between the Australian and the European prices, but that does not allow for 'going backwards' while the underlying pressures favour a higher price. Having said all that, it is important not to read too much into this series, beyond its being reflective of a middle price path..

These three indicator price series out to 2030 are shown in #### below; nominal prices are shown. We stress these are not presented as forecasts, but as indicators of the range of uncertainty that forms the backdrop within which the RELRP investment needs to be justified and managed. Indeed, as noted above, it is certainly possible that higher prices could emerge, especially if international agreement on concerted action is achieved, adding further to the insurance value of abatement options for the Australian livestock sector.

Chart 3 **Carbon price scenarios to 2030, nominal AUD**

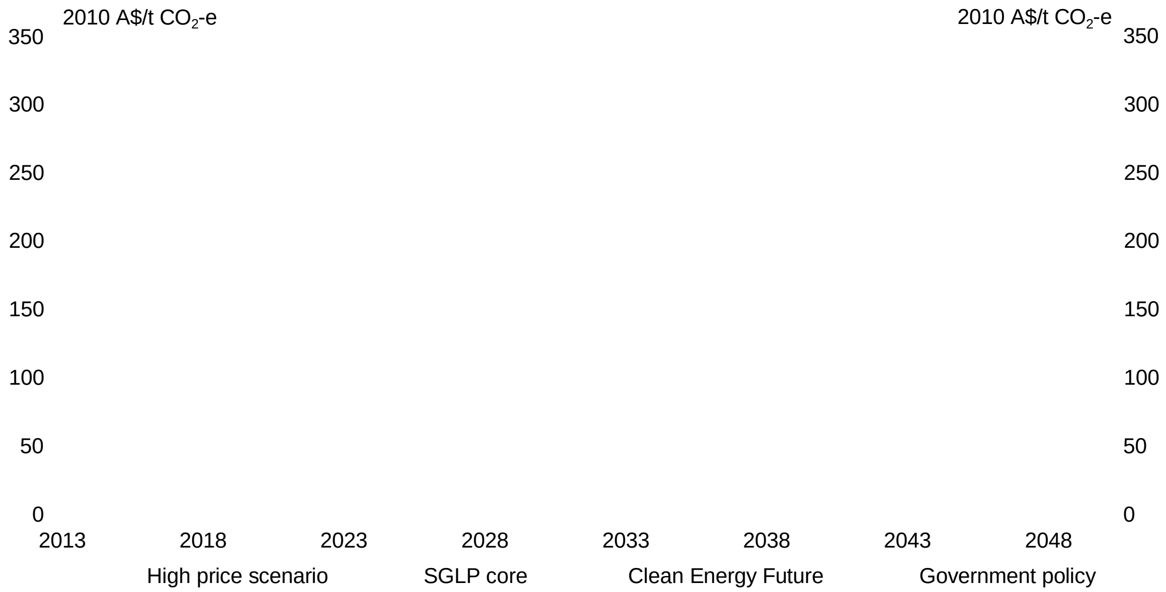


Source: ###references for Treasury and CER and note that the mid-range and low series have been adapted from these two sources by ACIL Tasman, as indicators of forward price possibilities only.

It is important to recognise that these nominal prices embed assumptions regarding inflation rates that are themselves uncertain. For purposes of assessing the RELRP investment, trends in real carbon prices, and these trends relative to the price of meat and livestock products, will be of greatest importance. All the above scenarios imply a cost on carbon running out into the future, with initial prices around $23 per tonne. The upper scenario implies a significant trend in real prices, approximately doubling the real carbon price out to 2030. The midrange scenario implies about a 50 per cent rise over the period, but with most of the growth deferred for several years. The low scenario actually entails a falling real price.

From the perspective of the RELRP, the real action may well lie in the time period beyond 2030. Even if response to the emerging prices can begin much earlier, the long lead times likely in relation to some approaches – notably animal breeding – suggest that a lot of the potential abatement may not be practically accessible until well into the 2020s and even beyond. It is significant, therefore, that the Treasury model, as set out in ## below, suggests a continuing strong trend towards rising real prices. Treasury developed 4 scenarios leading to the chart, but three entail, for all intents and purposes, the same prices. The high price scenario is, however, very much greater than these three.

Chart 4 **Treasury forecasts of trends in real carbon prices**



Data source: http://www.treasury.gov.au/carbonpricemodelling/content/chart_table_data/chapter5.asp, Chart 5.1

Note also that the prices in this chart are in 2010 dollars. Converted to 2012 dollars would imply all prices would shift up about 5 per cent.

4 Our approach

There are two distinct features of our approach to assessing the value created by the RELRP. The first is a *robust counterfactual* which allows us to compare what would have happened if MLA had chosen not to invest in the program with the current situation. This is a standard element of any impact assessment and requires some judgements as to what would have happened had MLA not invested in the program.

The judgements we have made are based principally on what incentives other would have to invest in the absence of an investment by MLA and the likely relevance of investments elsewhere for early application in Australia. The other important aspect of the counterfactual is the Australian and international policy approaches to reducing global warming within certain limits and the policies used to achieve this.

Our counterfactual is described in more detail in section 7.

It is important, though, to recognise that we are not prepared to assume that the RELRP is likely to deliver valuable capabilities that would not otherwise emerge from the substantial volume of work being done around the world, and even outside of the RELRP in Australia, in this field. RELRP is more likely to influence timing and the ease of translation of the research results into an Australian context – and may have implications for the value to the sector of associated IP.

The second feature of our approach is the employment of a *real options philosophy* as well as associated analytical tools to assess the impact of the program and the options it has created for future investment. Use of this approach is largely dictated by the above discussion, which recognises that the value offered by the RELRP should be seen in the portfolio of options being delivered to deal with forward threats and opportunities. This approach probes the additional value that MLA has achieved through assembling an managing the portfolio compared to the reduction in risk that could be achieved by simply investing in a large number of methane emissions projects and allowing statistics to do the work.

Real options also allows greater probing of the value of the portfolio over time as this method assess the opportunities that have been created for future investments to be made and the probability of those investments creating value due to key uncertainties being resolved or managed up front.

Another key feature of the real options approach – that again ties strongly into the ‘risk management’ perspective we have taken – lies in its emphasis on adequately valuing the *flexibility* offered by the portfolio of options. Instead of thinking about the value of R&D investment in terms of a scripted 'base case' in which the R&D is applied, the real options approach places strong emphasis on robustness in dealing with what is typically a high level of uncertainty regarding actual future outcomes.

The uncertainty relates not only to the success or failure of the research (viewed in convention terms) but uncertainty of the livestock operating environment.

This robustness can be probed in a range of ways, but all rely on recognition that there is a range of plausible futures within which decisions on whether and how to apply R&D outcomes will need to be taken. A portfolio of options that delivers protection against the more severely adverse prospects, possibly accompanied by options to better exploit some plausibly attractive future possibilities, will perform well when probed for robustness, even if the options are unlikely to make much difference under the most likely future scenarios. In this approach, the role of R&D in delivering insurance – against adverse risks and against being unable to take advantage of upside opportunities, is emphasised.

The potential for portfolio diversity to support greater robustness is well understood. Diversification can be a sound strategy even if (as it often does) it entails some reduction in expected profits because of the coverage it offers against plausible extremes. In the same way, insuring a firms buildings, fences and even crops against hailstorms can all involve the purchase of robustness at the expense of some expected profits.

At the same time, this paradigm favours thinking carefully about the best *form* of insurance. It encourages exploring different ways of insuring. Strong, high cost, pre-emptive strategy to limit risks might be looked upon as insurance with a *high up front premium*, but potentially *low excess*. An alternative approach may entail less pre-emptive strategy, but ensuring the capability exists to cope with more extreme possibilities, even if this would then entail higher costs. This can entail insurance that involves much lower up-front premiums, but higher excesses in the event that a 'claim' is needed. The right choice can depend on a range of factors but it is important that these trade-offs be probed.

This type of probing – of different ways in which to manage risks and different ways to effect the trade-off between limiting the damage from extreme events and limiting the costs incurred in the event that there are no extreme events – often yields powerful insights into better ways to plan and manage the risk management strategy. One outcome can be to dramatically lower expected costs while retaining strong insurance against particularly adverse consequences.

At the heart of this approach lies a realistic assessment of the plausible range of future conditions that might need to be accommodated and careful exploration of ways to better align the circumstances in which high costs are incurred with those situations in which those high costs deliver high value.

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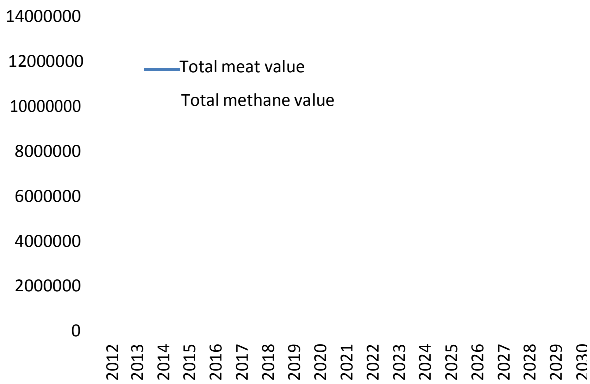
5 Why research methane?

The section establishes the case for researching methane from a livestock producers and economy wide perspective. The following sections build on this rationale for methane emissions research, and develop the counter factual.

5.1 A producers perspective

The stakes for livestock producers are high. The cost of emissions is likely to rise and rise significantly as emissions are reduced in the rest of the economy. The starting point of $23.00 per tonne is just that, a starting point. Prices for carbon dioxide and equivalent gases are projected to rise significantly above that rate of appreciation of meat prices. If meat prices and productivity rates continue at recent trend rates the opportunity costs of methane emissions as a proportion of meat value (at the farm gate) will grow rapidly.

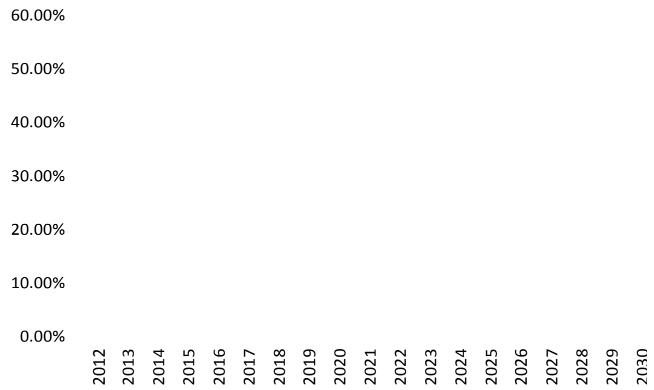
Chart 5 **Total meat and methane emission value (2012-2030, $'000)**



Data source: ACIL Tasman analysis based on Treasury CO2 emissions price projections, DCCEE livestock forecasts

When the value of methane emission is charted as a percentage of farm gate meat value the trend becomes even more apparent as can be seen in Chart 6.

Chart 6 **Methane 'value' as a proportion of total meat value (2012-2020)**



Data source: ACIL Tasman analysis based on Treasury CO2 emissions price projections

Looking at this trend from a livestock producer's perspective, if the opportunity cost of methane emissions follows the projected trend, the methane revenue stream as a proportion of total livestock enterprise revenues becomes substantial. By 2030, a livestock producer would be indifferent from giving up approximately 50 per cent of his total meat revenue if he could be paid the going rate for eliminating his methane emissions. Clearly this is a hypothetical, as not all methane emissions would be able to be eliminated, but it does demonstrate the importance of the methane emission opportunity costs in future enterprise decisions.

Given this projected price rise and the amount of emissions livestock makeup of the total national greenhouse gas emissions, pressure will mount over time to reconsider agriculture's exclusion from the proposed carbon trading scheme.

5.2 An Australian Government perspective

Australian agriculture makes up approximately 16 per cent of Australia's total greenhouse gas emissions. Enteric fermentation makes up approximately two thirds of agriculture's total emissions – about 10 per cent of total accounted emissions. If agriculture were totally excluded from providing any contribution to reducing the cost of greenhouse gas emissions reductions, the costs of achieving emissions reductions would fall more heavily on other sectors of the economy.

Therefore there are significant economy-wide incentives to develop mechanisms to access to agricultural emissions reductions opportunities where these might be more than competitive with the highest cost alternative abatement options that would otherwise need to be exercised. The reasoning parallels the arguments for some international trading in emissions restraint, as is proposed under current settings, to allow lower cost ways of abating atmospheric GHGs to be sought out and used in preference to higher cost ways. The same incentives of course underpin the case for exploring whether there are cheaper ways of delivering acceptable offsets from agriculture.

Accessing these opportunities is not only dependant on having a policy mechanism to access agricultural emissions reductions. There must also be a reasonable expectation that agriculture can supply cost effective emissions reductions.

The CFI is a policy mechanism designed to allow the economy to tap cost competitive emissions reductions from agriculture, to help contain the overall cost to the economy in achieving a given lavel or rate of emissions abatement. It is discussed further in section 5.3.

Importantly, there is growing evidence to suggest that a significant proportion of enteric methane emission reductions could be cost competitive with other sources of emissions reductions that are otherwise likely to be used to comply with the proposed GHG regime in Australia. What is important here is the economic cost of tapping into some enteric methane reduction relative to the most expensive of the alternatives that would otherwise be needed to meet emissions targets. The comparison is not with the average cost of other measures but with this marginal cost, that is expected to rise steadily as the permitted level of aggregate emissions is lowered, alongside growing demand for products that have traditionally involved significant emissions.

Against this background, the basic elements are in place – inviting the development, packaging and demonstration as a basis for certification of technologies and farm systems that can tap into these possibilities. This in turn feeds into the pointers to potential value – and potentially high value – from the RELRP.

As was flagged earlier, there is an additional 'insurance' case for ensuring that agricultural emissions are contained and that those emissions that do occur are cost justified, including in the presence of the carbon trading arrangements. The development of lower cost ways to contain emissions, or to demonstrate containment of emissions in a way that would permit offsets to be traded, could provide insurance against possible future policy change. This could occur through either or both of reducing the likelihood/severity of any future policy change, and reducing the consequential damage to the sector from a policy change (by delivering useful options to mitigate the damage). As was noted earlier, this insurance involves a natural risk hedging – with the benefits from access to offsets opportunities being greatest precisely when the costs of indirect impacts of the carbon market on agriculture, via input, processing and transport costs, are highest.

Similarly, there is likely to be value in insurance against the distinct possibility that acual carbon price outcomes could be higher than current projections, such as those used in Chart 5 and Chart 6 above. Again, we would expect some natural hedging, with RELRP outcomes offering greater value if the carbon prices rise higher than expected – just when the insurance is most needed.

In what follows, we have focused on value driven by the currently proposed policy settings, while recognising that actual carbon price outcomes are quite uncertain. However, it is important not to lose site of the additional insurance value against plausible changes in Australian policy and, indeed, plausible changes in international policy that could result in pressure on Australian policy settings.

5.2.1 Methane emissions abatement potential

Of course, Australian agricultural emissions can be abated. Reducing Australian livestock numbers would, in general, have that effect. Our interest is in potential for abatement that has reasonable *prospects for being cost effective* – in the sense that, inclusive of the value attached to the abatement and better risk management, enterprise and sector profitability and wider performance is improved, or at least maintained (relative to the alternative outcomes in the event that abatement is not pursued), as a result of such behaviour change and abatement. This does not require that the sector benefit overall from the carbon regime, but that it does benefit from adapting to the reality of the carbon regime in ways that exploit the opportunities to alter behaviour in order to offer offsets.

It is crucial to recognise that the target of methane R&D should not be the delivery of options to abate methane while maintaining production of traditional livestock products. If the objective is to deliver maximum value to the sector, and even to the Australian economy, then the implications of methane abatement strategy for production of traditional livestock products should be left flexible. At one extreme, the 'holy grail', would be delivery of a range of methane abatement options that effectively reduce the apparent 'inefficiency and waste' implied by methane production. Theoretically at least, such options might justify expanded production of traditional products. Some such possibilities may well exist – but are unlikely to be the main story.

More realistically, there is likely to be a trade-off involved – at least at the margin as decsions are taken on how far to push methane abatement strategy – where increased abatement will entail reduced production of some livestock products. This may be for technical reasons, but equally it may be for economic reasons in which the price of abatement offsets is high enough to justify modifying the 'product mix' in a way that delivers more offsets and less meat etc. This would not be fundamentally different from the more traditional situation where a higher wool price might justify breeding selection and farm management that lowers meat production but increases enterprise returns.

The purpose of the carbon policy is to discourage production that is not economically *justified inclusive of the opportunity cost of its associated emissions*. Inclusion of methane production from livestock within the CFI implies that it will be rationale to probe livestock production decisions in these terms – even though the production is not formally included in the emissions trading arrangements. Indirectly it is and indeed 'optimal' production patterns – in the sense of maximising returns from the land and other sunk capital – should, in principle, be quite similar between application of the CFI and inclusion in the trading scheme. In practice, there are limitations in implementation via the CFI and there is likely scope for enterprises to 'opt out' while retaining revenues that could be expected to at least slow the rate of response under the CFI incentives relative to inclusion in the emissions trading scheme.

More generally, we are concerned with the performance of the investments based around the land base now being used for livestock production. In this view, reducing livestock numbers is one of the available instruments – and this may be justified if high enough prices are being paid for offsets. Certainly some focus on that part of livestock production that entails only marginal profitability (relative to alternatives) and high emissions intensity is likely to warrant close scrutiny if a high price is being offered for offsets.

However, in terms of the value of the RELRP, our main interest is in *alternative production systems that could make economic sense* when assessed across the *expanded product mi*x that includes possible production and sale of offsets. If such systems allow for a cost effective reduction in the emissions intensity of meat and wool production then they could be of substantial interest.

There is a considerable body of work produced internationally and domestically that suggests that there are considerable potential cost competitive abatement opportunities from enteric methane emissions. More recent work, including some within the RELRP, suggests there may have been some excessive optimism in some of the conclusions, but the broad pattern is worth examining.

In Figure 4 the results of some overseas work (Moran, 2008) on the possible net costs of a range of changes in farm practices that might deliver abatement or sequestration services are set out. There are several enteric methane emissions reduction opportunities contained within the table. Care is needed in interpreting the chart – though the overall picture portrayed is considered important, and broadly consistent with a range of studies undertaken across several countries. Included in the important riders are the facts that: several of these instruments are dependent on technologies yet to be delivered, with no certainty of this happening; the cost estimates are dependent on uncertain science and in many cases will be very sensitive to site-specific (and country-specific) factors.

The work by Moran and others suggests that the upside potential of farm behaviour change, to deliver cost competitive abatement and sequestration services, appears high – as long as the downside risks can be managed.

The headline feature of the chart, and analogous charts from other studies, is the wide band of possibly very low cost, or even negative cost, farm changes when viewed in terms of the cost of abatement, net of any productivity benefits associated with the changes.

Figure 4 **Assessed potential cost effectiveness of measures (£2006/CO2t)**

Data source: Adapted from *(Moran, et al., 2008)*

5.3 The Carbon Farming Initiative

The Carbon Farming Initiative (CFI) was announced in July 2011 and represents an Australian Government scheme to help farmers, forest growers and landholders earn income from reducing emissions through changes to agricultural and land management practices. The objective is to give farmers, forest growers and landholders an opportunity to participate in the domestic and international carbon markets.

The CFI will cover carbon sequestration projects including reforestation, revegetation and projects that increase the secure storage of carbon in soils. On-farm projects that reduce emissions through 'better' on-farm management (e.g. production of biochar) can also qualify, as will some projects designed to avoid emissions from land clearing or deforestation. Participation is entirely voluntary and is aimed at the production of credits (officially called Australian Carbon Credit Units ACCUs) that can be sold to be used by emitters to offset their emissions. The CFI excludes from consideration some types of behaviour change where a decision has been taken not to offer incentives for such behaviour change because of high risks to other values – such as concerns for adverse environmental side effects.

5.4 The treatment of livestock emissions within the CFI

Included in the initiative, as supported activities, are measures to reduce methane emissions from livestock and manure management.

Examples of offset projects relating to livestock that could be eligible under this initiative are projects that;

- Reduce emissions from ruminants by manipulation of their digestive processes
- Capture and combust methane from livestock manure
- Utilise urease or nitrification inhibitors to, or with, livestock manure or fertiliser

Project activities to be included under the CFI may be developed by anyone – a member of the public, government, private corporations. These carbon offset activities must meet integrity criteria by proving to be creating additional and permanent reductions in greenhouse gas emissions, plus be able to be measured and verified. Requirements such as these are to be detailed in the offset methodology, which is submitted to the Domestic Offsets Integrity Committee as the first step in gaining project approval. Final methodology approval is made by the Minister.

The design of the CFI invites initiatives to be put forward by anyone who believes that there abatement activities meet the verification criteria. This opens up a significant opportunity for MLA, using the early results of the RELRP to expand the range of activities livestock producers may be able to obtain certification for. This has the potential to significantly increase the value that could be extracted from the RELRP and bring forward a range of abatement measures.

5.5 Offsets integrity criteria

The environmental integrity of this scheme underpins its ability to be formally recognised as an offset activity under the carbon tax. Abatement or sequestration activities under the CFI must meet the internationally recognised standards to ensure that activities are genuine and verifiable; this in turn drives consumer confidence and the market itself (DCCEE, 2011).

ACIL Tasman has elsewhere (ACIL Tasman, 2009) noted that, while these criteria are understandable and well-motivated, they could also have the effect of greatly increasing the effective cost of abatement. This flows from the approach which focuses on specific activities to be certified as delivering verifiable reductions. Referring again to the portfolio perspective discussed earlier, we have questioned whether a range of activities might not deliver very high likelihood reductions in overall portfolio emissions even though individual components cannot be verified to an acceptably high standard.

This issue of the statistical performance of a diverse portfolio of measures, using different technologies across different farming systems, relative to the verifiable performance of each component is potentially of great importance. In the earlier work, we flagged possible mechanisms for reducing the severity of the problem – the extent of unnecessary costs – while respecting the need for delivering abatement with a high level of confidence. The approaches discussed there included the use of formal financial options. We discuss some of these possibilities further in Section ## below – because the possibility of change in institutional arrangements to allow these costs to be lowered could add greatly to the value of RELRP and could have implications for the best structure of the RELRP investment moving forwards.

5.5.1 Additionality

The Greenhouse Offsets Standard requires additionality, defined as:

> Greenhouse gas emissions reductions generated by the project must be beyond what would be required to meet regulatory obligations under any Australian laws or regulation or undertaken as part of a "business-as-usual' investment. The level of additional emissions reductions generated by an offset project is the difference between the emissions associated with the project ('project emissions') and emission under a business-as-usual scenario (Department of Climate Change, 2009).

There is no explicit additionality test within the proposed CFI – firms can benefit, through the CFI mechanism, from 'business-as-usual' changes that lower emissions intensity alongside of special initiatives designed to allow compliance. There is no need for the additionality test within the CFI given the way it operates to deliver a reportable outcome.

This is not true of voluntary offsets, but an additionality test is still somewhat problematic. It can be hard to prove – especially where there is a trend in place (such as into minimum tillage methods) – and there are still questions, linked to the above discussion of timing, as to whether we wish to use offsets to accelerate the rate of take up of already economic measures.

An approach with some currency is that of rewarding farms that adopt practices at the leading edge – a willingness to reward 'best practice' on the assumption that this is more likely to be additional – and not rewarding other farms making changes at what may be a more rational point in time from a general risk management perspective. The desire to encourage innovation is understandable, but refusal to recognise that later farm changes, delivering the same levels of abatement, is harder to clearly justify. The approach again is relatively safe, in the sense of not rewarding changes that were in any case happening, but does risk slowing uptake, and even deterring it permanently, even though later wider adoption could offer high value abatement.

The two main areas of concern would be:

- innovations with high capital costs, or requiring radical and high skill changes in farm systems, where take-up rates are likely to be slow even if the innovations make sense economically; and
- changes that, while no longer at the leading edge, still only make sense if some of the value of the offsets is recognised.

Handling additionality, without deterring cost effective changes on-farm, is likely to entail close attention to baselines and trends in determining how offsets will be measured. Too liberal an approach to additionality could encourage gaming behaviour, in which enterprises actually slow their rate of change to increase their access to offset rights. In the initial stages of developing an offsets market, where capacity building is a priority along with achieving a net reduction in emissions, it may worthwhile erring toward liberal additionality test rather than risk constraining offset development through a heavy handed additionality policy.

However, in agriculture there is extensive adoption of new management practices and several large scale farmers surveys are conducted most years. There is also considerable productivity research, and associated grower surveys that could be employed to establish elasticities of supply that could be used to assess additionality of carbon services.

5.6 Permanence

Permanence requires the long-term storage of carbon or the avoidance of emissions. Carbon stores are generally considered permanent if they are maintained for at least 100 years. The reversal of carbon stores would undermine the fundamental function of the scheme.

Permanence has arisen as a key issue in other areas of abatement strategy, notably where these entail capturing and storing carbon – giving rise to questions of whether the carb on will later be rereleased from these stores. In agriculture, it is an important issue for 'biochar' initiatives and other means of building up soil carbon. Elsewhere, carbon capture and storage techniques, such as capture of CO2 emissions from coal-fired generation, and storing them in geological formations, has also been the subject of close scrutiny.

Logically, non-permanence need not be fatal, but it does diminish value. There may still be value in deferring some warming and in 'buying options' to have a more manageable problem some years in the future when new technologies may have emerged.

However, avoidance of methane emissions from livestock is, almost by definition, a permanent saving with a positive abatement impact. Apart from very limited scope for shifting the timing of emissions (that might be most relevant to some forms of manure management), permanence appears not to be a major challenge for livestock methane strategy.

5.7 Accounting for all emissions sources and sinks

The identification of all the direct and indirect emission sources and sinks within the scope of an activity defines the greenhouse gas assessment boundary. This boundary aids in assessing the greenhouse gas effects of the project, ensuring an accounting method of actual abatement and also acknowledging the issue of leakage.

Leakage occurs when there is an increase of emissions as a result of the activity. The increase though comes from outside the control of the project, and is often difficult to robustly measure or even estimate. Projects at particular risk of leakage issues are avoided deforestation and lowered livestock production.

In the case of livestock this occurs when one farmer lowers his animal numbers (or production of traditional livestock products) to reduce his level of emissions, but this reduction in supply to market is then picked up, at least in part, by another farmer. Currently there is no formal approach to deal with leakage. Suggestions have been made for discounting methodologies in abatement estimates.

The effect is real and does not require any 'gaming' of the rules.[1] It would flow naturally from existing market incentives. If half of Australia's livestock properties were to deliver a large reduction in their emissions, but the other half of producers were to expand their production in a way that returned half of the savings back to the atmosphere, this would be a challenge for the policy. Even if there are no initial adjustments for leakage, any sober assessment of the long term value of the RELRP would want to consider the possibility of future changes to policy to limit these effects.

This might favour some approaches to abatement relative to others – for example, measures that abate methane without reducing production would have few if any leakage concerns. Any measures that were complementary and actually encouraged an expansion in production might even be able to argue for a bonus rather than a discount – because these measures would tend to crowd out emissions from elsewhere in the system.

Leakage is a particularly difficult issue with voluntary offsets because livestock producers who choose not to target the production of offsets can then move to exploit opportunities emerging as a result of the abatement activities of others, without having to face the opportunity cost of their increased emissions. By choosing not to participate, they are less likely to see the marginal opportunity cost of their increased emissions, and less likely to have positioned themselves to limit these opportunity costs even if they see them.

Leakage could be viewed as a special case of impermanence, with at least a proportion of the nominal benefits being lost over time as a result of market responses to altered farm supply patterns. The issue is commonly treated separately and we retain the distinction here.

A cattle producer who switches to cropping may well be able to reduce enterprise emissions substantially – and could seek to be rewarded for the associated offsets. However, the fact that the enterprise has withdrawn from cattle production may, through normal market operations, lower market supply of beef, increase market prices and encourage other farms to expand production to satisfy demand.

1 Which does not preclude some gaming. In principle and without good policy and governance, if a family or company owned more than one property, there could be incentives to have some properties target the production of offsets, while others increase their emissions – for example, increase livestock intensity on some and crop intensity on others. This might be affected by rearranging the enterprise mixes across the various properties. However, the normal workings of livestock product markets probably are the greater threat. It is also worth noting that some of this leakage is likely to be to farms outside Australia.

For many of the internationally traded commodities Australian farmers produce farm level production changes will have a modest effect prices until the number of farms modifying production increases. The amount of substitution between one herd and another will be dependent on the elasticity of demand, which for most commodities is highly elastic, and supply. Supply elasticities will be subject the marginal costs of production of alternative suppliers. As a general proposition, substitution is likely to be real, but only partial – and to apply only where output of livestock products in reduced in some farms as they seek to increase production of offsets.

Enterprise-level reduction in livestock numbers will almost certainly overstate national reduction in livestock numbers – possibly quite substantially.

Leakage could impact on the value create by the program by discounting the abatement produced. From a livestock sector perspective, the key question would then be whether the quantity of offsets certified would be discounted; from a national perspective, there is an issue even if the quantity of certified offsets is not discounted, because overall carbon accounts will need to recognise that aggregate emissions are not falling by as much as the offsets nominally suggest.

The RELRP portfolio can reduce the impact of leakage by:

- Identifying research that is likely to avoid or limit significant production losses and therefore reducing potential price impacts and the incentives they post for increased production by others
  - This would favour approaches that tap into the 'inefficiencies' suggested by methane production to deliver lower methane intensity in the livestock products produced and would of course benefit from low operating costs
- Reducing within farm leakage by promoting abatement opportunities across the farming system
- Improving modelling to verify the likely extent of leakage (possibly using the meat market model MLA currently owns), and at least help limit excessive conservatism if adjustments for leakage are to be introduced

5.8 Accounting for variability

Natural climatic or production cycles associated with agriculture and forestry need to be accounted for in order to reflect their true abatement potential. This is done by adjusting abatement estimates over a relative time period.

5.9 Measurable and verifiable

In order to be able to quantify the actual abatement or removal of greenhouse gases and have it translatable into the market place it is important that activities have clear processes for data collection, monitoring and reporting. The utilisation of conservative assumptions, numerical values and sound procedures, plus the provision for independent audit, leads to consistency within the projects and initiative as a whole.

However, systematic conservatism applied at the level of individual activities could compound to a very high level of conservatism in the assessed overall level of abatement delivered by offset activities across the sector. As was flagged earlier, consideration may need to be given to ways of limiting this bias. Improved technologies for in-field monitoring may help greatly in this respect.

However, if substantial uncertainty remains at the level of activities on individual enterprises, it may be valuable (to both the sector and the national economy) to look at ways of dealing with the offset value offered across a more diverse portfolio of different activities on different properties. It may also be appropriate to look at the use of financial options as instruments to increase the incentives for sensible behaviour change ahead of definitive verification of all the implied abatement.

6 Description of the livestock methane program

The methane program is made up of 6 main themes. Within these themes there are 41 individually funded projects. Research on rumen management and manipulation is makes up 46 per cent of the total program costs (direct and in-kind contributions). The next largest area of research by value is genetic approaches to reducing methane emissions which accounts for 21 per cent of the program (see Table 5). When quantification of methane emission is included these three themes make up 83 per cent of the program by expenditure.

Table 5 **Summary statistics of the methane portfolio**

	Theme	Sub theme	Total cost (cash and in-kind)	% of total
1.	Quantifying methane emission measurement techniques		$4,462,516	16.62%
2.	Genetic approaches in sheep and cattle		$5,578,200	20.77%
3.	Manipulation of rumen fermentation	Pasture	$3,007,000	11.19%
		Rumen modification	$8,290,762	30.87%
		Supplements	$1,057,488	3.94%
		Total	**$12,355,250**	**46.01%**
4.	Improved management of livestock waste		$1,771,026	6.59%
5.	Farming systems and demonstrations		$1,705,910	6.53%
6.	Information management		$982,750	3.66%
	Total		**$26,855,652**	**100%**

Data source: MLA

Each of themes is discussed in more detail in the following sections.

We also discuss below (section 8the portfolio view we have taken of the program – the way in which we see it as a collection of jointly managed and highly complementary initiatives that, in general, cannot be assessed and judged in isolation from the other elements of the portfolio and the assumed ‘counterfactual’.

In particular, set in the context of opportunities under the CFI, there are strong complementarities between research directed at delivering options to lower emissions and research directed at delivering credible methodologies for demonstrating reduction – for example through in-field monitoring. Research into different mechanisms for lowering emissions can also be highly complementary (as well as, in a sense, competitive) because of both the potential for compounding abatement benefits through the use of several 'levers' and, given current uncertainties, the value in a diversified approach in increasing the prospects of developing a viable abatement strategy in a relatively short time period. Access to several levers can be particularly cost effective if each lever involves rapidly rising marginal costs in application – if the evidence suggests that useful abatement can be achieved at modest cost, but that seeking to extract more abatement entail rapidly rising costs per unit of additional abatement. Access to several levers may, subject to the way they interact, allow packing of a response that seeks to exploit the lower marginal cost elements of each to deliver a lower cost for any given level of abatement than could be achieved using any one lever in isolation.

A program that focuses on delivering several levers in parallel will tend to involve higher costs than would a program focused on the most promising lever. There is a trade-off here. In general though, if the challenge/opportunity being attacked is severe and urgent enough, if the different prospective levers all show promise but none is guaranteed to deliver a cost effective outcome, and especially if there is a likelihood of technical limits or rising marginal costs associated with each individual lever as it is pushed harder, then a parallel attack of this type can be highly cost effective. This case can be dramatically strengthened if there is a need to deliver credible emissions monitoring technologies alongside of emissions reducing technologies if the value of realised abatement is to be captured by the sector through the CFI mechanisms.

It is important that this understanding of the program as an interrelated portfolio is carried through into the assessment of the program. As is discussed later, it is quite feasible to have a program in which no individual project appears justified if assessed on a standalone basis, but where the overall program offers high value for money because of these interactions.

6.1.1 Quantifying methane emission measurement techniques

Measuring methane emissions reductions is a key to the development of any mitigation strategy driven by the value of the abatement that can be achieved – and is a central feature of this program (Newbold, McAllister, & Donnelly, 2011). However, the benefits of successfully developing accurate measurement innovations with the potential to be widely applied, extends far beyond underpinning the research program. Not only are there commercial returns that could be generated from the innovation (although this should be subservient to ensuring widespread adoption), potential impacts of the research include:

- It has the potential to allow greater innovation to be developed at the farm level as farmers will have the capacity to measure the results of changes to their systems and verify them:
  - This would allow for example seed stock producers to assess on much larger scale heritability and correlation with other traits
- Cheap, widely available verification would favourably interact with modelling and create feedback loops, by validating modelling results and/or providing greater precision for assumptions used as model inputs
- Increase the likelihood that Australian and international research would be successful and available to Australian producers
- Provide evidence that methane emissions are being reduced without the need to fully understand the mechanisms that produce the methane reductions
- Credible measured methane reductions would greatly assist offsets to gain accreditation under the CFI or to reduce the level of any discounting for uncertainty – with the potential to spur earlier implementation and delivery of benefits

Of course, the measurement technology could emerge from outside RELRP and still allow other elements of RELRP to be translated into valuable options. Conversely, successfully delivery of a good measurement methodology through the RELRP, earlier or more effectively than would otherwise be the case, should allow Australian livestock producers to benefit from technologies to allow cost effective abatement, whether these emerge from the RELRP or from elsewhere.

We have been told that a type of methane emission measuring technology, with attractive features in relation to both ongoing research and CFI compliance, is close to being patented but we have been given no details beyond this. If this technology is patented, becomes commercially available at relatively low cost, and has the credibility needed to support certified offsets the benefits could be significant. The scientific review is largely silent on the progress to date in regard to measurement technologies; we assume this silence is due to the commercially sensitive nature of this subprogram.

Most of the above benefits would apply even if the successful technology or technologies were to emerge from elsewhere. In terms of the counterfactual, we anticipate that, if there is an effective technology to emerge here, the impact of the RELRP involvement in altering the timing till available (at least statistically, in the sense of advancing the mean time till available) is likely to be modest. However, the value of control over a successful technology, that can be accepted as a basis for monitoring and accreditation in Australia and possibly internationally, could be considerable.

6.1.2 Genetic approaches in sheep and cattle

Variation in methane produced by individuals across a flock or herd is widely recognised. However, whether this variation is genotypic, and the extent of heritability, is critical exploiting these variations – as is an understanding of interactions with traditional production objectives. The scientific review has endorsed the aim of this theme and concluded that the variations are real. The scientific review concludes that if the early hereditability estimates are robust, the finding could be applied almost immediately and potentially has large impacts on methane emissions.

The early stage results of this work has verified significant variations of methane emission between animals (up to 26 per cent has been identified in one trial), and that early heritability rates could be as high as 0.15 for cattle and sheep.

However, the review committee raised concerns about the robustness of the findings to date, specifically:

- Divergence identified may be feed specific
- The interrelation between the factors that cause the variation, physiology, behaviour, and digestive ecology, is not known and may change over time and in quite small changes in the environment
- The measurement techniques used for larger scale screening may not be well correlated with the measurement techniques use to establish the initial variances which may distort the large scale screening results

However, the scientific review does not appear to have considered the impact that cheap robust emissions measurement technology may have on verification possibilities in the research program, or in the field by livestock producers and studs. This type of cross-portfolio interaction appears particularly well-suited to extracting greater value, earlier, from this work on genetics. It could both speed the time till these information gaps are filled and justify earlier, farm-level behaviour change based on promising impacts – if it supports the likelihood of earlier access to offsets markets.

The variances identified could still be certified as CFI instruments if they were discounted for the risks identified by the scientific review. At an early carbon tax value of $23t the level of discounting would probably make the resulting offset value unattractive for most livestock producers. But as the carbon price increases, even at relatively severe levels of discount the offset value improves significantly. Importantly, given that the genetic gains will require several generations of breeding, future price expectations should be the key driver of decisions, not the immediate price. A decision to commence selection implies expectations of a time series of plausible revenues running forward, with earlier access to greater abatement and offsets if and as the carbon price rises.

This is a good example where MLA could continue to invest in the technology to improve accuracy but work with the Government on ensuring that the technology can be applied earlier (adjusted for risk), securing options for earlier capture of potentially quite low cost abatement.

A related strategy that could be used in conjunction with discounting would be to develop options over the technology where some abatemebnt cannot be safely verified yet. Options would create the right to participate in any verified abatements that eventuate from the technology. For example, a cattle stud may offer bull purchasers a share of any credits that might be gained in the future from what early evidence indicates is a low emissions pedigree bull. There may be a small premium attached to the sale price for the right to participate in this upside potential if it eventuates.

An option over future emission value might work like this:

4. Suppose the early evidence suggests a likely abatement of 1 tonne of methane but can only safely support accreditation of half a tonne.
5. The accredited abatement of half a tonne would be built directly into the market prices for the bull (calculated on the average mating percentages, weaning rates etc)
6. An option would then be written over some, or all, of the half a tonne of additional abatement potential of the bull. The premium for this option would in a small increase in the purchase price of the bull
7. The stud then works with MLA to have the additional tonne of abatement verified.
8. If the stud is successful in getting the additional half a tonne verified the option held by the owner of the bull can then be exercised and the additional tonne of abatement value accrued to the bull owner of whomever holds the option at the time

The simple message of this example is that waiting for scientific verification is only one way to realise the full value of the genetic selection research that has been conducted so far. This is discussed in more detail in section 8. The commercial incentives for behaviour change, and the access to expected future benefits, might well be brought forward through the use of options instruments.

The same reasoning might apply to genetic breeding where there is high and uncertain volatility due to interactions with feed or other aspects fo the farm systems into which the genetic selection is introduced. If there are substantial risks that some farmers will not achieve much abatement, this could deter early action, including by some farmers who would later demonstrate high abatement. The possibility of pooling these risks across different farming systems, and using in-field monitoring to deliver a pooled abatement outcome that could be shared, might also favour earlier, cost effective behaviour change.

While we see a lot of scope for research outside Australia to make progress on the basic question of heritability, early utilisation of selection as a tool for abatement is likely to require work based around the Australian gene pools set within Australian farming systems and feed regimes. Even factors such as vulnerability to droughts may prove an important consideration. These matters do build to a solid *prima facie* case for some of this research being Australian-based if substantial lags are to be avoided.

Nonetheless, some of the above reasoning in respect of the use of options over abatement that is demonstrated in the future, and the polling of abatement benefits across different farms, could be used to reduce the lags in adopting strong overseas research.

6.1.3 Manipulation of the rumen fermentation

There are three main activities in this theme identified by the science review panel. They are:

9. Testing and developing feeding strategies and additives to reduce methane production in the rumen
10. Develop an application of tools to characterise the rumen microbial populations
11. Underlying fundament studies on rumen fermentation with a focus on hydrogen supply and methane production

The scientific review concluded that the research being undertaken in this subprogram is some of the best in the world, and a portion of the program is fundamental underpinning science aimed at identifying new mitigation strategies (Newbold, McAllister, & Donnelly, 2011).

Much of the rumen ecology is largely unknown in regards to methane production and by definition to a number of other rumen functions that are important to animal production and welfare in general.

Therefore it appears that extensive fundamental research needs to be done in this area, the results of which are likely to have significant implications across a large part of the wider MLA animal production investment portfolio.

The research into rumen modification is:

- Long term, complex and unlikely to yield short to medium term results highly uncertain but likely to have spillover effects in parasite control and general productivity improvement

- Like to underpin genetic research by improving understanding of why there are genotypic methane emission differences and what tradeoffs there might be with other traits

However, according to the budget of the RELRP provided to us by MLA, rumen modification investment make up about 30 per cent of the total RELRP program costs (see Table 5), and 67 per cent of the total rumen modification theme.

Pasture research makes up 24 per cent of the rumen theme. The primary activities of the pastures part of the program is screening pasture varieties for bioactive compounds that may suppress methane emissions from the rumen. This work appears to be at very fundamental stage although some early prospective plants have been identified.

A number of supplements have been identified in this subprogram with lipids emerging as early prospective feed additives. The science review panel concluded that short to medium term delivery seems feasible in the case of algal lipids. Similar early value generating strategies to those suggested for the genetics program could be employed in regard to supplements. There is likely to be considerable value in combining genetics and supplements in some of these approaches.

The main constraint on the use of supplements is the extensive nature many of the livestock enterprise operate in Australia. Delivering supplements to a large portion of the flock or herd at rates that would significantly reduce emissions may be prohibitively expensive in the short to medium term.

6.1.4 Improved management of livestock waste

Managing emissions from waste management is a small part of the RELRP, accounting for only 6.59 per cent of the expenditure of the whole program. Manure emission account for approximately 4 per cent of total GHG emissions from livestock (Newbold, McAllister, & Donnelly, 2011).

It appears the focus of the program on the use of urease inhibitors has delivered some important information on the impact of these inhibitors but does not support the use of these inhibitors as particle means of reducing N_20 emissions produced from ammonia.

It is highly likely that given the large scale intensive animal industries in the US, Canada, Europe that the potential for adoption of overseas innovations is likely to be high. Although there is likely to be some need to adopt oversees technology to Australia conditions, this adaptation requirement is not likely to be as great as that for extensive livestock enterprises.

Prima facie, these considerations could be viewed as lending support to the relatively low emphasis given to these possibilities within the RELRP – the more aggressive counterfactual would tend to support less aggressive investment. This of course would not mean that strong results emerging from the work would not support ramping up the effort – and certainly does not imply any playing down of the importance of waste management as part of an overall package 'solution'.

6.1.5 Farming systems and demonstrations and information management

These themes appear to be at an early stage of development but could play an important role in disseminating some of the early findings if MLA chooses to adopt some early value creating options, and/or decides to implement some early research results.

It is also likely that progressive improvement in the system modelling, as it applies to the use of a range of levers with different interactions and marginal cost curves, could prove powerful tools for guiding the evolution of the RELRP. In effect, the type of information that could be yielded by such modelling could be used to prioritise additional research efforts as well as to help develop soundly-based packages of measures that might sensibly be considered for implementation in the short- to medium-term.

An escalation of these themes could be important in maximising the value of cheap robust measurement systems if the current patents lead to early commercialisation of the research results. This will be particularly true if the more promising systems involve the use of several levers where the precise interactions in a given farm context are not yet well-understood – so that credible abatement that can translate into offsets is likely to depend heavily on actually measured outcomes. Modelling could then help guide the design of the package, inclusive of monitoring arrangements to document realised abatement.

As will be discussed in more detail in section 8, systems approaches, supported by targeted extension and readily accessible models could capture some early stage emission reduction value, and be an important component of MLA's engagement with Government to influence the development of the institutional arrangements for the CFI.

7 Counterfactual

The counter factual has three elements:

- The extent to which similar abatements would have been or will be produced in the absence of MLA investments (the additionality question). This could be due to:
  - Farmers reducing emissions as a by-product of pursuing traditional productivity gains or other on farm activities
  - Others (most likely the private sector) investing in similar research, in Australia or overseas – delivering results applicable in an Australian context
- The extent to which these projects would have been combined into a portfolio and the resultant portfolio benefits realised (the portfolio effect)
- The extent to which international research results (assuming they are produced) could be adapted to Australia conditions at low cost (contributions from spill-ins)
  - Recognising that the very skills that RELRP is fostering and maintaining in Australia could be highly relevant to the sound and rapid adaptation and exploitation of approaches developed overseas

The basis of the counter factual is threefold:

- The total amount of emissions
- The amount of emission per unit of saleable output (meat, milk and wool)
- The extent to which additional methane reductions would have been produced based on innovations produced in the absence of MLA investments

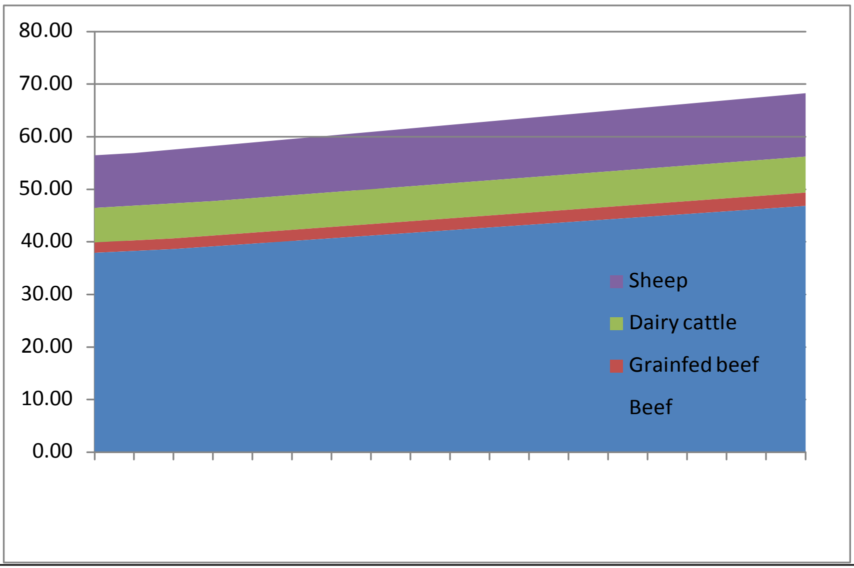
The base line measure of methane emissions is dependent on two factors:

- The number of livestock
- The productivity of the livestock enterprises

7.1 Total emissions and the number of livestock

The projected rise in livestock emission between 2012 and 2030 is 21 per cent (see Chart 7). This is due almost entirely to a projected rise in livestock numbers. Livestock numbers are forecast to rise due to moderate demand growth for livestock products globally, and modest productivity growth. Increases in livestock numbers are likely to be tempered by competition for resources from other land uses and agricultural activities – and possibly by some response to the rising value of methane abatement. A more detailed account of livestock numbers and projections is provided in Appendix 10.2C.

Chart 7 **Livestock emissions trend forecasts**



Data source: Based on ABARES livestock numbers forecasts and DCCEE emissions factors

The main variables of the total amount of methane emissions are listed in Table 6. The table shows that the combined effect of these variables is for emissions to trend around a based case of between 9.5 per cent over to 7.5 per cent below expected 2030 levels.

Table 6 **Estimated livestock emissions trends sensitivities**

	2010	2011	2012	2013	2014	2015	2020	2025	2030
	%	%	%	%	%	%	%	%	
HD: Higher demand	0.2	0.4	0.6	0.7	0.9	1.1	2.1	3.1	4.4
LD: Lower demand	-0.2	-0.3	-0.5	-0.7	-0.9	-1	-2	-2.9	-4
HP: Higher productivity in Australia	0.1	0.2	0.3	0.3	0.4	0.5	0.9	1.4	1.8
LP: Lower productivity in Australia	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.3	-1.7
HS: Higher slaughtering weight/milk yield	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.8	-1.2	-1.5
LS: Lower slaughtering weight/milk yield	0.1	0.2	0.3	0.4	0.5	0.5	0.9	1.3	1.6
HPI: Higher input prices	-2.2	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1	-2.1
LPI: Lower input prices	2.1	2	2	2	2	2	2	2	2.1
Extended drought	-0.5	-3.4	-2.1	-1.6	-1.5	-1.5	-1.4	-1.4	-1.5
High	1.6	2	2.4	2.8	3.2	3.5	5.4	7.4	9.5
Low	-0.6	-3.4	-2.1	-1.6	-1.9	-2.2	-3.8	-5.6	-7.4

Data source: (CIE, 2010)

The data in this table show the effect of different types of productivity growth on expected total emissions. Higher productivity per head (higher meat, milk and wool yield) is expected to reduce total emissions. However, higher Australian total factor productivity (where all total outputs are compared to total inputs) leads to higher emissions[2]. This is due to the increased competitiveness of Australian producers, where total factor productivity (TFP) is higher than international competitors, leading to a rise in output from the Australian industry.

Where Australia does not achieve a competitive advantage over international rivals (where rivals match Australian productivity growth), no growth in emission is expected (CIE, 2010).

The relationships between productivity, international competitiveness, methane emissions and the RELRP is important when considering the linkages between the RELRP and the wider MLA research and marketing investment portfolio. One of the primary aims of MLA is to improve Australian livestock producers' competitiveness and increase demand for Australian livestock products. Success in this primary aim would lead to an increase in total methane emissions.

However, the level of emissions – and likely trends – is relevant to agriculture to the extent that this could influence future policy treatment of agricultural emissions. In the context of potential access to voluntary offsets markets, the total is less relevant. These markets can be expected to 'cherry pick' opportunities amongst farmers or groups of farmers who can credibly offer and guarantee behaviour change that would deliver a change in their emissions. These opportunities could arise whether overall agricultural emissions are rising or falling (though these trends may influence the level of 'additionality' that can be demonstrated credibly).

Similarly livestock producers can cherry pick the range of innovations produced by the RELRP portfolio, now inclusive of the potential abatement products, to optimise the profitability of their enterprise.

Reducing livestock numbers is perhaps the most simple activity but, as discussed extensively in this report, is likely to be the most prone to leakage if used a single instrument. However, there are nuances to this strategy that could be introduced to reduce the extent of leakage permanence and uncertainty over the science.

2 In reality, as emissions become valued, with an associated opportunity cost, it will be appropriate to use a broader measure of total factor productivity, inclusive of these opportunity costs. Here, there may be some interaction between the presence of a carbon price in Australia and its absence in some competitor countries, even with Australian agriculture formally excluded from the emissions market. As was noted earlier, under some circumstances it may be efficient to limit traditional production in order to achieve higher value gains in production of saleable offsets. These effects will, however, be limited by the fact that not all producers will move early to optimise returns inclusive of abatement opportunities.

A related issue here is that of potential for substitution of emissions between farms. If some farmers start to offer offsets to a market as a result of behaviour change that reduces their levels of meat and/or wool production, then there will be spillover effects, in which this contraction, via consequential price rises, creates incentives for increased production from other farms who are not participating in the supply of offsets. We return to these matters later, but note here that they are likely to require careful handling via the institutional arrangements if the offsets are to have sufficient credibility.

The way in which livestock numbers are reduced can make significant difference to the net contribution this mitigation strategy can make and to reducing the potential for leakage out of the livestock sector and between livestock enterprises. The way livestock numbers could be reduced that may increase net mitigation efficiency includes:

- Identifying and culling underperforming animals such as dry cows etc
- Reducing the proportion of lactating calving/lambing females of the total herd (that is increasing the amount of meat produced per cow per year)
- Selecting sires with earlier maturing/higher weight gain genetics
- Turning off stock earlier by meeting weight and conditions specifications earlier
- Earlier culling as a region enters drought conditions

There are logically strong incentives for producers to adopt these management activities to increase profitability even in the absence of being confronted with the opportunity costs of the methane emissions. This poses challenges for demonstrating additionality for these types of emissions reductions under an offsets regime. Nonetheless, access to offsets market seems likely to accelerate the use of such methods and to justify pushing them further than would otherwise be economic.

These types of management changes are also strong drivers of TFP trends.

The systems and demonstration theme of the RELRP program covers the types of methane reduction activities relating to herd structural changes and management improvements of the types discussed in this section. The 'system and demonstration' theme accounts for approximately 6.5 per cent of total program expenditure.

7.2 Emissions intensity

There is a long history of research recording positive correlation of methane emissions and livestock productivity (see appendix 10.2D). More recently this work has achieved new status as climate change policies evolve and agriculture's contributions to national abatement strategies are considered.

Fundamentally, the more of the feed consumed by the animal that is dedicated to maintaining the animal rather than producing saleable meat, milk or wool, the greater the methane emissions per unit of saleable output.

Therefore, at pure maintenance, the amount of emissions per unit of output could be viewed as infinite[3], and as the animal becomes more productive the emissions per unit of output falls.

There are two reasons for variations in emissions intensity this:

- The first is that as meat, milk or wool production per animal increases, the smaller the proportion of feed consumed is dedicated to maintaining basic life functions of the animal (see appendix 10.2D)
- The second reason is that there appears to be variability in the feed conversion efficiency. Feed conversion efficiency variability is determined by number of things but can be divided into three categories:
  - Variations between feed types
  - Variations between animals of the same type and production status
  - A combination of the feed and animal intake conversion variability

Where there the producer is not confronted with the opportunity cost of the methane emissions, there remains productivity incentives to reduce methane emissions per unit of output. Therefore establishing a counter factual would assume a declining trend in emission intensity over time as producers seek to maintain and improve competitiveness by increasing productivity.

Where producers are confronted with the opportunity cost of the methane reductions, they will seek to optimise the profitability of their enterprises by changing the proportion of livestock product lines produced in response to changing prices and costs of production of each.

The additionality test, and therefore a trend away from the counterfactual, will be satisfied where it can be demonstrated that in the absence of the opportunity cost of the emission a reduction would not have occurred. This will occur when:

- There is a trade-off between reducing emissions and other livestock products
- Where there is no trade-off but there is a direct cost associated with achieving the reduction

[3] Recognising that a short period of maintenance, for example in the lead-in to a drought that may not last long, could be proven to be emissions reducing. This could occur if the drought does not last and if the maintenance strategy has allowed the avoidance of the emissions associated with rebuilding a diminished herd/flock. There is a necessary trade-off induced by the lack of certainty in relation to droughts, but a trade-off that could be made less severe by strategies that lower the emissions intensity of maintenance.

- A combination of the above

7.3 Other sources of methane emissions reduction innovation

It is clear from the literature review conducted for this project, and from the scientific review of the program commissioned by MLA that there is extensive international research being conducted into methane emission from livestock, and techniques and technology to reduce these emissions.

The counter factual is well summarized by the expert scientific review panel engaged by MLA in 2011 to review the science of the program:

> The overall assessment of the panel is that the present research program is on par with other programs in the world and is taking logical approaches to mitigate methane. Programs may be described as being basic science (broadly, seeking new knowledge) or applied science (seeking solutions). Although some solutions are being arrived at, mainly through nutritional management, this global effort has not delivered viable additives or modifiers that provide solutions with widespread commercial application. It is generally felt that basic research will deliver new knowledge which in turn will support innovation and new solutions. The Australian effort has every prospect of delivering in this sphere (Newbold, McAllister, & Donnelly, 2011).

The authors recognise that the program is on par with international research efforts averaged around a distribution of leading and lagging programs. In this context, it is almost certainly adding to the value of the overall effort, and in particular adding to the value of Australia's ability to exploit results emerging from this overall effort. As a proportion of the overall effort, the RELRP is significant, but at least as important is the extent to which the RELRP is working with Australian livestock, in Australian production systems. This adds valuable diversity to the overall international portfolio – diversity that is almost certainly tilted in favour of advancing opportunities for Australian producers relative to overseas producers.

The key reasons that we believe that the benefits of the RELERP would be fewer or slower to emerge, in the absence of MLA investment in the program, can be summarised as:

- The research is specific to Australian livestock industries, suggesting scope for earlier applicability to Australian livestock sector conditions – suggesting that applicable options for the Australian livestock sector could emerge earlier than would otherwise be the case and with the possibility that the industry could derive some gains from the implied control of IP
- The additional effort brought to bear by the MLA investment and the potential to influence other research to be more readily applicable to Australia

 - These effects could plausibly increase the prospects for earlier valuable breakthoughs, and essentially bring forward the mean time till the value becomes available to the Australian livestock sector (and, indirectly, to the wider Australian economy via the carbon market). Given the scale of the value of enteric emissions, and the potential price curve, small changes to timing of adoption of innovations can have a large value for Australian producers
- Potentially, the scale and scope of the research planning and management processes that MLA make possible as the industry R,D&E body and its ability to influence better and earlier industry adoption of worthwhile outcomes, via its linkages into the Australian livestock sector
 - An important part of the scope economies generated by MLA investing in the program is that the expertise being developed within the program may be relevant to the rapid assessment and implementations of options emerging from other programs (MLA and other funded programs) – delivering earlier benefits to Australia and the Australian livestock industries even from overseas breakthoughs.

Against this background, the counterfactual has been approached as one still involving progressive improvements without MLA involvement, but in a way that involves longer expected lead times and perhaps greater need for later adaptation to local conditions.

The counter factual is potentially strengthened by limited international action to reduce emissions as limited policy activity posts less incentives for research to be invested in a for livestock emission reductions; Australia and New Zealand now arguably face the most concrete incentives at a substantial price to find ways to lower livestock emissions. Lower investments in other countries mean that the potential for spill-ins falls further unless the methane emission results from work in other areas of livestock management.

8 The program as a portfolio

The portfolio perspective is central to our approach to assessing the RELRP. While it does include some R&D projects that show prospects for delivering applicable tools for lowering emissions (or increasing emissions efficiency), the rationale lies well beyond this.

One very clear example of cross-portfolio interactions, alluded to earlier, stems from research into better methods of monitoring emissions in the field. In itself, successful delivery of a high credibility and low cost monitoring technology would not alter sector emissions. However, such a technology could prove a powerful enabler for bringing together other elements in the portfolio to deliver emissions reduction/management in ways made demonstrable by the monitoring technology. Very plausibly, such a technology (irrespective of who develops it) could unleash very substantial value across the range of research directed at delivering levers for adapting livestock emissions.

The monitoring technology on its own would have little value. Equally, there might be behaviour change 'levers' which, on their own, would also have little value because of the difficulty in meeting verifiability requirements. But in combination, the two could deliver very substantial value. It would be a mistake to attempt to value either in isolation from the other.

Such a monitoring technology could be expected to have even wider value – underscoring more focused, responsive and cost effective research programs looking into optimal packaging of levers in ways suited to enterprise-specific application. The technology could then be used both to allow early implementation of available levers and to support more rapid moves towards optimisation – within research programs and even at the farm level.

Furthermore, a sound monitoring technology could substantially reduce the level of constraint imposed on RELRP by limitations in our understanding of interactions across various levers and different farming systems. If the technology allows offsets to be based around outcomes realised from packages of measures, then the need to understand in detail the science of interactions is reduced. Optimal 'packaging' of measured could progressively emerge from trials of different combinations, while offsets could be being generated early, well ahead of any detailed knowledge of the interactions other than their outcomes in the field.

More generally, RELRP is designed to build (in conjunction with results emerging from elsewhere) our understanding of possible 'levers' for adapting livestock management to a carbon-priced world. Even if some of these 'levers' offer value in their own right, the main impacts from the program are likely to be in the form of changes to farming systems, entailing the use of a range of levers, to deliver the most cost effective adaptation to carbon pricing.

More immediately, much of the research now being done is unlikely to deliver, directly, a high value management strategy. Rather, in combination with results emerging from other projects, inside and outside RELRP, these projects can be expected to *support more efficient evolution of packages of measures* that could prove cost effective under certain plausible ways in which the carbon, and livestock products, markets evolve over the coming years.

This packaging of elements using a range of tools will need to be undertaken with an understanding of how the different tools are likely to interact with each other – and with other aspects of livestock production. The precise combination to deliver the best outcome will vary over time as well as between enterprises – affected by changes in other input and output prices, by rainfall patterns and pasture conditions and, of course, by carbon prices. Where selective breeding (of animals, pastures etc) are involved then the best use of other tools can be expected to alter as the breeding programs 'bite'.

The potential returns from the portfolio can be classified into three broad categories:

- Short term immediate returns where existing research is adapted for the industry and implemented to capture early gains
  - Lessons learnt from these early applications – ranging from actual field results through to a better understanding of the practicalities and costs of these measures, will in turn feed back into the portfolio as additional information on which to base future planning of both research and its application.
- Longer term investments resulting from research that is at an early or fundamental stage that has a greater than zero chance of producing technologies that can be implemented in the medium to long term
- Purchasing a range of options that allows the industry respond to future changes to policy, industry circumstances or spill-ins from international research efforts

Many of these benefits are likely to be generated by a simple portfolio of research projects and rely on the mix of fundamental, applied and extension investments made by the project manager. However, much greater value is likely to be realised if the portfolio is progressively optimised in the light of industry and carbon market trends and growing understanding of the interactions between the different 'tools'.

It is worthwhile at this stage reviewing the relevant aspects of the industry and carbon price that will determine if this portfolio is likely to optimise the value to levy payers over time. The three key factors influencing the portfolio value are:

- Agriculture is excluded from the carbon tax and trading scheme at present but as emissions are reduced across the economy pressure may build to bring agriculture in, especially if its emissions are growing as a proportion of total Australian emissions. Keeping in mind that MLA's objectives are to increase Australian livestock producers competitiveness and demand for livestock products
- The carbon price is projected to increase over time as low cost abatements are utilised moving the market to higher cost options over time to meet national abatement targets
- International research is being undertaken in many of the same areas as the RELRP. These programs will produce some abatement options before they are developed in Australia and many will be application to Australian livestock enterprises with appropriate adaptation capacity

If we compare the portfolio as it stands with what we know about the carbon markets, and international research, we can make an assessment of the addition value likely to be created by the RELRP.

The six key themes are assessed by the program managers as being balanced between fundamental, applied and extension. In the Milestone 14 report (01-05-2011) the proportion was estimated by the program managers as:

- 25.1 per cent fundamental
- 59.4 per cent applied
- 15.5 per cent communications

In the Milestone report the entire portfolio is considered to be strategic in nature although there are some early stage benefits that could be delivered if:

- Measurement technology currently being patented delivers a cheap, large scale cost effective way of verifying abatements
- Institutional arrangements could be modified to accept early application of offset activities (appropriately adjusted for risk), especially if these 'discounted' applications include future options over the value of any abatement later demonstrated in excess of the level initially assumed for purposes of selling offsets.

However, if we consider the portfolio from a risk management point of view it could be characterised along the following lines:

- Low risk (shorter term payoff):
  - Supplements have demonstrable impacts on methane emissions and could be used now with the appropriate advice on application and production system design
  - Measurement techniques are improving, with one innovation being patented
- Moderate risk medium term payoff:

- Genetic selection and heritability research has shown encouraging early heritability results but needs further verification and assessment of correlation with other traits
- High risk, potentially much longer term, but potentially with much higher payoffs and potential spillovers:
  - Direct rumen modification (still mapping and researching rumen processes and flora)

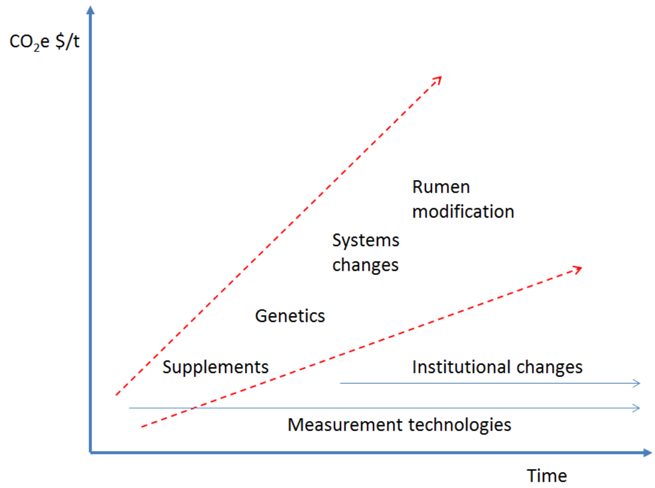
This profile is presented in more detail in Table 7

Table 7 **Summary of the research portfolio**

Program area	Cost weighting	Benefit	Risk
Supplements	11.20%	Demonstrable reductions in CH_4 already available	Low
		May have some productivity benefits	Low
		Adoption likely to be limited to where supplements are currently used intensively (dairy and feedlots)	Moderate
Measurement	16.62%	Returns from commercialisation	Low
		Facilitate greater investment from industry	Low to moderate
		Likely to have productivity benefits beyond CH_4 management	Moderate
Genetics	20.77%	Heritability, could be improved with verification	Low to Moderate
		Positive correlation with other traits	Moderate
		Identified genetic variation could lead to genetic markers	Moderate
		Facilitate transgenics	High (due to poor acceptance of products as well as high technical risks)
Direct rumen modification	3.94%	Unknown but could be substantial with high spillovers	High
Pasture screening	30.87%	Unknown but with high spillovers	High
Systems	6.53%	Could be significant but difficult to be compliant with CFI	Moderate to High

This profile of potential payoff and the relationship with the carbon price projections is illustrated in Figure 5. This profile of the portfolio provides potential outcomes with high value but longer development times, such as the rumen management research, which matches the projected carbon price curve well. It is at least plausible that practical strategies based in this research could reach ‘market’ in time to deliver significant protection against carbon prices should they rise substantially over the next couple of decades. Other, more market-ready strategies are likely to be needed in the shorter term and may well usefully complement rumen management in the longer term.

Figure 5 **Stylised presentation of payoff of the program**



The interaction of the various components of the portfolio appears to offer considerable early value. The more important interactions include:

- Measurement technology providing verification to the research portfolio
- Modelling and systems research that provides the ability to aggregate early stage abatement activities to harness statistical risk management
- Rumen modification research that will provide more robust verification results that underpins supplements, genetics and pasture research
- Extension and demonstration investments that will allow early adoption of technology and combined with measurement technology could provide import feedback for the research program as a whole

This value can be enhanced by some institutional changes that would allow some early benefits to be captured:

- Recognition of early stage offsets that while needing to be fully verified, could be recognised on the likely lower bound payoff they would achieve (i.e. discounted for risk)
- Acceptance of portfolios of abatement activities that harness statistical risk management opportunities
- The creation of options to capture abatement value when and if it is verified in future (see Box 2).

The options perspective does raise a logical concern here. If there were reasons to think that moving early on some of the options could limit the future value of more promising options with longer time scales to market, then caution would be justified. Early actions could effectively ‘extinguish’ some of the value of longer-term options. Real options cautions against pre-emptively locking into costs that might later be regretted, because of the associated loss of flexibility to exploit future options.

However, these concerns appear unlikely to prove a significant issue here. The more immediate options are likely to tie into the use of farm system changes – including feeds, supplements, drought management strategy etc – that are unlikely to lock in long term costs, nor to have a rapid impact on the other basic forward options. This does not mean that future genetic selection or rumen modification technologies might not imply different farm systems or feed regimes, but rather that early use of farm system and feed changes are unlikely to lock in large future costs.

The situation would possibly have been quite different if the early options were tied mainly into animal genetic selection, with promising longer term prospects through feeds or rumen modification. Here, there would be a question as to whether selection for animal genes, using what is now known, might cut across some of these other options.

Box 1 **Upside options need not create new information needs, nor add much complexity**

It would be quite feasible to routinely issue options over upside revisions of accreditation rules without introducing substantially greater complexity to the market. While the existence of the options is likely to intensify the pressures to improve the science or address defects in the rules, this is an opportunity and an options market can operate without any major changes.

All that is required is a system that allows previously accredited farm behaviour changes, for which safe credits have already been issued, to be resubmitted based on the original documentation plus the information contained in the option document itself. If the then available science, and standard accreditation process, would recognise a higher level of abatement or sequestration, then all that is needed is a process to:

- Reassess the total credits, using the new accreditation rules, and to issue fresh credits for the difference between the new and the earlier assessments; and
- Incorporate these additional credits into the options document, providing a basis for further reassessment in the future.

What is involved here is a sensibly evolving accreditation process. This evolution will make sense whether options have been issued or not – the rules are reviewed periodically to factor in new information. The fact that the rules may change over time provides the basis for one or more tranches of option value to be realised, by having past actions reassessed within current rules.

Box 2 **Example of increasing incentives from pooling risk across a portfolio**

Consider the case of a farm behaviour change being assessed for a carbon credit. The assessors recognise substantial uncertainty as to the level of carbon that might be captured and conclude that the distribution of plausible outcomes is approximately a Normal distribution, with a mean of 7.9 tonnes and a standard deviation of 3 tonnes. They adopt a project focus, in which a safe lower bound is interpreted as the 1 percentile outcome – a level of accredited abatement that will be delivered 99 per cent of the time. This results in credit being issued for 1 tonne of carbon abatement, even though the expected abatement is 7.9 tonnes. Incentives are very weak.

What now if we could pool 100 such measures, spread across different forms of behaviour change, different farms, regions, rainfall patterns, production systems – even countries. Purely for simplicity, assume all offer the same distribution of possible outcomes.

If assessed case by case, the assessors would conclude that each offers safe abatement of 1 tonne and would issue credits for 100 tonnes of carbon.

However, if instead they looked at the distribution of the portfolio of 100 initiatives, again using the 1 percentile safety rule, they would reach a very different conclusion – because a 'Central Limit Theorem' applies to the distribution. The 1 percentile of the portfolio is 718 tonnes, not 100 tonne. Each farm contributes 7.18 tonnes, not 1 tonne, to the safe lower bound performance of the portfolio, and could receive credit for over seven times the abatement that would be recognised in a project-by-project assessment process. The whole climate change initiative gains from the greatly enhanced, and now much less biased, incentives to deliver abatement and sequestration.

The remaining upside – the gap between the 718 tonnes credit and the expected contribution of 790 tonnes, and the 540 per cent chance that the actual outcome could be greater again, could then be tapped by issuing options over this upside – to be exercisable if and when the assessment rules are changed to reflect new information.

Any or all of more stringent safety standards, larger portfolios, greater uncertainty on individual initiatives and scope for including in the portfolio some measures whose outcomes are negatively correlated (self-hedging) would serve to strengthen the point made by this example. There is no requirement for all initiatives to be identically distributed.

9 Results and findings

9.1 Value drivers

The discussion in the body of the report sets out reasons why it would not be credible to look to modelling the impact of the methane abatement portfolio in deterministic terms – mapping out a trajectory of innovations delivered over time as a result of the program being in place (the traditional methodology for cost benefit studies). The rationale for investing in the portfolio is, instead, more sophisticated than that. It relies instead on a broad range of potential impacts that, collectively, are likely to *change the shape of statistical distribution* of forward opportunities for the meat and livestock sectors to derive benefits from methane abatement strategies.

These benefits will rely on advances in our understanding of drivers of methane emissions in livestock and of levers for modifying those emissions. It will also rely heavily on the adaptation of successful science into practically implementable – and commercially attractive – strategies that may well involve packaging of more than one 'intervention' and may possibly involve aggregation back to input providers (or possibly across multiple enterprises).

These strategies will need to allow for practical implementation and for credible demonstration of abatement in ways that will allow credit to be granted in the formal or informal offsets markets – and sufficient credit, at a sufficient price, to justify any heightened costs in both initial implementation and ongoing strategy maintenance.

9.2 Impact of RELRP on timing

A key message to emerge from the assessment in the main report, is the *critical role of lead times* in shaping the value of investment in abatement options. While it is not inconceivable that the RELRP will reveal valuable abatement strategies that would never have emerged out the counterfactual, such a development seems unlikely. Programs around the world are pursuing the same broad themes in relation to animal, plant and rumen microbe genetics, use of supplementation and farm management systems (including manure management). It is possible that strategies exist that could apply in some Australian conditions but no others, but far more likely that there will be broad strategies differing economics in different contexts, but with broad transferability of the underlying science and approach.

Instead, what seems likely to be far more important in driving the economics of the RELRP is its potential to impact on the timing till practical and cost effective strategies become available and applicable in Australian conditions. This impact on timing can arise in two broad ways:

- The additional resources brought to the overall international effort as a result of the RELRP investment could bring forward the time till there is a significant breakthrough in our knowledge of the basic science
  - The RELRP investments may bring distinctively new capabilities to bear
  - More probably, and in any case additionally, the RELRP resources will add 'additional irons to the fire', which can be especially valuable when the research requires trawling through a large number of prospects – whether these be gene/environment combinations, potential supplements, potential feeds etc. This would seem a fair representation of a large part of the current efforts.
- The RELRP investment could result in more rapid translation of a science breakthrough into an approach that is practically implementable in Australian conditions
  - This might result from the use of Australian livestock and livestock systems in identifying prospective interventions, making the translation to commercial application faster, easier and more certain
    - … This could even include the explicit identification of high prospectivity sires, already selected as suited to Australian conditions, and shortlisting of pasture and supplement prospects based on those that are likely to be suited to Australian conditions
  - It might also be helped from the development of skills in Australia, through work in the RELRP, that are well suited to the adaptation of the science
  - As relevant is the issue of time till abatement that is credible enough to support accreditation for purposes of offsets sales can be achieved, where RELRP may deliver a longer time series of experience on which to base earlier accreditation.

Success in bringing the time till availability forward can deliver benefits in two broad ways:

- Given that Australia is implementing a carbon pricing regime and opening up opportunities to sell offsets based on methane abatement, earlier availability of options could equate to opportunities to tap into commercially attractive revenue streams for a period where this would not otherwise be possible.
  - Effectively, earlier availability can translate to the avoidance of opportunity costs in the form of lost revenue from sales of sales of offsets.
- Were RELRP to allow for the timing till availability in Australia to be advanced relative to any competitors who are also facing carbon pricing

regimes, there may be added benefits in the form of enhanced competitiveness as a result of this shift in relative timing till strategies are available.

- For example, were RELRP's involvement to result in faster adaptation of overseas research to Australian conditions – for example of NZ research based in NZ livestock conditions (genes, pastures, farming systems etc) to Australian conditions, then this could cushion any loss of relative competitiveness from early NZ implementation of these strategies.
- The same reasoning applies even more strongly to strategies initially developed in Australia, with likely lags in adaptation to other countries.

Some of the lead times are substantial. If genetic heritability in livestock is of the order of 15 per cent, then the time that necessarily arises (at least without genetic engineering that would bring its own problems) between subsequent generations implies many years before a high proportion of such genetic capability can be transmitted to a sizeable proportion of the herd or flock. The same constraints are not inherently involved in all genetics work – notably in relation to rumen microbes, but there the science at present appears to be lagging. Supplements may well entail the shortest lead times, though even there, demonstration of impact to a level that allows accreditation of offsets may take a considerable time, especially if the effects are highly volatile across different farms etc.

9.3 Framework for random R&D breakthroughs

We seek to develop here a simplified, but broadly credible, framework for considering how these timing impacts might arise – and the effect they have on forward risks and opportunities. This requires a framework that is fundamentally statistical/probabilistic in nature. We cannot script when a breakthrough will occur, if at all – nor whether Australian research will in fact result in earlier delivery. We have to take a probabilistic approach.

Both scientific breakthroughs, and the delivery of practical implementation strategies, are likely to be a 'lumpy' matters, with substantial discrete breakthroughs occurring at points in time. This might be the identification and publication of science results, demonstrating heritability, or the impact of a supplement under specific test conditions – or the translation into a strategy for which an accreditation process has been agreed and established. The big uncertainties relate to when (and possibly whether) such breakthroughs will occur and, at this stage, to the magnitude of impact and implementation cost.

In some cases (such as animal genetic improvement through breeding programs) implementation may involve gradual attainment of reduced emissions, but reaching a point where there is a breeding program with strong indications of impact and agreed accreditation arrangements is again a discrete, point in time event.

For simplicity, we start by considering the statistical distribution of the time till one specific discrete breakthrough is achieved. The discussion here parallels an earlier ACIL Tasman assessment of some of CSIRO's research programs – including an analysis of CSIRO's lapsing program review in 2006, and some public health programs within the pHealth Flagship. In common with RELRP, the pHealth Flagship involved adding to the quantum of research resources directed at some high cost public health challenges – such as Alzheimer's disease and colorectal cancer.

Massive resources are being applied internationally, but CSIRO brought a relatively unique package of skills, especially in relation to early markets of disease development, while adding slightly to the overall level of resourcing. The question was then whether this increment was cost justified by the implied bringing forward of the timing to a significant breakthrough. The ACIL Tasman assessment concluded that, while it was unlikely that the CSIRO efforts would make a big difference, there was a small but real chance that they would – and, given the costs of these diseases, a robust case for further investment was favoured.

In leading up to that assessment, we assembled a framework for dealing with the statistical distribution of the time till a major breakthrough is achieved. The logic is set out in detail in appendix 10.2F.

In summary the methodology models three ways in which the RELRP adds value for Australian livestock producers to the international research effort under way:

12. By adding an iron(s) in the fire, where the probability of a scientific breakthrough is increased due to the additional effort of the MLA funded work in Australia:
    a) This is sensitive to, but not dependant on, the likelihood of success of the RELRP research compared to the likelihood of success of international research
    b) The relativity of likelihood of success is based on a number of typical factors influencing the probability of research success including:
        i The quality of the research and the prioritisation of the various specific parts of the research portfolio
        ii The extent to which the RELRP research if filling gaps in the international research effort, particularly in areas that are more likely to be relevant to Australian production systems
13. By maintaining research capacity working in Australia MLA is reducing the time it would take to adapt international breakthrough to Australian

conditions. The key variable is the extent to which the technology is able to be adopted by Australian producers. This will vary depending on the divergence of the characteristics of parts of the Australian production system and overseas production systems. For example, supplements to manage emissions from intensive animal systems (enteric methane and manure emissions) are likely to be more universally applied as Australia has a relatively small intensive animal production sector compared to North America and Europe

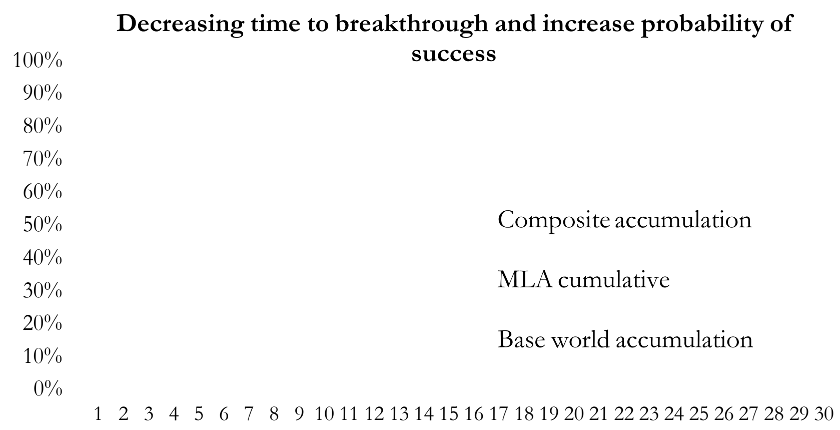
14. Adoption rate of new technology by Australian producers are likely to be quicker and higher if it comes through an MLA research, development and extension program. If the innovation is able to be extended through MLA's extensive communications networks with growers and even associated with other innovations or broader systems research adoption is likely to quicker than if a new extension system had to be purpose built

The model begins with the establishment of the base case (counterfactual where the rest of the world is investing in the enteric methane reductions (ROW)) which is then modified to determine how the probability of scientific success and time to adaption and adoption changes in a world where MLA invests in the RELRP. A wide range of real world phenomena, including in relation to R&D, failure of equipment and occurrence of some natural phenomena, can be modelled under the assumption that the probability of a discrete event occurring in a given time interval (say 1 year) is reasonably constant. For example, consider an R&D program that is systematically trawling through hundreds of candidate gene sequences, rumen microbe patterns or potential feed supplements, looking for a high impact pattern that could underpin a methane abatement strategy. Assume the assessment of each will take on average a certain amount of time and that there are fixed resources directed at the exercise. A structure along these lines would appear to align well with this constant rate of success assumption.

Where this assumption applies, it is possible to infer the statistical distribution of the time taken to achieve a breakthrough. The appropriate distribution function is the exponential function which is the illustrated as the green line in Chart 8. The blue line in Chart 8 is the MLA distribution function with a slightly lower probability of success but with the same mean time to success.

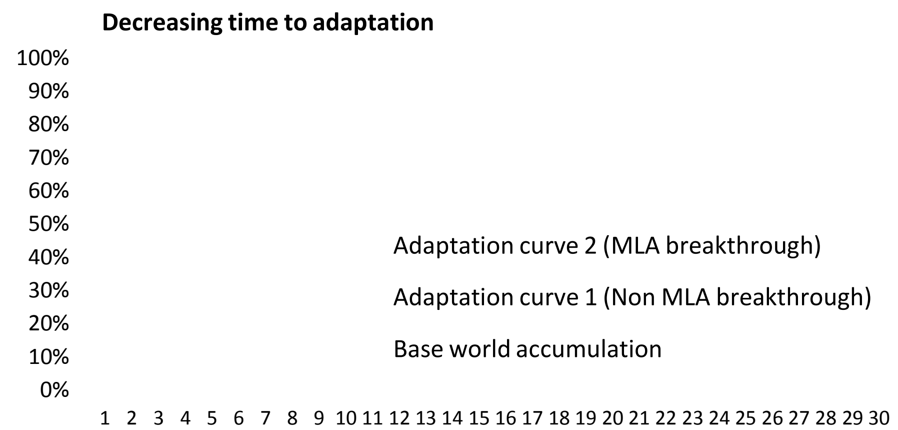
The red line in the Chart 8 is the combined MLA and ROW distribution which shows that there is a significant increase in the probability of a successful outcome (shifting the curve up) and a reduction in the mean time until success (increasing the slop of the curve). The area between the green curve and the red curve is the option value created by the RELRP investment.

Chart 8 **Conceptual basis of the RELPR value creation model (probability of success x year)**



The purple line in Chart 9 shows the second of the ways in which RELRP value is modelled. This is where the innovation comes from overseas and where the capacity of the RELRP allows the innovation to the adapted to Australian conditions faster than if this capacity had not existed (shifting the curve to the left only).

Chart 9 **Conceptual basis of the RELRP value creation model (probability x year)**



The blue line in Chart 9 shows how the green curve (the base case) is both moved up (increasing the probability of success and decreasing the mean to success) and to the left (reducing the time of adaptation).

The area between the blue and green curves in Chart 9 is the option value of the investment in the RELRP where the scientific breakthrough is due to the investment in RELRP (and therefore adapted to Australian conditions) before adjusting for differences in the rates adoption between a non-RELRP innovation and an RELRP innovation. The different rates of adoption are highly depending on the type of innovation and theme of the RELRP it comes from.

The results of the model are then subjected to three carbon prices scenarios (as discussed in section 3.1).

The results of the model are therefore presented in a matrix format where the results of a non-RELRP and RELRP methane reduction innovation are analysed based on three price scenarios (see table

Table 8 **RELRP theme option value**

	Non-MLA innovation	MLA innovation
Low carbon price (modified CER)	$xx	$xx
Mid carbon price	$xx	$xx
High carbon price (Treasury)	$xx	$xx

These results are also presented graphically as shown in Chart 10and Chart 11

Chart 10 **Example abatement probability curve (m/t CO_2e)**

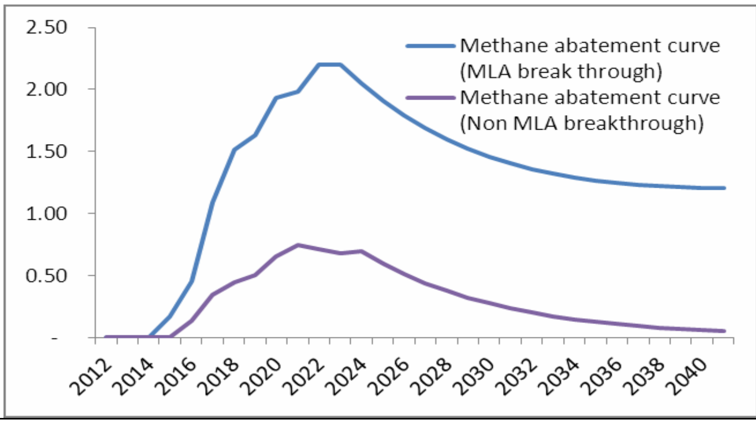
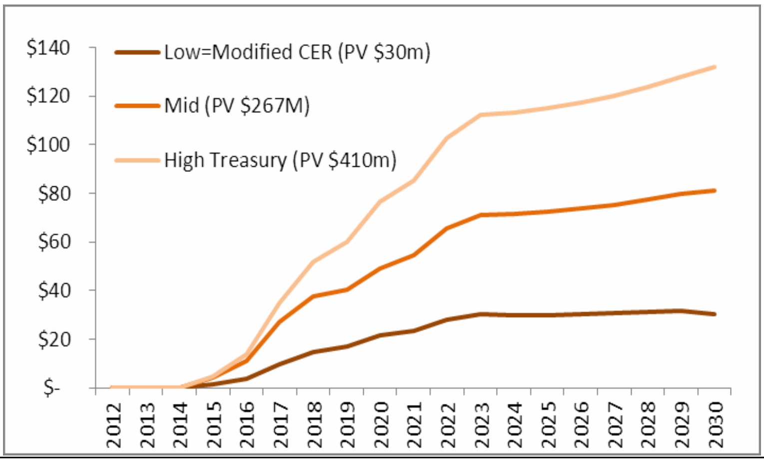


Chart 11 **Example abatement probability value curve ($m)**



The structure of the model therefore established a series of parameters that change the position of the exponential distribution curve that represents the base case. The key parametres are summarised as:

1. The probability of a breakthrough occurring in genetic selection technology occurring in the rest of the world (ROW), and, given that there is to be a breakthrough, the average time till such a breakthrough occurs
2. The probability of a breakthrough occurring in genetic selection technology occurring in the RELRP, and, given that there is to be a breakthrough, the average time till such a breakthrough occurs
3. The efficacy of the breakthrough (expressed as the average percentage reduction per animal)

15. If a scientific breakthrough was made overseas, how much faster would it be adapted to Australian conditions than it would have been adapted if the RELRP had not been established and continued to be funded

4. The rate of adaption likely if the innovation occurred overseas or stemmed from the RELRP

The model was run on three key themes of the RELRP, genetics, nutrition (supplements), and rumen intervention. The reason why these themes were chosen is because they:

- Represent the bulk of the RELRP investment
- Are core technologies being developed where measurement, information management, farming systems have value in the their own right but are largely support technologies for the core theme

The parameters used to run the model for each of these themes, and the results are discuss in detail in the following sections.

9.4 Genetics

The first of key themes we modelled was the genetic selection theme. The key parameters used to model the options value of this theme are set out in Table 9 and Table 10. The difference between the tables is the difference between the suitability of the innovation to be adapted to Australian conditions: high transferability means that the technology can be quick adapted to Australian conditions, low transferability means it would take longer (and cost more) to adapt the technology to Australian conditions.

In the case of genetics, the adaptation variance lies in the ability of using genetics from international sources in Australian cattle. For many breeds, particularly dairy cattle, a significant amount of genetic material is imported as semen for use in Australia cattle studs. This suggests that the transfer of a low emission bull is likely to be relatively straight forward if it is discovered and developed in breeds currently used by Australian studs (such as Angus, Hereford, Friesian etc).

However, if the genes are from cattle that are from a breed not widely used in Australian the incorporation of these genetics would take considerably longer without using genetic engineering. Therefore we have modelled both scenarios.

The assumptions we have used for each scenario are contained in Table 9 and Table 10.

Table 9 **Key parameters (low adaptation capacity of ROW innovation)**

Key parametre	Assumption
Probability of ROW success in breakthrough	95%
Mean time to ROW breakthrough	3 years
Time to adapt/become certified	5
Probability of RELRP breakthrough	85%
Mean time to RELRP breakthrough	2 years
Time to adapt and become certified	1
Likely efficacy (% per animal reduction ROW and RELRP)	20%
Changes in adoption rate between an RELRP and ROW innovation	
Increase in peak adoption	0%
Increase in slope of adoption curve (adoption rate)	More rapid early adoption

Table 10 **Key parameters (high adaptation capacity of ROW innovation)**

Key parametre	Assumption
Probability of ROW success in breakthrough	95%
Mean time to ROW breakthrough	3 years
Time to adapt/become certified	3
Probability of RELRP breakthrough	85%
Mean time to RELRP breakthrough	2 years
Time to adapt/become certified	1
Likely efficacy (% per animal reduction ROW and RELRP)	20%
Changes in adoption rate between an RELRP and ROW innovation	
Increase in peak adoption	0%
Increase in slope of adoption curve (adoption rate)	More rapid early adoption

In setting the parameter for the genetic theme modelling we have also taken into account the relative size of the cattle population in Australia and the ROW. Australia's cattle population varies between 26 and 28 million head on average[4]. The Australian herd is approximately 5 per cent of the Brazilian herd and 10 per cent of the US cattle herd ((Economic Research Service, 2012). Therefore the likely diversity and selection pressure in these countries alone would suggest that low methane emission animals could be identified and bred for far more quickly than in Australia.

The genetic diversity of methane reductions was measured in one research project (B.CCH 1006) at 26 per cent (half accounted for by one bull). If this variation is correct and the heritability is verified at around the 0.15 as early results indicate, the scale of value of emissions reductions for this innovation are calculated as:

4 http://www.mla.com.au/Prices-and-markets/Trends-and-analysis/Beef/Forecasts/MLA-Australian-cattle-industry-projections-2012/3-Australian-cattle-industry-projections-Australian-cattle-herd

- 26% (B.CCH 1006) half associated with one bull (out of the eight tested)
- At a heritability of 0.15 using sires at 10% less methane than average = 0.07 x 0.1 = 0.75%

To calculate the options value of the genetics theme we used a similar formula to that above and incorporating some estimates of the time it would take to generate enough low emission bulls and rams. We also modelled out the diffusion of the male genetics through a typical herd with a simple livestock production model based on:

- Mating rates
- The average useful life of bulls and rams
- Female replacement rates (CFA and death rates)

The key assumptions we used in the simple genetics model are contained in Table 11 and Table 12. The genetic gain modelled achieves a 13 per cent emissions reduction over 18 years in cattle and a 14 per cent reduction the sheep over 18 years. This is broadly consistent with the results of genetic selection methane abatements modelled in (Alford, Hegarty, Parnell, Cacho, Herd, & Griffith, 2006).

Table 11 **Assumptions used in modelling for cattle**

Variable	Assumption
Weaning rate	80%
Cow productive life span (years)	8.00
Initial CH_4 differential per bull	20%
Heritability	15%
Discount rate (nominal)	10%
Cow death rate	3%
Initial factor one (single parent)	1.50%
Initial factor two (both parents)	3.00%

Data source: ACIL Tasman analysis

Table 12 **Assumptions used in modelling for sheep**

Variable	Assumption
Weaning rate	75%
Ewe productive life span (years)	5.00
Initial CH_4 differential per ram	20%
Heritability	15%
Discount rate (nominal)	10%
Ewe death rate	3%

Initial emission factor one (single parent)	1.50%
Initial emission factor two (both parents)	3.00%

Data source: ACIL Tasman analysis

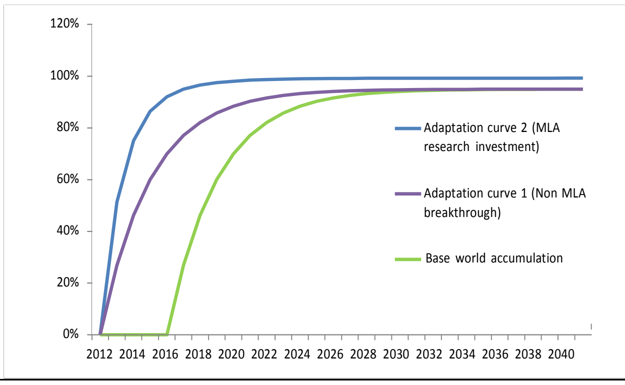
9.4.1 Results of a low adaptation genetic innovation

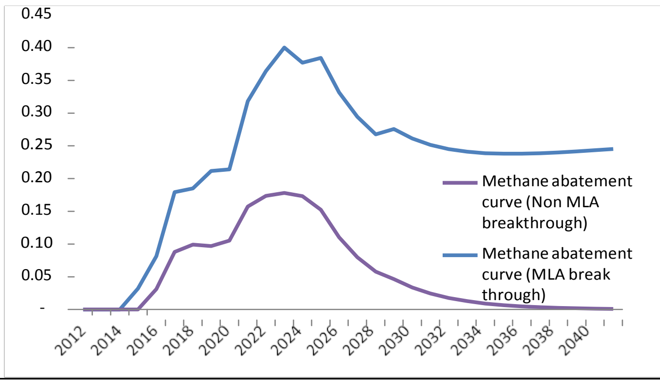
The results of the genetic selection modelling are shown in Chart 12. The chart on the left shows how the parameters used in the modelling show that contribution to a breakthrough made by the RELRP is significant but the majority of the total value is enabling any genetic breakthrough to be adapted to Australian conditions more quickly compared to the counter factual.

In our view the relative weighting of the benefits to adaptation over breakthrough reflected the relative size of the Australian herd compared to the size of the herd in the rest of the world. The dominance of the cattle emissions masks the potentially higher breakthrough potential and adaptation value of sheep genetics, where Australia's share of the international flock is higher and likely to require greater adaptation of the genetics as little if any imported genetics is used in the Australian flock. This is due to the Australian flock's dependence on merino genetics.

The chart on the right side shows that annual distribution per annum of potential abatements.

Chart 12 **Exponential distribution curve of genetics program and the probability distribution of potential abatements from genetics research in the RELRP**





The option value of the RELRP is shown in Table 13 using the three carbon prices scenarios. The value of the genetics program reflects the:

- Rate of heritability (15 per cent) of the methane reductions between generations
- The time it would take to breed sufficient commercial quantities of bulls and rams (long lead time)

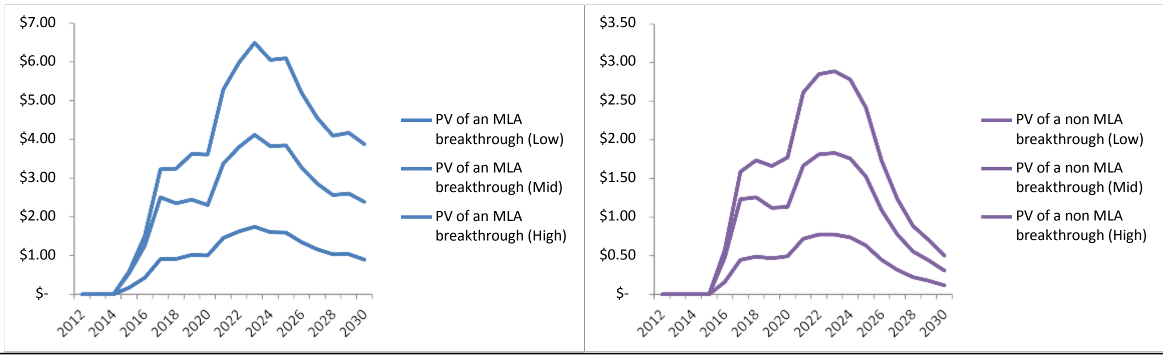
- A relatively conservative rate of genetic gain over time where the rate of gain declines over the modelled period

However, we believe that this reflects a conservative view of the value of the genetics program as much higher value would be generated following the initial adoption period, and the rate of genetic gain per generation of stud animals may increase as greater selection pressure is applied and new sources of variance between animal is identified.

Table 13 **RELRP genetics option value (low capacity to adapt international innovation)**

	Non-MLA innovation	MLA innovation
Low carbon price (modified CER)	$7m	$18m
Mid carbon price	$17m	$44m
High carbon price (Treasury)	$26m	$68m

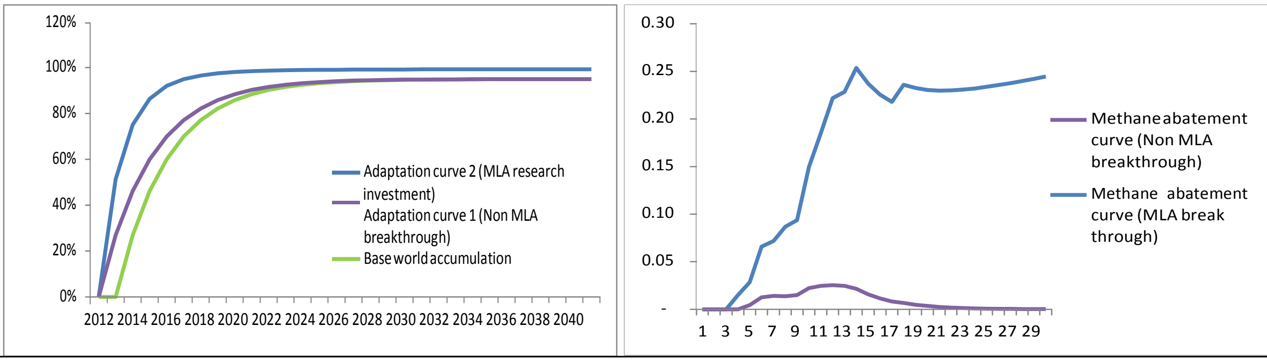
Chart 13 **Annual distribution of probability of a MLA (left) and non MLA (right breakthrough) x carbon price**



9.4.2 Results for high adaptation genetic innovation

The following charts and table show the results of a the same scenario as modelled in the previous section but where high levels of variability are identified and bred for in breed in the ROW which have high applicability to Australian conditions. Therefore the value of adaption of the RELRP is reduced.

Chart 14 **Exponential distribution curve of genetics program and the probability distribution of potential abatements from genetics research in the RELRP**



Under this scenario the option value is lower than where adaptation potential is lower. This scenario implies that Australian producers have an increased capacity to free ride on the ROW.

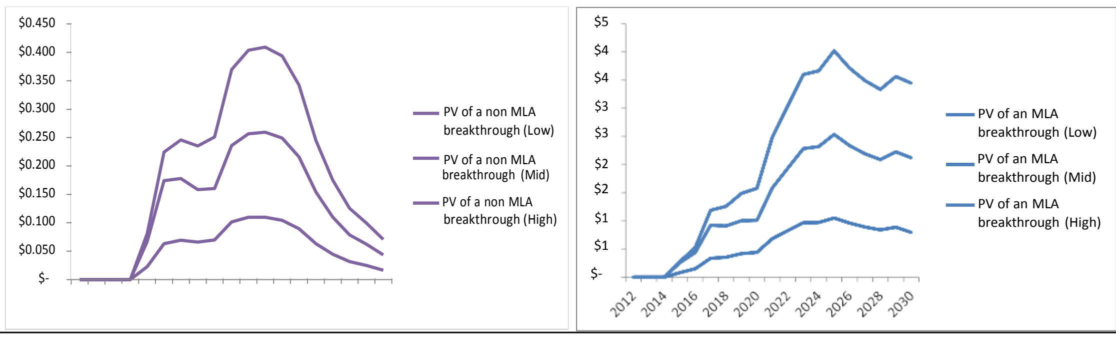
We believe that the ability to free ride is constrained by several factors including:

- Lower incentives in the ROW to identify and select for low methane emissions animals due to weaker emissions abatement policy setting
- The capacity to adapt international genetic variance is potentially overstated in the high adaptation scenario due to a lack of certainty about the genotypic and phenotypic interactions of methane emissions variance

Table 14 **RELRP genetics option value (high capacity to adapt international innovation)**

	Non-MLA innovation	MLA innovation
Low carbon price (modified CER)	$1m	$11m
Mid carbon price	$2m	$26m
High carbon price (Treasury)	$4m	$41m

Chart 15 **Annual distribution of probability of a MLA (left) and non MLA (right breakthrough) x carbon price**



9.4.3 Genetics decision tree

The results of the modelling have been incorporated into a decision tree diagram to illustrate the way a series of decisions about the genetics theme could be made in response to assessments of the carbon price projector at regular intervals. The key assumptions used in the decision tree (and those in the rumen intervention and supplements results sections) are:

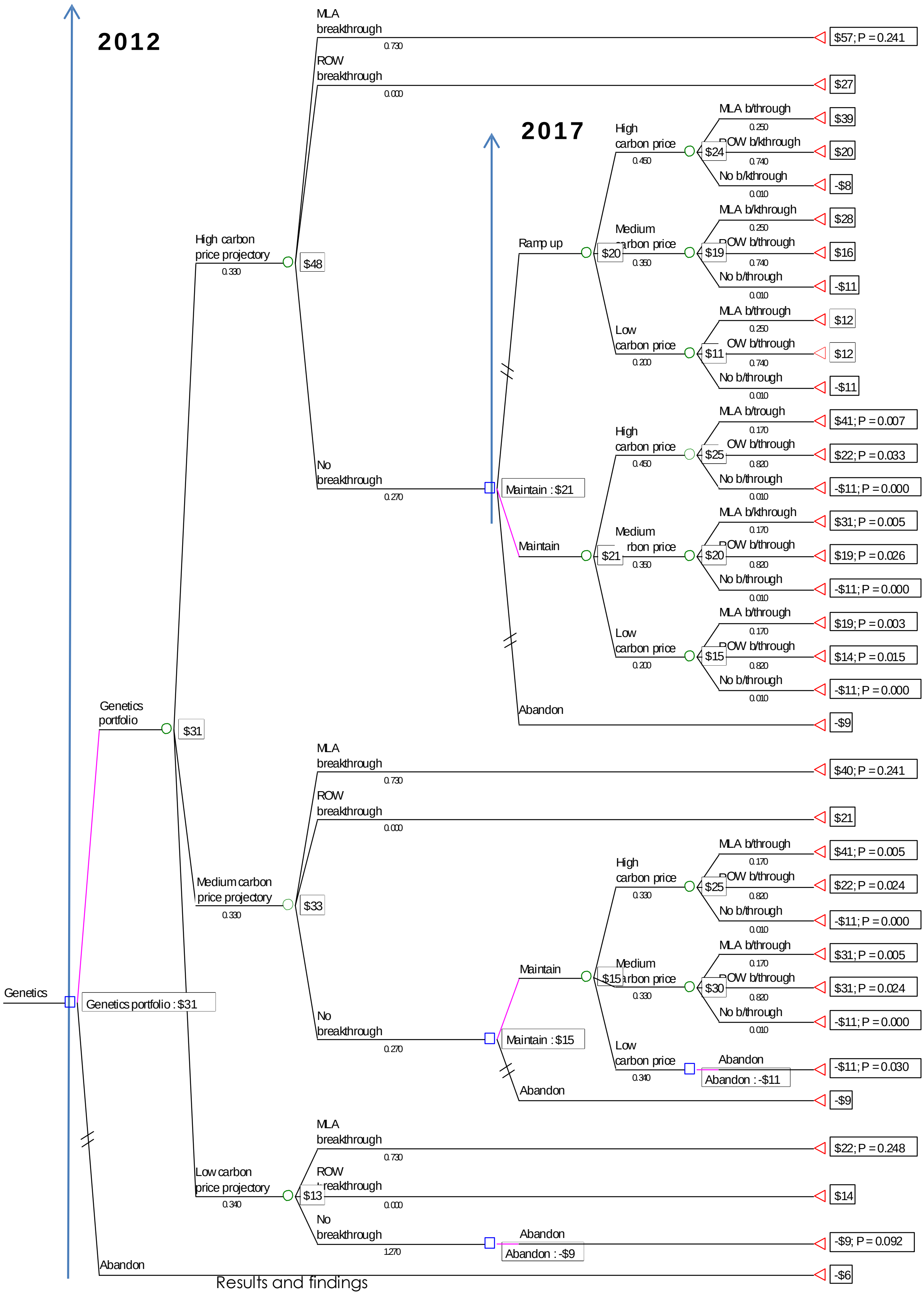
- The programs are assessed every five years
- The costs of the program are based on those in Table 5
- A ramping up of the program is a doubling of spending on the program for five years
- The three carbon price scenarios (high, medium, and low) are assumed to be equally probable
- The probabilities of a breakthrough are taken from the models for each theme
- Where ramping up occurs, an increase in the probability of an MLA breakthrough is assumed
- It is also assumed the once a breakthrough occurs there is not further investment in that stream. This is unlikely, particularly where carbon prices are moving to the upper (or higher) range of the projections used in this analysis. Rather the decision not to model any additional research reflects a sensible cut off for this study rather than reflecting a cessation of the research investment.

Each of the themes are assembled into a discrete decision tree which does not take into account the results of the other programs. This has been done to simplify the decision trees to allow a discussion of each theme. However, each theme does interact with the others. For example a major breakthrough in the rumen intervention theme would impact on the decision to continue to supple the genetics and supplements programs. The greater the convergence of the science underpinning each theme the more likely events in one theme will impact on another. The lower the level of convergence, (i.e. the greater the complementarity of the themes) the greater the option value of each theme in the event that the other themes do not produce a breakthrough.

As with the results of the modelling we caution against adding the values of each of the decision trees together. We believe that that there is likely to considerable overlap between the results.

The results of the genetics decision tree analysis show that, even when confronted with uncertain carbon prices the 'option value' of the program appears to outweigh the costs at the first decision point.

Figure 6 **Genetics decision payoff tree**



Once the cost of the program accumulates, under a low carbon price projector, the costs begin to outweigh the potential gains and the program at current levels of expenditure would need to be reassessed. However, at medium carbon price projections, it appears to be sufficient benefits that could be captured to justify a continuation of the program at current levels of expenditure.

The benefits of ramping up the program, in response to a high carbon price projector, are highly sensitive to the extent which is it likely that the RELRP would increase its likelihood of success because of the additional expenditure. The increase in the probability of a breakthrough is likely to be driven by:

- Additional gaps that are likely to be filled by the additional investments where the gaps are in the domestic or international research portfolio
- The marginal quality of the research does not diminish

9.5 Rumen intervention

In contrast to the genetics parameters the rumen intervention theme is characterised as higher risk (less certainty of a scientific breakthrough), with a greater mean time to breakthrough, but when the breakthrough occurs it is likely to be much quicker to implement compared to genetic selection. Pasture screening has not been included in this modelling, and the supplements theme is modelled separately and discussed in the following section.

This modelling does not take into account the potentially large spillovers that may result in a wide range of animal management areas from a greater understanding of the rumen biology and ecology.

Table 15 **Key parameters for the rumen intervention theme**

Key parametre	Assumption
Probability of ROW success in breakthrough	65%
Mean time to ROW breakthrough	12 years
Time to adapt/become certified	2
Probability of RELRP breakthrough	55%
Mean time to RELRP breakthrough	12 years
Time to adapt and become certified	1
Likely efficacy (% per animal reduction ROW and RELRP)	25%
Changes in adoption rate between an RELRP and ROW innovation	
Increase in peak adoption	5%
Increase in slope of adoption curve (adoption rate)	More rapid early adoption

We have also assumed that the rumen breakthrough is likely to be more efficacious than the genetics pathway but also recognised that the two technologies could be converging on the same fundamental pathway of achieving reductions. However, there appear to be opportunities to make the genetic and rumen intervention themes more complementary that are discussed in more detail in section 10.

We have also assumed a larger divergence in a breakthrough occurring in the ROW and RELRP, but this may be conservative given the high quality of the research being undertaken in Australia compared to the ROW as reported by the scientific review (Newbold, McAllister, & Donnelly, 2011). If the RELRP probability of success where increased to match that assumed for the ROW in the parameters the PV of the options values (based on an RELRP breakthrough) increase by 16 per cent. This means that the model is moderately sensitive to the relative chances of success between the RELRP and the ROW.

The options value of the rumen theme is higher due to the moderately higher efficacy, and due to the potentially greater direct application where genetics has to rely on heritability and slow adoption rates driven by the physical constraint of having enough bulls and rams.

When these factors are combined the potential upside of the investment is much larger than that anticipated by the genetics theme.

Table 16 **RELRP rumen intervention option value**

	Non-MLA innovation	MLA innovation
Low carbon price (modified CER)	$10m	$125m
Mid carbon price	$25m	$304m
High carbon price (Treasury)	$38m	$470m

Chart 16 **Exponential distribution curve of rumen theme and the probability distribution of potential abatements from rumen research in the RELRP**

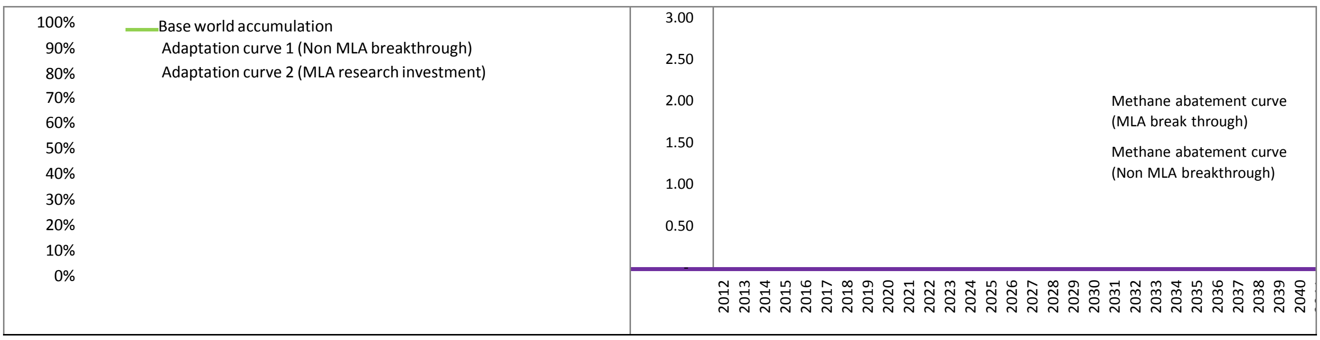
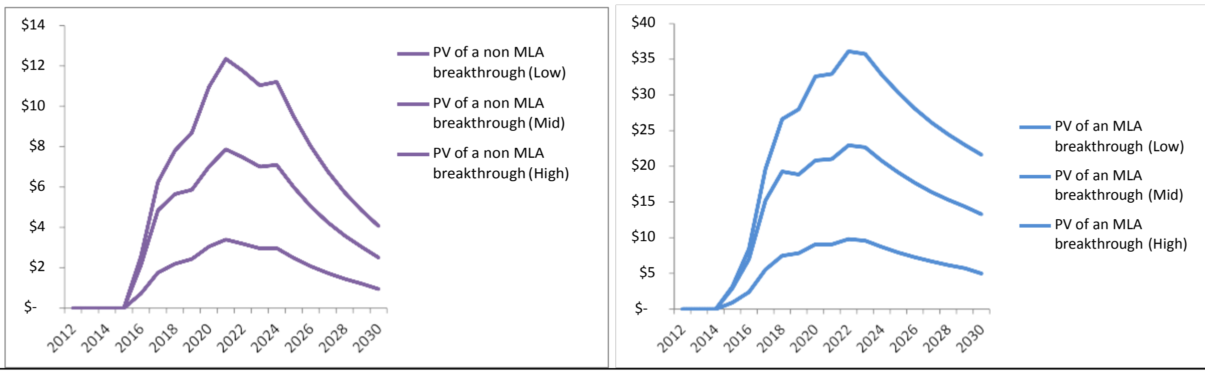


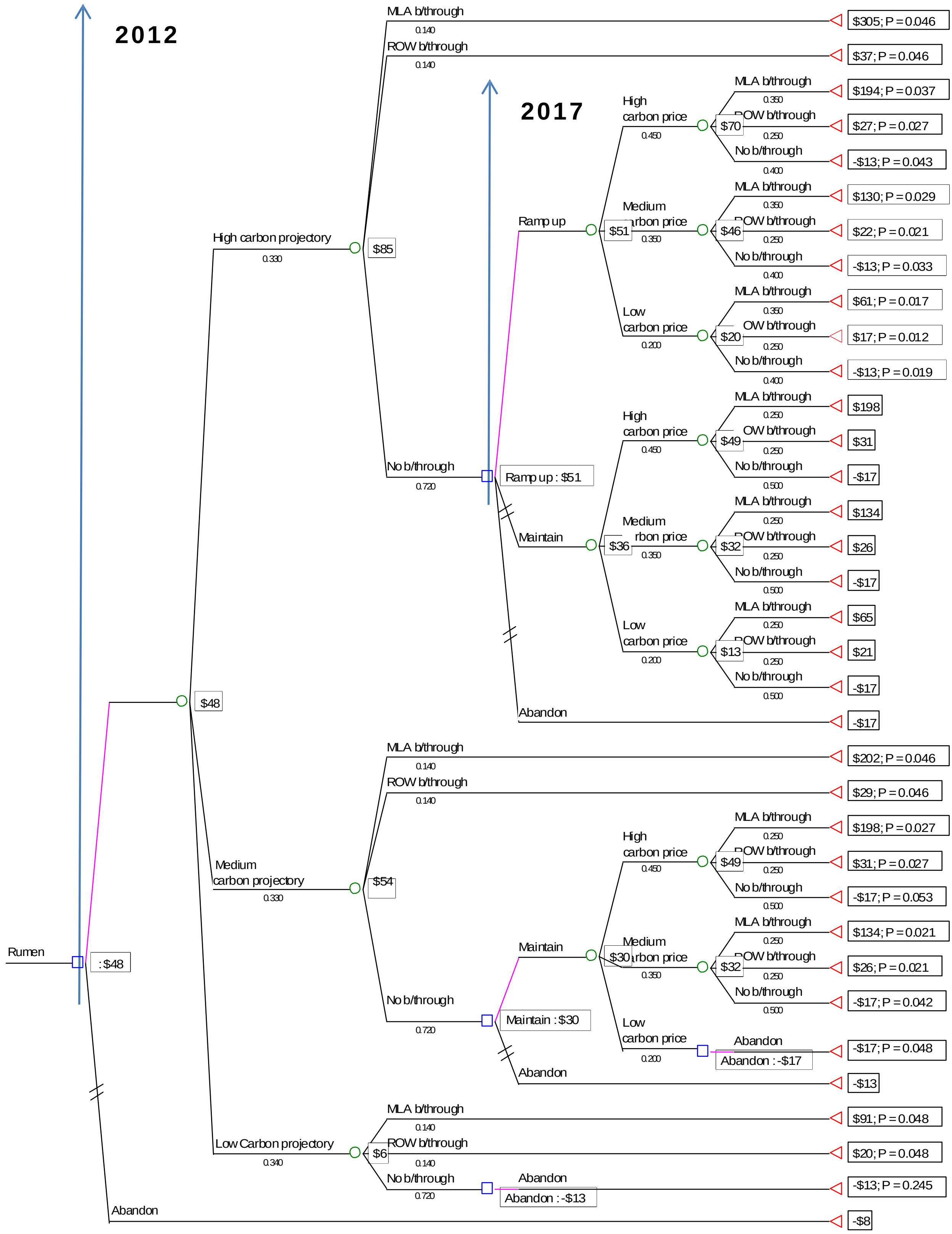
Chart 17 **Annual distribution of probability of a MLA (left) and non MLA (right breakthrough) x carbon price**



9.5.1 Rumen intervention decision tree

The rumen decision tree shows a similar result to the genetics decision tree. That is, even under a low carbon price a continuation of the program at current levels produces a positive result. However, under a high price scenario there appears to be grounds for ramping up the program (in this case doubling the expenditure at the next review period in five years time). This is because we have assumed that the additional RELRP investment is able to substantially increase the probability of success, and the payoff from a breakthrough, would be high due to the high carbon prices.

Figure 7 **Rumen decision tree**



9.6 Supplements

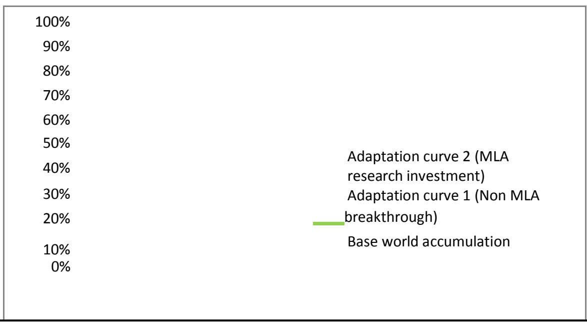
The parameters used to model the supplements theme reflect a generally more advanced research theme where a number of compounds have been identified as being able to reduce methane emissions from livestock. Therefor the probability of a commercial breakthrough is high and there is relatively little difference between the RELRP and the ROW.

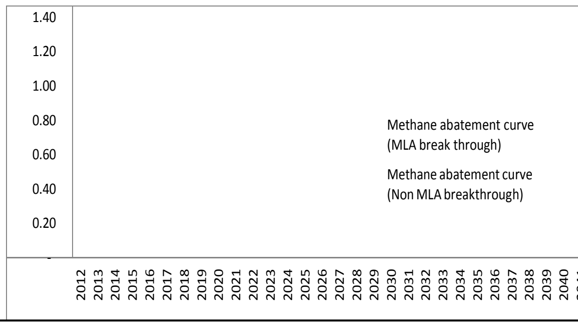
However, in Australian extensive animal production systems the role of supplements may be restricted due to the capacity of the some forms of supplementation to be fed to stock. This is particularly so for northern cattle where the cost of delivering supplements to stock on a regular basis would be logistically difficult and expensive. Unless the supplement is able to be included in lick blocks which are widely used in northern systems, emissions reductions using from this theme for the majority of northern cattle would be restricted.

Table 17 **Key parameters**

Key parameter	Assumption
Probability of ROW success in breakthrough	80%
Mean time to ROW breakthrough	6 years
Time to adapt/become certified	2 years
Probability of RELRP breakthrough	75%
Mean time to RELRP breakthrough	6 years
Time to adapt and become certified	1
Likely efficacy (% per animal reduction ROW and RELRP)	15%
Changes in adoption rate between an RELRP and ROW innovation	More rapid early adoption
Increase in peak adoption	10%
Increase in slope of adoption curve (adoption rate)	More rapid early adoption

Chart 18 **Exponential distribution curve of the supplements theme and the probability distribution of potential abatements from supplements research in the RELRP**



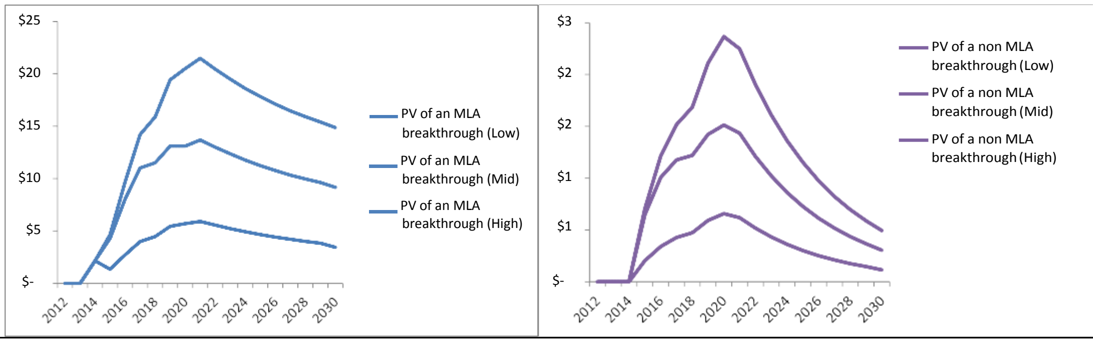


The options value of supplements, compared to genetics and rumen intervention, reflect the more advanced stage of the technology, the greater potential rate of adoption, although the efficacy may be lower.

Table 18 **RELRP supplements option value**

	Non-MLA innovation	MLA innovation
Low carbon price (modified CER)	$6m	$72m
Mid carbon price	$14m	$175m
High carbon price (Treasury)	$21m	$264m

Chart 19 **Annual distribution of probability of a MLA (left) and non MLA (right breakthrough) x carbon price**



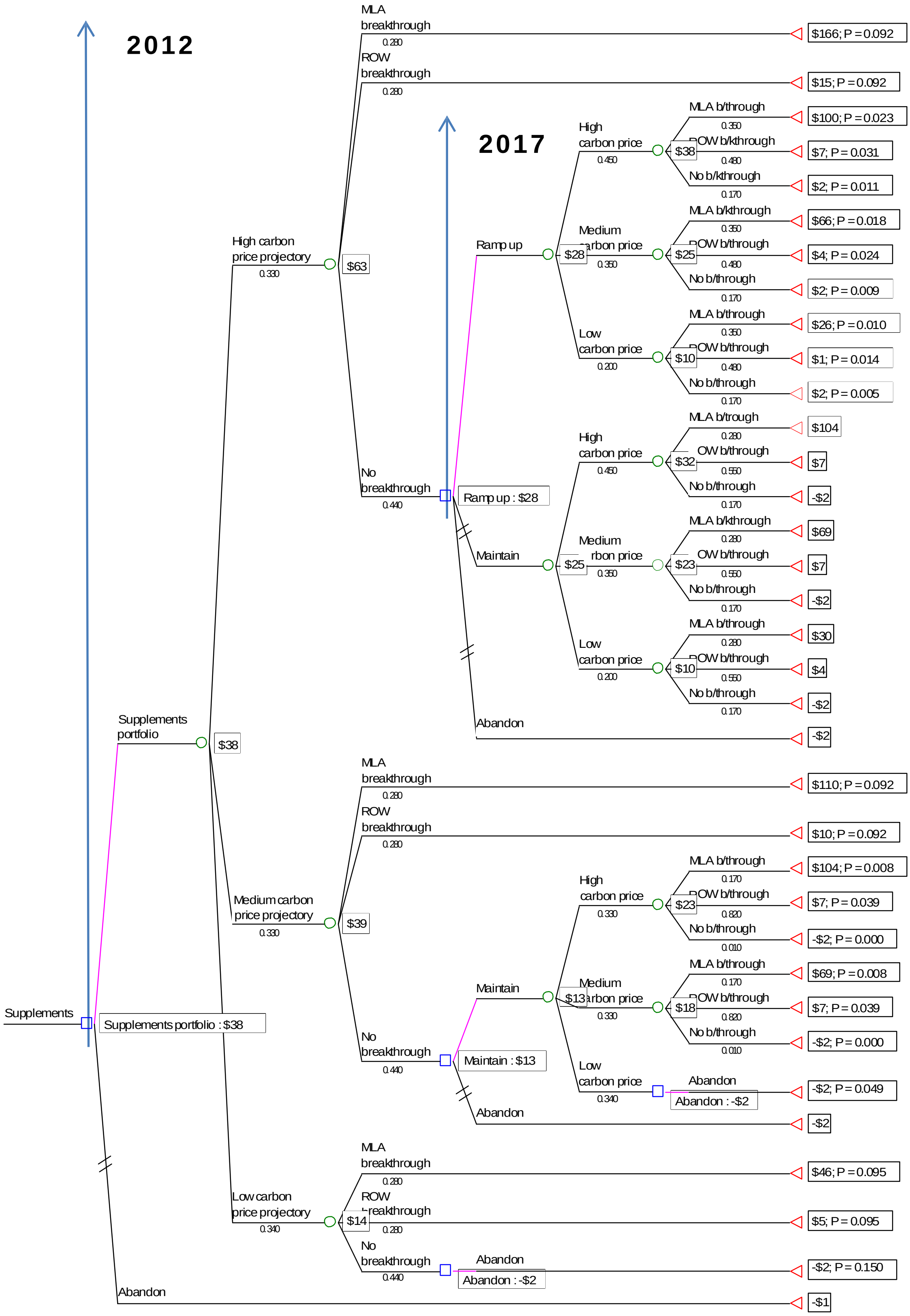
9.6.1 Supplements decision tree

The supplements decision tree shows a similar result to that of the rumen intervention results. The difference in between the rumen and supplements investments is that the rumen intervention total combined probability of success is assumed to be lower than supplements. Also it is assumed that supplements will be quick to adopt (although over less animals due to logistics and cost constraints). This advantages of supplements outweighs an assumed reduction in efficacy between rumen intervention and supplements. This is where supplements are assumed to offer a 15 per cent reduction in methane emissions, and rumen intervention 25 per cent.

The supplements are also the lowest cost research assumed to be $1m over a five year period.

The supplements, like genetics, will offer substantial insurance value for some cattle production systems in Australia against high carbon prices and the uncertainty about rumen intervention. This insurance value can be increased if, again like genetics, the supplements theme can be oriented toward complementary science to rumen intervention and genetics.

Figure 8 **Supplements decision tree**



9.7 Summary of modelling results

The results of the modelling show how the characteristics of each of the themes translate into a series of options values overlaid with three carbon price scenarios. There is considerable conservatism built into the modelling and each of the results should be viewed as a lower bound range of potential value.

The results should provide some confidence that under all but the lowest carbon price scenario, the key themes demonstrate significant risk management value over a 10 year investment horizon. The results also show that over the next five years the options value are positive against abandoning the RELRP. Maintaining the investments creates the option for MLA to abandon the research at the next significant review date, or ramp up the rumen and supplements themes (unless major breakthroughs are made between now and then).

In section 5.1 the scale of the opportunity costs of the emissions from livestock were discussed in detail. The modelling has shown the proportion of the methane emissions reduction options that has been created by individual themes within the portfolio is large with considerable upside potential.

At this stage it is not possible to determine to what extent the modelling results are additive as this depends on the extent to which each of the themes are converging on the same suite of methane reduction technologies but using different pathways.

However, taken individually each present a sound case for continuation of the current scale of the program with some potential reshaping to exploit some of the complementary features of the themes and optimise the option value of the program as a whole.

10 RELRP as an options portfolio

The last few sections have summarised modelling of the plausible impact of each of RELRP's main lines of attack on methane emissions from livestock. Reflecting the broad approach adopted – and especially the way that MLA involvement in each of these areas modifies the forward timing and prospects of the relevant counterfactual – these assessments assemble into a series of insights into these R&D elements as building blocks for pursuing opportunities to constrain methane emissions.

In this section, we report on a more systematic analysis and assessment of the overall RELRP portfolio, viewed as a combination of the building blocks.

The previous discussion looked at the case for adding additional 'irons to the fire' in relation to each individual theme of the RELRP – irons additional to those already supported within each theme by the counterfactual. The rationale for adding extra irons lies in the potential to bring forward the time till a serious capability for commercially viable methane reduction might emerge.

In this section we look also at the case for having additional irons in the RELRP fire, in the form of strategic investments in more than one of these theme areas. The case for doing this will rely again on bringing forward the time till a commercially viable methane reduction capability might emerge, and especially bringing forward the time till the most cost effective capability, or package of capabilities, has been identified. Focusing RELRP on the single most prospective of the possibilities might be deficient either because it turns out that another approach is more attractive, or because the best strategy involve a mix of approaches.

As with the counterfactual, diversification of the strategy across technical possibilities bring insurance against the most prospective of the approaches proving deficient, or taking longer than expected to deliver. As with the assessments of individual technologies set out earlier, inclusion within RELRP of significant work across themes also builds potentially valuable options in the form of capability to more rapidly adapt research breakthroughs emerging overseas.

Of course, these are reasons for diversification across technologies, but are not in themselves adequate justifications for such diversification. There are opportunity costs in not focusing limited resources on the most prospective of the approaches to balance against the risks that this assessment of prospectivity proves incorrect. RELRP is an investment in risk management and should be judged in relation to its effectiveness in limiting risks and its value for money in doing so.

The discussion of the individual approaches certainly developed strong support for the view that some investment, through RELRP, is cost justifiable and likely to remain so into the short- to medium-term future. In this Section we look more carefully at what might be said of the appropriate balance of effort across the different themes, and about the overall scale of investment in RELRP that might seem justified.

To do this, we draw together the key features of the building blocks that have emerged from the assessment to date and look more closely at how they might interact – technically and in terms of insurance against some of the themes not proving up rapidly enough – to secure better prospects for better sector performance into the future.

10.1 Features of the building blocks

The general picture might be summarised as follows:

- Each of animal genetics, feed supplements and rumen chemistry appear to offer solid prospects for delivering effective instruments to reduce methane emissions or emissions intensity in livestock.
  - The basic science to underscore very high confidence in delivering technical capability to do this through animal selection and the use of supplements is at a sufficiently advanced stage to suggest little risk that these capabilities will not emerge from further research.
    - … This science includes demonstrated heritability of lower propensity for emitting methane and evidence that this need not significantly limit scope for also selecting for other production characteristics
  - Similarly, there is strong evidence that some supplements can deliver substantial methane reduction capability in some farming systems
  - The work on modifying rumen chemistry directly, by changing the characteristics of the microbes in the rumen, is not as advanced, but the indications remain strong and this approach may well prove the most valuable in the longer term..
- Improvements through animal genetics (via traditional selective breeding as opposed to gene modification), while clearly demonstrated as feasible, do not lend themselves to rapid rollout across the livestock industries.
  - Long breeding cycles, coupled with relatively modest variation across animals and modest heritability, and likely initially constrained rates of adoption, combine to suggest it will take many years to tap into a substantial proportion of the theoretical long term potential.
  - This limits the likely value of these programmes, if assessed on a present value basis, but the modelling nonetheless points to the

potential for these technologies to prove quite cost effective in the medium term.

  - Their value is likely to be greatest in the event that the other technologies prove slow to deliver while carbon prices strengthen significantly over time – in this sense they can be seen as offering valuable insurance for the sector, even if it turns out that claims against the insurance are never needed because more cost effective response mechanisms emerge in time.
  - They may also be seen, more generally, as supporting the long term sustainability of the sector in the face of risks in relation to future carbon prices – the potential for very substantial reduction in the methane intensity of the sector, using progressive animal genetic improvements – appears substantial.
- A feature of the animal genetics work is that the best specific selections may prove highly specific to farming systems, climate, soils etc.
  - There may be constraints on how readily overseas genetic selection can be transferred into the Australian herds and flocks without starting to interact strongly, and negatively, with other desirable production characteristics.
  - There may be analogous issues in transferring experience within Australia across different herds and farming systems.
  - The modelling has considered possibilities for both rapid and slow transfer – but we have formed the view that rapid transfer from overseas is likely to be difficult. This has direct implications for the value of RELRP.
- Proven supplements have the potential for much more rapid deployment – and may prove well suited to the containment of costs in accessing offsets markets through various aggregation models.
  - Again, however, the best choice of supplements is likely to be fairly specific to farming systems and will depend on the range of sources of supplements that might be cost effectively accessible.
  - This suggests significant effort is likely to be needed in translating proven science into cost effective practical systems for on-farm deployment on a wide scale.
- A potentially important question – with implications in considering the overall RELRP portfolio – lies in the mechanisms through which animal breeding and supplements are likely to deliver their impacts – and how this might interact, in time, with direct modifications of the rumen chemistry.
  - If the main mechanism through which breeding could deliver more methane efficient production is by delivering a gene structure that is conducive to the development of rumen organisms that deliver more methane efficient rumen chemistry, this approach may compete significantly with the alternatives.

- … On the other hand, it is plausible that different animal genetics could influence the potential for efficient reductions in methane through either or both of supplements and direct interventions to alter rumen flora. There may well be complementarity that increases the value of both strands of research.

- Similarly, if supplements are supporting better rumen chemistry by supplying additional nutrients that assist more balanced digestion, then there is the real possibility of this approach competing with direct rumen modification.

  - … Again, however, it would seem plausible that targeted use of supplements may in time prove complementary with improved rumen chemistry – effectively allowing the delivery of an improved mix of inputs to the rumen processes and possibly allowing improvements in rumen microbiology to deliver even greater impacts.

In broad terms, each of these themes has emerged from the theme by theme analyses as showing promising stand-alone economics. This is true of both the broad technical approach being pursued overseas as well as within Australia, and of the incremental impact of the RELRP work in each area.

For reasons flagged above, the stand-alone economics of the animal genetics work appears the weakest, assessed in terms of risk weighted present value. But risk weighted benefits appear, on this stand-alone assessment basis to be well in excess of likely costs. Of particularly importance here, as an additional dimension of value, is the high insurance value offered by this approach given the uncertainties that remain with direct rumen interventions.

Both supplements and especially rumen modification, even after taking into account the heightened risks and the likely lead times till the science case is firmly established, look highly prospective.

Importantly also, the potential for complementary action across the different themes – for improved animal genetics and/or strategic use of supplements to enable targeted modification to rumen chemistry to deliver greater value – also stands as a clear pointer to the value in pursuing multiple themes, as well as 'extra irons', channelled through RELRP, directed at each theme.

In relation to each theme, a key message that has emerged from the theme by theme analyses is the way that RELRP's involvement delivers value strongly through the way that its research is building and maintaining capability to exploit breakthroughs wherever they occur – within Australia or overseas. In broad terms RELRP's involvement has been assessed as having a modest favourable impact on the prospects and timing till a major science breakthrough – but as then having a major impact on the time taken to move from the breakthrough to deployed capability that is benefiting the Australian livestock sector.

10.2 More on the cross-portfolio synergies

Of course, the fact that the work in each research theme looks promising assessed on a stand-alone basis is still not enough to definitively justify the research effort.

For example, suppose it were known that, within 10 years, there would be a readily deployable (across the Australian livestock sectors) and socially acceptable technology for modifying the rumen chemistry at low cost and high impact. Suppose further it was known that this technology would not rely strongly on animal genetics improvements as enablers for this large impact – and that the technology would largely crowd out the value in animal selection for lower methane. This last possibility would seem highly plausible if animal selection is largely effective via the modifications it encourages in rumen chemistry.

Under these circumstances, it would relatively easy to demonstrate, using modifications of the above models, that further investment in animal genetics to lower methane emissions is probably not cost justifiable. The long lead times in rolling out the capability would interact with the above assumptions to largely eliminate the contribution of animal genetics to overall portfolio performance and value.

Of course we do not know these things about rumen modification, and the interaction between animal genetics and rumen modification is not yet clear. So the above statements should not be interpreted as implying that animal genetics research should not continue. Rather, the above discuss sets out the logical basis for justifying continued animal genetics research. We have already inferred that if supplements and rumen modification fail to prove up, then the animal genetics work is justified. The above discussion suggests that enough confidence in the rumen modification work, coupled with a strong interaction between animal genetic and rumen modification mechanisms for lowering emissions would render continued investment in animal genetics unjustified.

It follows that there is some form of 'crossover' between these two extremes that imply quite different strategy for RELRP. The case for continued investment, through RELRP, in animal genetics therefore rests on the uncertainty as to whether and when rumen chemistry modification will be proven up and whether animal genetics may offer improvement potential over and above any that will be achieved through direct rumen modification. It is not inconceivable, for example, that rumen chemistry could support a 40 per cent reduction in methane, that animal genetics improvements could also, in time, support a similar reduction, and that the combination of the two could support a 50-60 per cent reduction. This would seem to involve the animal genetics delivering impact through either a different mechanism that direct rumen modification, or via rumen modification that will not be possible in the medium term through direct measures.

Similarly, given the possibility that supplements, in combination with improve rumen microbiology, could support a more efficient meat production process, with lower methane emissions, than will otherwise be possible through rumen modification alone, there is likely to be a case for sustaining supplements research while carefully assembling a better understanding of these key insights.

The Australian livestock sectors faces threats from climate change (irrespective of their causes) and threats from likely policy responses to the threats of climate change. The overall threats are substantial and we believe they call for a robust strategy that is likely to prove beneficial to the sector across most of the key uncertainties that are still to play out.

Certainly under the more aggressive carbon price scenarios modelled earlier, all three themes could deliver very substantial value, individually and collectively. The three themes appear highly complementary in the managing the risks that a potentially high value strategy is missed, or heavily delayed in coming to market. All three offer value that offers a natural hedge against the uncertainty about carbon prices – the value of each theme, and of eventual convergence on a composite response strategy, will rise strongly if an as the carbon price rises strongly. In this sense, RELRP represents true insurance for the sector.

Importantly though, a strategy which sought now to focus only on the most prospective of the three themes would appear much less robust. This arises for two distinct sources:

- This approaches increases exposure to the risk of missing out on early access to high value options, should it emerge that there are serious problems with the 'preferred theme'; and
- This approach would run down local capability in relation to the less preferred themes, adding substantially to the time likely to be involved in capturing the benefits from these themes should a high value breakthrough occur elsewhere in the world.

Looking at RELRP as an options portfolio, directly principally at better managing carbon price risks, we have certainly formed the view that a high level of diversification – Australian involvement in each theme to increase the prospects for a major breakthrough and to support faster and more effective tapping of any breakthroughs – makes robust sense.

This of course does not mean it is not appropriate to ask whether some rebalancing of the portfolio would not make sense – increasing the intensity of work on one area relative to another. Of course there is a need for progressive adaptive management of the portfolio. However, the current uncertainties – as to timing and the nature of the interactions across the different themes – appear to strongly support a significant RELRP presence in all areas, while looking closely at opportunities to reduce the key uncertainties that constrain the scope for better focusing resources on a winning strategy.

It would seem highly desirable to have current knowledge of these key interactions across the different themes assembled as soon as possible and subjected to close scrutiny within the options paradigm. What is the scope for modifying RELRP to bring forward the time till some of these uncertainties will be substantially reduced? Is there scope for targeting animal genetics and supplements research in ways that increase the prospects for it complementing rumen chemistry research rather than competing with it? Can and should the research be restructured to increase the value of the options for more rapid adaptation and deployment relative to maximising the impact on the time to science breakthrough?

This last question is an important one, given our assessment of the significance of these options, for rapid adaptation and deployment, as key drivers of the value of RELRP. The scientists understandably continue to see large uncertainties in the science, but it is important also to recognise the timelines that seem increasingly likely in relation to carbon prices. Given existing evidence of the real impacts that can be gained from both animal genetics and supplements, there may be a case for shifting some effort in favour of early utilisation of what we already know, relative to truly pinning down the science that is in any case the subject of intense work via the counterfactual.

In practice, these considerations could favour a greater spread across herds and farming systems – something that may well now be easier and more cost effective with the emerging technologies for in-the-field monitoring. They could also favour greater emphasis on the practicalities of delivering certified credits, capable of being traded as offsets, relative to the effort directed at delivering even greater reductions. Laboratory-demonstrated reductions are not the same as acceptable levels of abatement, for offsets purposes, from real application across the Australian herds and flocks. The demands for effective demonstration of real world impact could prove a major factor determining the time till the benefits are accessible by the Australian livestock industries.

A Literature review

Tannins determined by various methods as predictors of methane production reduction potential of plants by an in vitro rumen fermentation system

Anuraga Jayanegara, Norvsambuu Togtokhbayar, Harinder P.S. Makkar, Klaus Becker, Tannins determined by various methods as predictors of methane production reduction potential of plants by an in vitro rumen fermentation system, Animal Feed Science and Technology, Volume 150, Issues 3-4, 14 April 2009, Pages 230-237

- determining the relationship between chemical constituents for plant materials and methane production parameters at 24 hour of incubation in the in vitro Hohenheim gas method
- the leaves and roots of some specific plants have considerable potential to reduce enteric methane production from ruminants

Evaluation of dietary strategies to reduce methane production in ruminants: A modelling approach

Benchaar, C., Pomar, C. and Chiquette, J. 2001. Evaluation of dietary strategies to reduce methane production in ruminants: A modelling approach. Can. J. Anim. Sci. 81: 563–574.

- modelling analysis of different nutritional strategies to reduce methane production from ruminants
- simulated strategies; dry matter intake, forage to concentrate ratio, nature of concentrate (fibrous vs starchy), type of starch (slow vs rapid degraded), forage species (legume vs grass), forage maturity , forage preservation method (dried vs ensiled), forage processing, and upgrading and supplementation of poor quality forages (straw)
- modelling showed that methane production can be reduced by increasing dry matter digestibility and the proportion of concentrate in the diet, replacing fibrous concentrate with starchy, using less ruminally degradable starch, using more digestible forage (less mature and processed forage), using legume forage over grass, using silage over hay

Supplementation with whole cottonseed causes long-term reduction of methane emissions from lactating dairy cows offered a forage and cereal grain diet

Grainger C, Clarke T, Beauchemin KA, McGinn SM, Eckard RJ (2008) Supplementation with whole cottonseed reduces methane emissions and can profitably increase milk production of dairy cows offered a forage and cereal grain diet. *Australian Journal of Experimental Agriculture* **48**, 73–76.

C. Grainger, R. Williams, T. Clarke, A. D. G. Wright, and R. J. Eckard, "Supplementation with whole cottonseed causes long-term reduction of methane emissions from lactating dairy cows offered a forage and cereal grain diet," *Journal of Dairy Science*, vol. 93, no. 6, pp. 2612–2619, 2010

- fifty lactating cows were fed either the control diet of forage and cereal or a supplemented diet with whole cottonseed over a 12 week experiment primarily to determine if there was a reduction in methane production
- the addition of whole cottonseed resulted in a persistent reduction in methane emissions from the cows

Mitigating methane production from ruminants; effect of calcium nitrate as modifier of the fermentation in an in vitro incubation using cassava root as the energy source and leaves of cassava or Mimosa pigra as a source of protein

Inthapanya S, Preston T R and Leng R A 2011: Mitigating methane production from ruminants; effect of calcium nitrate as modifier of the fermentation in an *in vitro* incubation using cassava root as the energy source and leaves of cassava or *Mimosa pigra* as source of protein. *Livestock Research for Rural Development. Volume 23, Article #21.* Retrieved December 2, 2011, from http://www.lrrd.org/lrrd23/2/sang23021.htm

- An in vitro experiment to evaluate different treatments on the production of methane gas
- treatments used; cassava leaf meal plus urea, cassava leaf meal plus calcium nitrate, Mimosa pigra leaf meal plus urea and mimosa leaf meal plus calcium nitrate
- calcium nitrate when replaced by urea has a greater ability to reduce the production of methane per unit of fermented substrate

Screening the activity of plants and spices for decreasing ruminal methane production in vitro

Screening the activity of plants and spices for decreasing ruminal methane production in vitro R. García-González, S. López, M. Fernández, R. Bodas, J.S. González 14 November 2008 (volume 147 issue 1 Pages 36-52)

- a screening trail to test 158 different plants, herbs and spices for their potential to modify ruminal fermentation in vitro, particularly with respect to decreasing methane production
- identification of rhubarb and frangula to contain active secondary compounds that target ruminal methanogenic microorganisms

Cattle selected for lower residual feed intake have reduced daily methane production

Hegarty RS, Goopy JP, Herd RM and McCorkell B (2007) Cattle selected for lower residual feed intake have reduced daily methane production. *Journal of Animal Science, 85(6): 1479-1486*

- experiment on steers to quantify the relationship between methane production and feed use efficiency
- found that animals with high feed use efficiency produce less methane (and also had a lower methane cost of growth)

Characterisation of variation in rumen methanogenic communities under different dietary and host feed efficiency conditions, as determined by PCR-denaturing gradient gel elctrophoresis analysis

Mi Zhou, Emma Hernandez-Sanabria, and Le Luo Guan (2010) Characterization of Variation in Rumen Methanogenic Communities under Different Dietary and Host Feed Efficiency Conditions, as Determined by PCR-Denaturing Gradient Gel Electrophoresis Analysis, Applied and Environmental Microbiology, June 2010, p. 3776–3786 Vol. 76, No. 12

- analysis of 56 beef cattle which differed in feed efficiency as well as diet to explore how ruminal methanogenic diversity affects host feed efficiency and results in differences in methane production
- results showed that methanogenic communities are greatly affected by diet, and that these communities are strongly associated with the feed efficiency of the host
- also, that the size of the mathanogenic population did not correlate with differences in feed efficiency, diet or metabolic measurements. Therefore showing that the structure of methanogenic community at the species or strain level may be more important for determining host feed efficiency under different dietary conditions

The genome sequence of the rumen methanogen Methanobrevibacter ruminatium reveals new possibilities for controlling ruminant methane emissions

Leahy SC, Kelly WJ, Altermann E, Ronimus RS, Yeoman CJ, et al. 2010 The Genome Sequence of the Rumen Methanogen Methanobrevibacter ruminantium Reveals New Possibilities for Controlling Ruminant Methane Emissions. PLoS ONE 5(1): e8926. doi:10.1371/journal.pone.0008926

- sequencing of the 2.93 Mb genome of *M. ruminantium*
- insight into the lifestyle and cellular processes of a rumen methanogen and the identification of genes and proteins that can be targeted to reduce methane production
- very important for future study as it has defines vaccine and chemogenomic targets for the broad inhibition of rumen methanogens

Development of a vaccine to mitigate greenhouse gas emissions in agriculture: vaccination of sheep with methanogen fractions induces antibodies that block methane production in vitro

Wedlock DN, Pedersen G, Denis M, Dey D, Janssen PH, et al. (2010) Development of a vaccine to mitigate greenhouse gas emissions in agriculture: Vaccination of sheep with methanogen fractions induces antibodies that block methane production in vitro. NZ Vet J. 58(1):29-36

- understanding the immune responses of ruminants to methanogens by vaccinating 20 sheep and measuring their antibody responses to M. ruminantium M1 antigens in sera and salivia. The antigens recognised by the antisera were visualised and then tested *in vitro* and measured for effect on cell growth, methane production and ability to induce agglutination
- the results demonstrate that antigens from methanogens are immunogenic in ruminats, and that the antisera from those sheep vaccinated with fractions of methanogens have a significant impact on these organisms, inducing cell agglutination and decreasing growth of methanogens and production of methane

Ruminal methanogenesis as influenced by individual fatty acids supplemented to complete ruminant diets

F. Dohme, A. Machmüller, A. Wasserfallen, and M. Kreuzer, "Ruminal methanogenesis as influenced by individual fatty acids supplemented to complete ruminant diets," *Letters in Applied Microbiology*, vol. 32, no. 1, pp. 47–51, 2001.

- study of 7 different fatty acids (50 g/kg to a ruminant diet) effects on rumen fermentation using the rumen simulation technique (RUSITEC)
- Methane release and methanogenic counts suppressed by 3 of the fatty acids with the others showing no corresponding effect
- 2 of those 3, plus 2 others adversly affected ciliate protozoa, suggesting independence from the methane-suppressing effect of medium-chain fatty acid

Effect of supplementing myristic acid in dairy cow rations on ruminal methanogenesis and fatty acid profile in milk

N. E. Odongo, M. M. Or-Rashid, E. Kebreab, J. France, and B. W. McBride, "Effect of supplementing myristic acid in dairy cow rations on ruminal methanogenesis and fatty acid profile in milk," *Journal of Dairy Science*, vol. 90, no. 4, pp. 1851–1858, 2007.

- supplementing the diet of 12 multiparous Holstein dairy cows with myristic acid (5%)

- the myristic acid reduced methane production by 36%

Effects of mixtures of lauric and myristic acid on rumen methanogens and methanogenesis in vitro

C. R. Soliva, I. K. Hindrichsen, L. Meile, M. Kreuzer, and A. Machmüller, "Effects of mixtures of lauric and myristic acid on rumen methanogens and methanogenesis *in vitro*," *Letters in Applied Microbiology*, vol. 37, no. 1, pp. 35–39, 2003.

- looking at the most effective mixture non-esterified lauric and myristic acid to suppress ruminal methanogenesis, and its effects on the methanogenic population
- myristic acid enhanced the methane-suppressing effect of lauric acid in certain mixtures

Inhibition of methanogenesis by tea saponin and tea saponin plus disodium fumarate in sheep

Z. P. Yuan, C. M. Zhang, L. Zhou, et al., "Inhibition of methanogenesis by tea saponin and tea saponin plus disodium fumarate in sheep," *Journal of Animal and Feed Sciences*, vol. 16, pp. 560–565, 2007.

- 8 Huzhou sheep were used to study the effects of tea saponin, tea saponin plus disodium fumarate and cocunut oil on their methane emissions
- tea saponin and tea saponin plus disodium fumarate both worked to decreased methane emissions from the sheep

Methane output and diet digestibility in response to feeding dairy cows crude linseed, extruded linseed, or linseed oil

C. Martin, J. Rouel, J. P. Jouany, M. Doreau, and Y. Chilliard, "Methane output and diet digestibility in response to feeding dairy cows crude linseed, extruded linseed, or linseed oil," *Journal of Animal Science*, vol. 86, no. 10, pp. 2642–2650, 2008.

- experiment on 8 multiparous lactating Holstein cows using 3 different forms of linseed fatty acids (crude linseed, extruded linseed and linseed oil), looking at methane output using the sulfur hexafluoride tracer technique, total tract digestibility and performance of the cows
- all forms significantly decreased daily methane emissions but to different extents
- negative effects found on milk production

Methane emissions from beef cattle; effects of monensin, sunflower oil, enzymes, yeast, and fumaric acid

S. M. McGinn, K. A. Beauchemin, T. Coates, and D. Colombatto, "Methane emissions from beef cattle: effects of monensin, sunflower oil, enzymes, yeast, and fumaric acid," *Journal of Animal Science*, vol. 82, no. 11, pp. 3346–3356, 2004.

- 16 Holstein steers were used to measure methane and carbon dioxide emissions, total-tract digestibility and ruminal fermentation from diets supplemented with monensin, sunflower oil, proteolytic enzymes, Procreatin-7 yeast, Levucell SC yeast and fumaric acid
- sunflower oil, ionophores, and possibly some yeast products can be used to decrease the GE lost as methane from cattle, but fiber digestibility is impaired with oil supplementation.

The effect of oilseeds in diets of lactating cows on milk production and methane emissions

K. A. Johnson, R. L. Kincaid, H. H. Westberg, C. T. Gaskins, B. K. Lamb, and J. D. Cronrath, "The effect of oilseeds in diets of lactating cows on milk production and methane emissions," *Journal of Dairy Science*, vol. 85, no. 6, pp. 1509–1515, 2002

- 36 lactating Holstein cows were assigned to diets containing 2.3,4 and 5.6% fat (whole cottonseeds and canola oilseed additions) to determine the effect on milk composition, production and methane emissions
- supplementation did not affect methane emissions but did increase the efficiency of milk produced per unit of methane emitted

Propionate precursors and other metabolic intermediates as possible alternative electron acceptors to methanogenesis in ruminal fermentation in vitro

C. J. Newbold, S. López, N. Nelson, J. O. Ouda, R. J. Wallace, and A. R. Moss, "Propionate precursors and other metabolic intermediates as possible alternative electron acceptors to methanogenesis in ruminal fermentation *in vitro*, British Journal of Nutrition, vol.94, no.1, pp.27-35, 2005.

- 15 potential precursors of propionate were tested for thier ability to decrease methane production by ruminal fluid in virto
- sodium fumarate was the preferred propionate precursor for use as a feed ingredient to decrease methane emissions from ruminants

Effect of refined soy oil or whole soybeans on intake, methane output, and performance of young bulls

E. Jordan, D. Kenny, M. Hawkins, R. Malone, D. K. Lovett, and F. P. O'Mara, "Effect of refined soy oil or whole soybeans on intake, methane output, and performance of young bulls," *Journal of Animal Science*, vol. 84, no. 9, pp. 2418–2425, 2006.

- 36 Charolais and Limousin cross-bred young beef bulls were fed diets of either refined soy oil or whole soybeans to measure DMI, animal performance and enteric methane emissions
- both decreased daily methane output when expressed in terms of liters/day, l/kg of DMI, %age of GE intake, liters /kg of ADG and l/kg of ADCG
- diet had no effect on ruminal protozoal numers

Effects of addition of tea saponins and soybean oil on methane production, fermentation and microbial population in the rumen of growing lambs

H. L. Mao, J. K. Wang, Y. Y. Zhou, and J. X. Liu, "Effects of addition of tea saponins and soybean oil on methane production, fermentation and microbial population in the rumen of growing lambs," *Livestock Science*, vol. 129, no. 1–3, pp. 56–62, 2010.

- 32 Hizhou lambs were studied for their methane production and fermentation and microbial populations on diets with the addition of tea saponins, soybean oil and tea saponins plus soybean oil
- concluded that tea saponins and soybean oil have an inhibitory effect on methane production when added to their diet
- both show different action against the protozoa, methanogens and other rumen microbes involved in methane formation

Crushed sunflower, flax, or canola seeds in lactating dairy cow diets: effects on methane production, rumen fermentation, and milk production

K. A. Beauchemin, S. M. McGinn, C. Benchaar, and L. Holtshausen, "Crushed sunflower, flax, or canola seeds in lactating dairy cow diets: effects on methane production, rumen fermentation, and milk production," *Journal of Dairy Science*, vol. 92, no. 5, pp. 2118–2127, 2009.

- 16 lactating dairy cows fed one of 4 dietary treatments 1) commercially available calcium salts of long chain fatty acids 2) crushed sunflower seed 3) crushed flaxseed 4) crushed canola seed
- all 3 oilseed treatments decreased methane production by an average of 13%
- canola and sunflower treatments reduced emissions at expense of digestibility

Comparative evaluation of the effects of coconut oil, oilseeds and crystalline fat on methane release, digestion and energy balance in lambs

A. MacHmüller, D. A. Ossowski, and M. Kreuzer, "Comparative evaluation of the effects of coconut oil, oilseeds and crystalline fat on methane release, digestion and energy balance in lambs," *Animal Feed Science and Technology*, vol. 85, no. 1-2, pp. 41–60, 2000.

- 12 lambs had their diets supplemented with either coconut oil, crushed whole oilseeds (rape, sunflower and linseed) or rumen-protected crystalline fat to measure the effects on methane release, digestion and energy balance
- All reduced methane release per kg live weight. Coconut oil 26%, rapeseed 19%, sunflower seed 27% and linseed 10%

Influence of antibiotics and a deaminase inhibitor on volatile fatty acids and methane production from detergent washed hay and soluble starch by rumen microbes in vitro

C. J. Van Nevel and D. I. Demeyer, "Influence of antibiotics and a deaminase inhibitor on volatile fatty acids and methane production from detergent washed hay and soluble starch by rumen microbes in vitro," *Animal Feed Science and Technology*, vol. 37, no. 1-2, pp. 21–31, 1992.

The effect of varying levels of coconut oil on intake, digestibility and methane output from continental cross beef heifers

E. Jordan, D. K. Lovett, M. Hawkins, J. J. Callan, and F. P. O'Mara, "The effect of varying levels of coconut oil on intake, digestibility and methane output from continental cross beef heifers," *Animal Science*, vol. 82, no. 6, pp. 859–865, 2006.

Effect of refined coconut oil or copra meal on methane output and on intake and performance of beef heifers

E. Jordan, D. K. Lovett, F. J. Monahan, J. Callan, B. Flynn, and F. P. O'Mara, "Effect of refined coconut oil or copra meal on methane output and on intake and performance of beef heifers," *Journal of Animal Science*, vol. 84, no. 1, pp. 162–170, 2006

Rumen microbial responses in fermentation characteristics and production of CLA and methane to linoleic acid in associated with malate or fumarate

X. Z. Li, R. J. Long, C. G. Yan, S. H. Choi, G. L. Jin, and M. K. Song, "Rumen microbial responses in fermentation characteristics and production of CLA and methane to linoleic acid in associated with malate or fumarate," *Animal Feed Science and Technology*, vol. 155, no. 2–4, pp. 132–139, 2010.

B Agriculture and greenhouse abatements in Australia

Australia's greenhouse gas emissions in 2009 were assessed at 545.8 Mt CO_2-e (million tonnes of carbon dioxide equivalent) (Australian National Greenhouse Gas Accounts, 2011). The largest contributor was the energy sector accounting for 76.5 per cent of emissions, followed by agriculture, responsible for 15.5 per cent. Other sources of emissions came from industrial processes and waste, 5.4 and 2.6 per cent respectively.

Emissions from agriculture are mainly in the form of methane (CH_4) and nitrous oxide (N_20). For the purpose of greenhouse gas accounting, emissions from the agricultural sector are broken down into sub-sectors;

i *enteric fermentation from livestock* - CH_4 emissions created from the microbial fermentation of feed during digestion

ii *manure management* - CH_4 and N_20 emissions associated with animal wastes from manure management systems

iii *rice cultivation* - CH_4 emissions from the decay of plant and other organic material when the fields are flooded

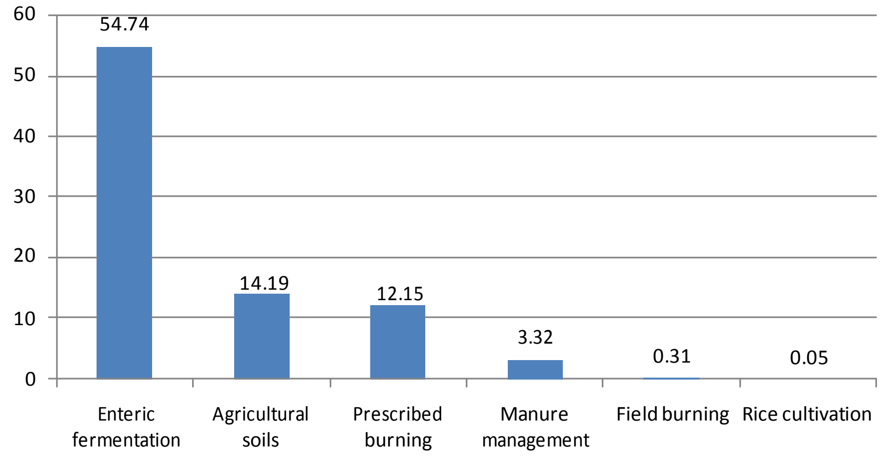
iv *agricultural soils* - N_20 emissions from fertiliser application, crop residues, animal wastes and biological nitrogen fixing from crops and pastures

v *prescribed burning of savannas* - CH_4 and N_20 emissions created as a result of burning tropical savanna and temperate grasslands

vi *field burning of agricultural residues* - CH_4 and N_20 emissions associated with the burning of field stubbles

These sub-sectors vary significantly in their contribution to emission levels from agriculture as a whole, as displayed in Figure B1. Enteric fermentation accounts for a dominant 64.6 per cent of agricultural emissions.

Figure B1 **Greenhouse gas emissions from agriculture, 2009**



Source: National Greenhouse Gas Accounts

There is an active debate about appropriate assessment of GHG emissions from agriculture, particularly linked into the manner in which agricultural processes tend to cycle carbon. However, enteric fermentation processes in ruminants are relatively well-defined (if not always well measured) in the way they take in carbon, largely from atmospheric carbon dioxide via plant material, and convert that carbon into CH_4. It is the potency of atmospheric methane as a greenhouse gas – indicatively about 21 times that of the same weight of carbon held as atmospheric carbon dioxide – that drives the concerns for this conversion from one form of atmospheric carbon to another.

B.1 Livestock emission trends

Agriculture's emissions overall have decreased over the years 1990 to 2009 by 2.4 per cent (or 2.1 Mt). Enteric fermentation has experienced a decrease of 14.4 per cent (or 9.1 Mt) from the reported 1990 figure to 2009, but manure management has increased by 60.6 per cent (or 1.2 Mt) (see Figure B2). In 2009 emissions from enteric fermentation totalled 54.7 Mt CO_2-e and from manure 3.3 Mt CO_2-e.

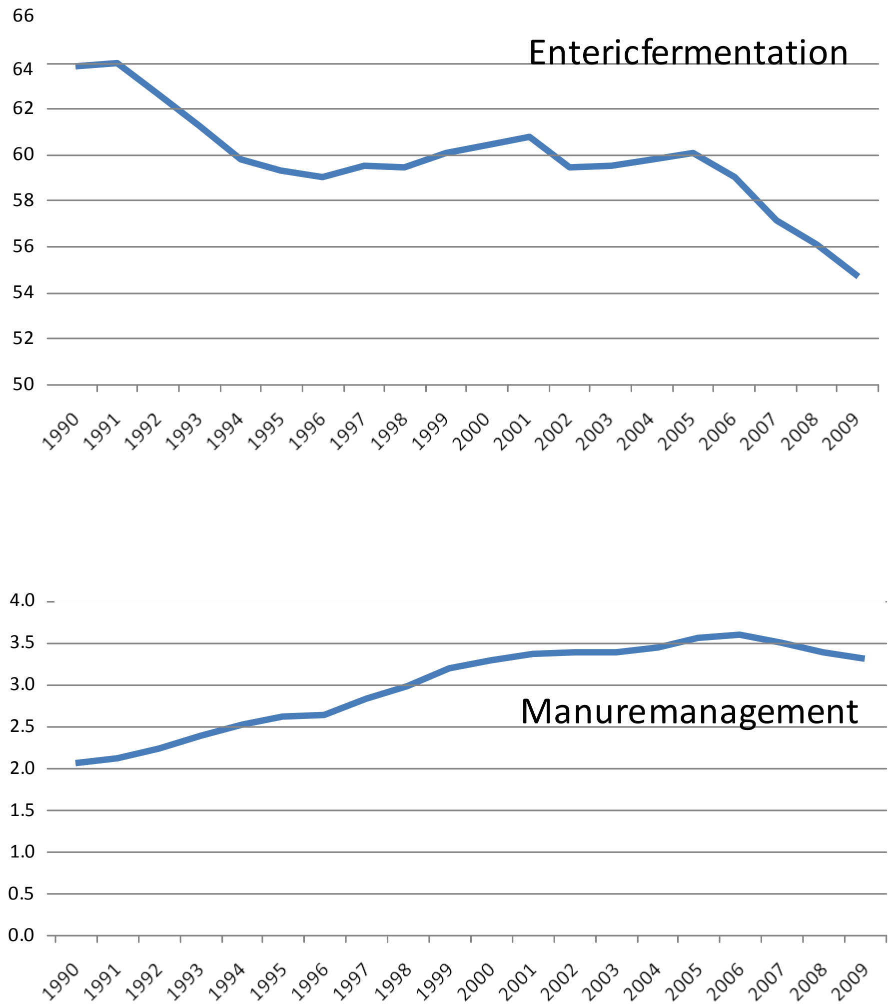
The significant decrease in emissions from enteric fermentation has been driven by a 58.1 per cent fall in sheep numbers across Australia over the last two decades; this has been offset though by a 9.1 per cent increase in the beef cattle herd (Australian National Greenhouse Gas Accounts, 2011). The Australian cattle herd is currently in a rebuilding phase. Total herd numbers for 2011 have reached 28.8 million, the highest they have been in the last 10 years. Compared to 2010 the total herd is up by 2.3 million, driven by better seasonal conditions, high prices and strong international and domestic demand.

The increasing levels of manure management emissions can also be attributed to the increased number of cattle. In the main this increase has come from feed lotted cattle and their associated methane emissions from manure. Since 1990 these methane emissions have increased 6 fold (Department of Climate Change and Energy Efficiency, 2011).

These same factors highlight that there will inevitably be some cycling in herd numbers and emission levels – prolonged droughts (that are likely to increase in frequency under climate change projections) and/or low returns (compared to alternative uses of the land) will tend reduce herd numbers and emissions, but the effect will generally be followed by recovery.

In 2009 emissions from cattle were responsible for 78 per cent of all livestock

Figure B2 **Greenhouse gas emissions from enteric fermentation and manure management, 1990-2009**

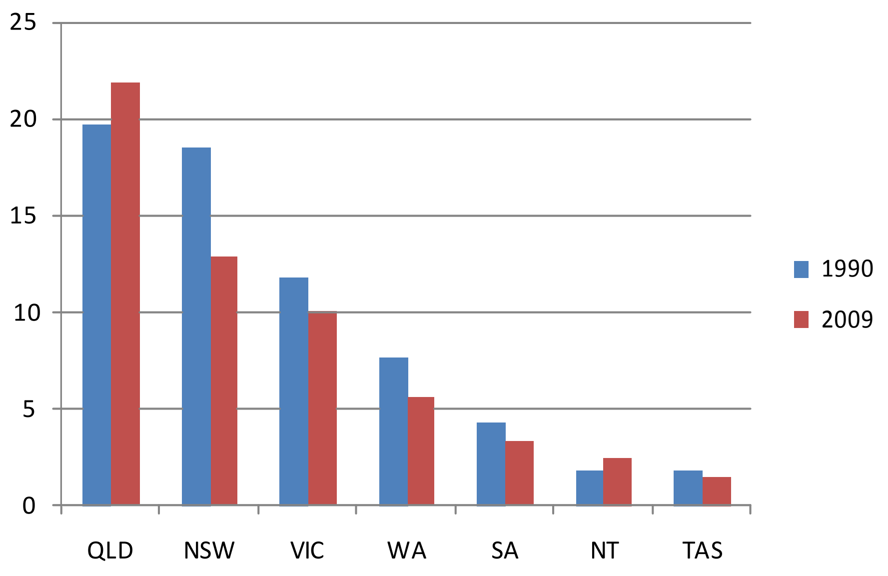


Data source: National Greenhouse Gas Accounts emissions, followed by sheep at 19 per cent and all other livestock at 3 per cent (Australian National Greenhouse Gas Accounts, 2011).

B.2 Livestock emission trends by state and territory

As mentioned previously, decreasing sheep flock numbers have contributed significantly to the reduction in emissions experienced in agriculture. Figure B3 displays on a state and territory level how emission levels form livestock have changed from 1990 to 2009. Queensland has seen a large increase in emission levels that may be explained by the larger cattle numbers in 2009, 40 per cent greater than in 1990. Queensland and NSW are responsible for the majority of livestock emissions in Australia, they also boast the larger numbers of cattle and feedlots in Australia.

Figure B3 **Livestock emissions by state and territory for 1990 and 2009**



Data source: National Greenhouse Gas Accounting

B.3 Accounting for cattle and sheep emissions

Greenhouse gas emission accounting in Australia conforms to the international guidelines adopted by the United Nations Framework Convention on Climate Change (UNFCCC). Methane and nitrous oxide emissions from livestock are managed through the Australian Greenhouse Emissions Information System (AGEIS).

It is important to understand the way emissions are measured and/or calculated when investigating the potential to abate or offset so as to ensure that research efforts and industry adjustments are meaningful and effective. It is also important to ensure that inventory accounting is true and accurate.

Table B1 below presents the annual data used in the calculation of greenhouse gas emissions in 2009. Livestock emissions from cattle are separated into those that are pasture fed and those in feedlots due to the differences that arise with feed and waste handling. Sheep are assumed to all be pasture fed.

Table B1 **Livestock data used to estimate emissions, 2009**

Source category	2009
Number of beef cattle	
Bulls >1	540,306
Bulls <1	162,127
Steers <1	2,903,978
Steers >1 (adjusted for feedlot animals)	4,919,586
Cows 1 to 2	3,464,153
Cows >2	9,438,391
Cows <1	2,674,013
Number of dairy cattle	
Milking cows	1,677,582
Heifers >1	521,735
Heifers >1	350,986
Dairy bulls >1	47,331
Dairy bulls <1	16,100
House Cows	-
Number of feedlot cattle	
domestic class/ average 75 days on feed	
Annual turnoff	739,901
Annual equivalent numbers	152,035
export class/ average 140 days on feed	
Annual turnoff	167,628
Annual equivalent numbers	64,296
Japan ox class/ average 250 days on feed	
Annual turnoff	1,424,369
Annual equivalent numbers	975,595
Number of sheep	
Rams	370,230
Wethers	10,013,652
Maiden ewes (intended for breeding)	7,256,590
Breeding ewes	33,610,266
Other ewes	1,239,938
Lambs and hoggets	20,249,007

Data source: ABS and Australian lot Feeders Association

B.4 Enteric fermentation

Enteric emissions are calculated based around national means for an animal's gross energy intake, live weight and feed digestibility. An average conversion rate is used to refer to the fraction of gross energy that is converted to methane during the fermentation process. Activity tables available from the Department of Climate Change and Energy Efficiency step out the background information required for the calculation of enteric emissions, Figure B4 shows a condensed version of this for cattle and sheep.

Figure B4 **Background accounting data for agricultural emissions from enteric fermentation in cattle and sheep**

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION			IMPLIED EMISSION FACTORS (3)
	Population size (1)	Average gross energy intake (GE)	Average CH_4 conversion rate (Y_m) (2)	CH_4
1. Cattle	26,129.24			76.48
Option A:				
Dairy Cattle (4)	2,545.51	239.01	7.26	114.67
Non-Dairy Cattle	23,583.73	130.53	8.39	72.35
3. Sheep	72,463.39	17.04	6.16	6.93
10. Other *(please specify)*				
Non-Dairy Cattle - Feedlot	1,192.80	200.46	5.82	77.11

(1) Parties are encouraged to provide detailed livestock population data by animal type and region, if available, in the NIR, and provide in
(2) Y_m refers to the fraction of gross energy in feed converted to methane and should be given in per cent in this table.
(3) The implied emission factors will not be calculated until the corresponding emission estimates are entered directly into Table 4.
(4) Including data on dairy heifers, if available.

Disaggregated list of animals (b)		Dairy Cattle	Non-Dairy Cattle	Sheep
Weight	(kg)	485.04	381.97	45.57
Feeding situation (c)		Pasture	Pasture	Pasture
Milk yield	(kg/day)	15.27	NE	NE
Work	(h/day)	NO	NO	NO
Pregnant	(%)	NE	NE	NE
Digestibility of feed	(%)	76.11	59.00	66.60

(a) See also Tables A-1 and A-2 of the IPCC Guidelines (Volume 3. Reference Manual, pp. 4.31-4.34). These data are relevant if Parties do not have data on average feed intake.
(b) Disaggregate to the split actually used. Add columns to the table if necessary.
(c) Specify feeding situation as pasture, stall fed, confined, open range, etc.

Data source: Department of Climate Change and Energy Efficiency

B.5 Manure management

The measurement of emissions from manure requires accounting for the methane and nitrous oxide gases. Calculations for methane are based around different climatic regions, the animal's live weight and daily excretion amount plus the way, or where, the manure is managed. Nitrous oxide emissions concern the amount of nitrogen excreted and under which waste system. Activity tables available from the Department of Climate Change and Energy Efficiency step out the background information required for the calculation of manure emissions. Figure B5 shows a condensed version of manure management for methane emissions for cattle and sheep, and X for nitrous oxide emissions from sheep and cattle manure.

Figure B5 **Background accounting data for agricultural emissions from methane manure management in cattle and sheep**

GREENHOUSE (AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION							IMPLIED EMISSION FACTORS (4)
	Population size	Allocation by climate region (1)			Typical animal mass (average)	VS(2) daily excretion (average)	CH_4 producing potential (Bo)(2) (average)	CH_4
		Cool	Temperate	Warm				
	(1000s)	(%)			(kg)	(kg dm/head/da	(m^3 CH_4/kg VS)	(kg CH_4/head/yr)
1. Cattle	26,129.24							0.90
Option A:								
Dairy Cattle (	2,545.51	NO	93.24	6.76	485.04	2.85	0.24	8.87
Non-Dairy C	23,583.73	NO	42.92	57.08	381.97	NE	NE	0.04
3. Sheep	72,463.39	NO	94.53	5.47	45.57	NE	NE	0.00
10. Other livestock *(please specify)*								
Non-Dairy Cattle - Feedlot	1,192.80	NO	42.19	57.81	534.99	2.00	0.17	2.90

(1) Climate regions are defined in terms of annual average temperature as follows: Cool = less than 15°C; Temperate = 15 - 25°C inclusive; and Warm = greater than 25°C (see table 4.2 of the IPCC Guidelines (Volume 3, Reference Manual, p. 4.8)).

(2) VS = Volatile Solids; Bo = maximum methane producing capacity for manure IPCC Guidelines (Volume 3, Reference Manual, p.4.23 and p.4.15); dm = dry matter. Provide average values for VS and Bo where original calculations were made at a more disaggregated level of these livestock categories.

(3) Including data on dairy heifers, if available.

(4) The implied emission factors will not be calculated until the corresponding emission estimates are entered directly into table 4.

Additional information (for Tier 2) (a)

Animal category	Indicator	Climate region	Animal waste management system						
			Anaerobic lagoon	Liquid system	Daily spread	Solid storage	Dry lot	Pasture range paddock	Other
Dairy Cattle	Allocation (%)	Cool	NO	NO	NO	NO	NO	NO	NO
		Temperate	4.92	0.39	1.35	NO	NO	93.34	NO
		Warm	2.32	0.00	5.41	NO	NO	92.27	NO
	MCF(b)	Cool	NO	NO	NO	NO	NO	NO	NO
		Temperate	90.00	35.00	0.50	NO	NO	1.00	NO
		Warm	90.00	65.00	1.00	NO	NO	2.00	NO
Non-Dairy Cattle	Allocation (%)	Cool	NO	NO	NO	NO	NO	NO	NO
		Temperate	NO	NO	NO	NO	NO	100.00	NO
		Warm	NO	NO	NO	NO	NO	100.00	NO
	MCF(b)	Cool	NO	NO	NO	NO	NO	NO	NO
		Temperate	NO	NO	NO	NO	NO	NE	NO
		Warm	NO	NO	NO	NO	NO	NE	NO
Sheep	Allocation (%)	Cool	NO	NO	NO	NO	NO	NO	NO
		Temperate	NO	NO	NO	NO	NO	100.00	NO
		Warm	NO	NO	NO	NO	NO	100.00	NO
	MCF(b)	Cool	NO	NO	NO	NO	NO	NO	NO
		Temperate	NO	NO	NO	NO	NO	NE	NO
		Warm	NO	NO	NO	NO	NO	NE	NO

Data source: Department of Climate Change and Energy Efficiency

Figure B6 **Background accounting data for agricultural emissions from nitrous oxide manure management in cattle and sheep**

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION								IMPLIED EMISSION FACTORS	
	Population size	Nitrogen excretion	Nitrogen excretion per animal waste management system (AWMS) (kg N/yr)						Emission factor per animal waste management system	
	(1000s)	(kg N/head/yr)	Anaerobic lagoon	Liquid system	Daily spread	Solid storage and dry lot	Pasture range and paddock	Other	(kg N_2O-N/kg N)	
Cattle	26,129.24		14,742,045.85	1,138,155.11	4,937,657.21	NO	1,216,305,348.15	NO	Anaerobic lagoon	0.00
Option A:									Liquid system	0.00
Dairy Cattle	**2,545.51**	**121.65**	**14,742,045.85**	**1,138,155.11**	**4,937,657.21**	**NO**	**288,835,071.18**	**NO**	Solid storage and dry lot	0.02
Non-Dairy Cattle	**23,583.73**	**39.33**	**NO**	**NO**	**NO**	**NO**	**927,470,276.97**	**NO**	Other AWMS	0.02
Sheep	**72,463.39**	**7.05**	**NO**	**NO**	**NO**	**NO**	**511,122,338.65**	**NO**		
Other livestock *(please specify)*										
Non-Dairy Cattle - Feedlot	**1,192.80**	**83.60**	**NO**	**NO**	**NO**	**99,720,491.11**	**NO**	**NO**		

Data source: Department of Climate Change and Energy Efficiency

C Livestock trends in Australia

Table C1 **Type table title here**

	Slaughterings ('000)	Average weight (kg)	Production (kt)	Value ($)
Beef cattle				
2006	8 854	247	2 188	
2007	8 960	243	2 180	
2008	8 771	246	2 161	
2009	8 411	250	2 106	
2010	8 273	257	2 129	
Lamb				
2006	19 483	20.5	399.8	
2007	20 971	20.8	435.6	
2008	19 970	20.4	406.6	
2009	20 493	20.7	424.5	
2010	18 609	21.6	401.9	
Mutton				
2006	13 113	20.5	269.4	
2007	11 661	21.0	245.2	
2008	11 235	21.4	240.1	
2009	9 411	21.2	199.8	
2010	6 159	22.6	139.1	

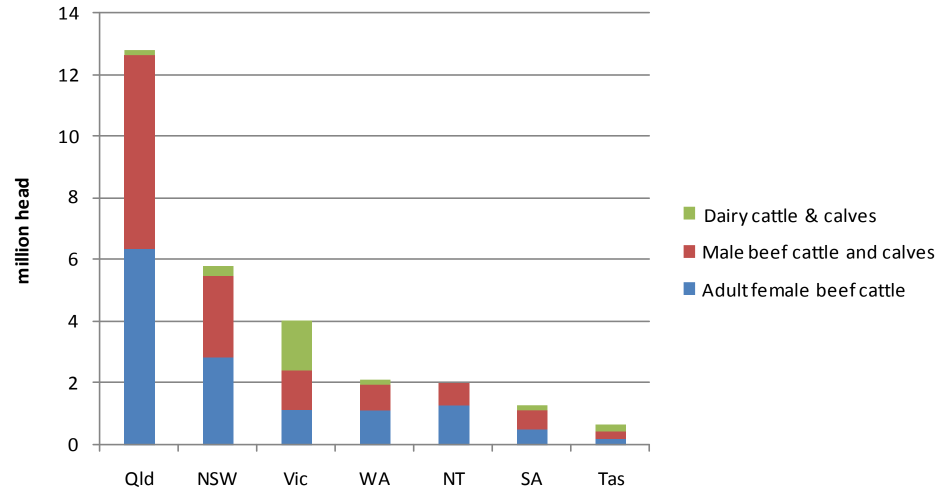
Data source:Overwrite this text with the table's data source

Table C2 **Type table title here**

	Sheep shorn (million)	Average cut per head (kg greasy)	Shorn wool production (kt greasy)	Clean yield (%)	Value ($)
2006/07	110.08	4.09	450.22	62.90	
2007/08	94.86	4.30	407.88	62.60	
2008/09	86.31	4.29	370.60	62.80	
2009/10	82.94	4.25	352.74	63.20	
2010/11	84.83	4.34	368.33	64.90	

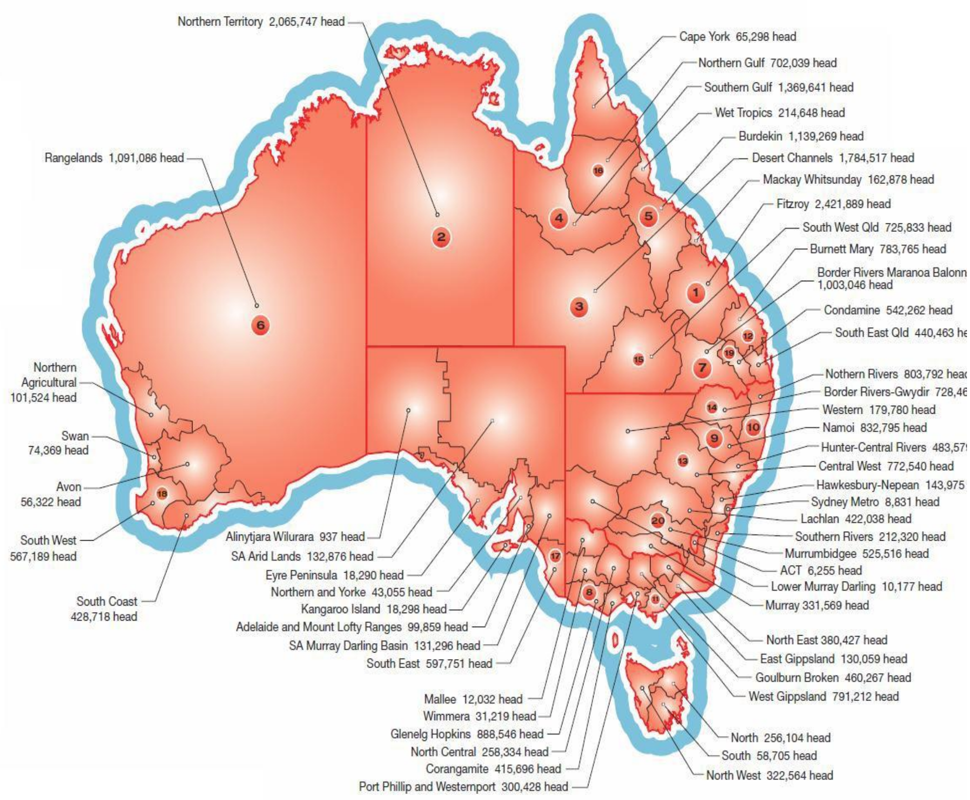
Data source:Overwrite this text with the table's data source

Figure C1 **Herd numbers by state and broken down by class, 2011**



Source: ABARES

Figure C2 **National cattle numbers by national resource management region, June 2010**

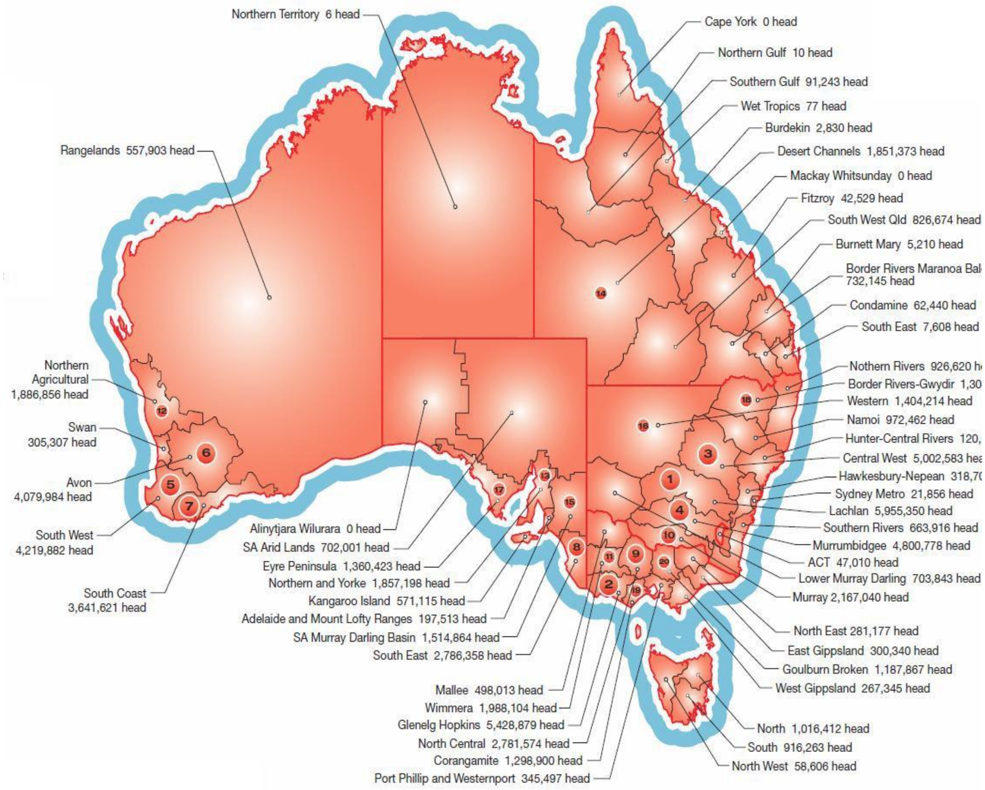


Data source: ABS and Australian Government Land and Coasts

The vast areas of the Rangelands in Western Australia, as seen in Figure C2, can be disaggregated into four main areas; the Gascoyne, Mid West, Pilbara and the Kimberly, as shown in Figure C3. The Gascoyne and Mid West regions have an estimated beef cattle herd of around 100,000 head each. Stocking is heaviest in the more northern areas of these regions although the southern parts are growing as traditional sheep country is adapted. The Pilbara has an estimated 280,000 whilst the Kimberly accounts for approximately 60 per cent of the Rangelands numbers, 625,000 head of cattle (RIRDC, 2010). Heard growth in the Rangelands has expanded by 30 per cent since 2000.

Figure C3 **Regions of Western Australia**

Figure C4 **National sheep numbers by natural resource management region, June 2010**



Data source: ABS and Australian Government Land and Coasts

C.1 Feedlot cattle

The Australian Lot Feeders' Association reports 700 accredited feedlots throughout Australia. In general these feedlots are located close to cattle and grain supplies. The south east Queensland region has the majority of these feedlots, and in 2010 had 1.71 million head of cattle on feed, representing 57 per cent of the total 3 million cattle in Australia being feed lotted (see Figure C1). The northern tablelands and Riverina region of New South Wales are other areas highly populated with feedlots, accounting for 0.87 million feedlot fed cattle in 2010, equivalent to 29 per cent of all cattle in feedlots. Feedlots can also be found in Victoria, South Australia and southern Western Australia.

The beef feedlot industry has expanded significantly over the last 10 years, back in 2004 AUS-MEAT Ltd reported 551 feedlots in Australia with a capacity to run just under 1 million cattle. In 2010 that capacity now sits at nearly 5.2 million.

Table C3 **Cattle feedlot numbers and capacity broken down by size and state, 2010 and 2011 (Jan-Sept)**

	Numbers on feed 2011 (Jan-Sept)	Capacity 2011 (Jan-Sept)	Capacity utiisation 2011 (Jan-Sept) %	Numbers on feed 2010	Capacity 2010	Capacity utiisation 2010 %
Australia						
< 500 head	36,154	187,391	19%	57,734	299,706	19%
500-1000 head	94,187	271,932	35%	99,445	345,006	29%
1000-10000 head	813,175	1,415,597	57%	1,028,835	1,865,821	55%
> 10000 head	1,341,552	1,989,937	67%	1,819,203	2,656,232	68%
Total	2,285,068	3,864,857	59%	3,005,217	5,166,765	58%
NSW						
< 500 head	5,970	21,407	28%	10,271	29,686	35%
500-1000 head	12,652	59,260	21%	18,460	88,407	21%
1000-10000 head	165,228	347,799	48%	176,596	454,928	39%
> 10000 head	551,974	828,719	67%	670,103	1,142,292	59%
State total	735,824	1,257,185	59%	875,430	1,716,313	51%
Qld						
< 500 head	23,489	125,670	19%	28,888	188,538	15%
500-1000 head	49,605	140,867	35%	63,880	197,640	32%
1000-10000 head	501,405	694,206	72%	618,452	925,768	67%
> 10000 head	700,638	947,218	74%	999,231	1,277,624	78%
State total	1,275,137	1,907,961	67%	1,710,451	2,589,570	66%
Vic						
< 500 head	1,079	3,255	33%	2,725	5,862	46%
500-1000 head	18,900	19,400	97%	-	3,100	0%
1000-10000 head	50,105	92,997	54%	70,665	102,680	69%
> 10000 head	88,940	184,000	48%	149,869	216,316	69%
State total	159,024	299,652	53%	223,259	327,958	68%
SA						
< 500 head	3,185	9,190	35%	5,689	13,360	43%
500-1000 head	11,866	20,725	57%	17,105	29,659	58%
1000-10000 head	58,099	66,495	87%	69,573	84,845	82%
> 10000 head	-	-		-	-	
State total	73,150	96,410	76%	92,367	127,864	72%
WA						
< 500 head	2,431	27,869	9%	10,161	62,260	16%
500-1000 head	1,164	31,680	4%	-	26,200	0%
1000-10000 head	38,338	214,100	18%	93,549	996,900	9%
> 10000 head	-	30,000	0%	-	20,000	0%
State total	41,933	303,649	14%	103,710	406,060	26%

Data source: *ALFA/ MLA National Accredited Feedlot Survey*

Table C4 **Total cattle turnoff from feedlots by state, 2008 - 2011(Jan-Sept)**

	NSW	Vic	Qld	SA	WA	Total
2011 (Jan-Sept)	*506,800*	*170,204*	*1,063,946*	*75,515*	*53,841*	*1,870,306*
2010	634,526	207,305	1,468,631	110,831	112,318	2,533,611
2009	587,444	161,614	1,374,959	77,281	130,601	2,331,899
2008	570,099	150,271	1,212,738	76,910	124,485	2,134,503

Data source: ALFA/MLA National Accredited Feedlot Survey

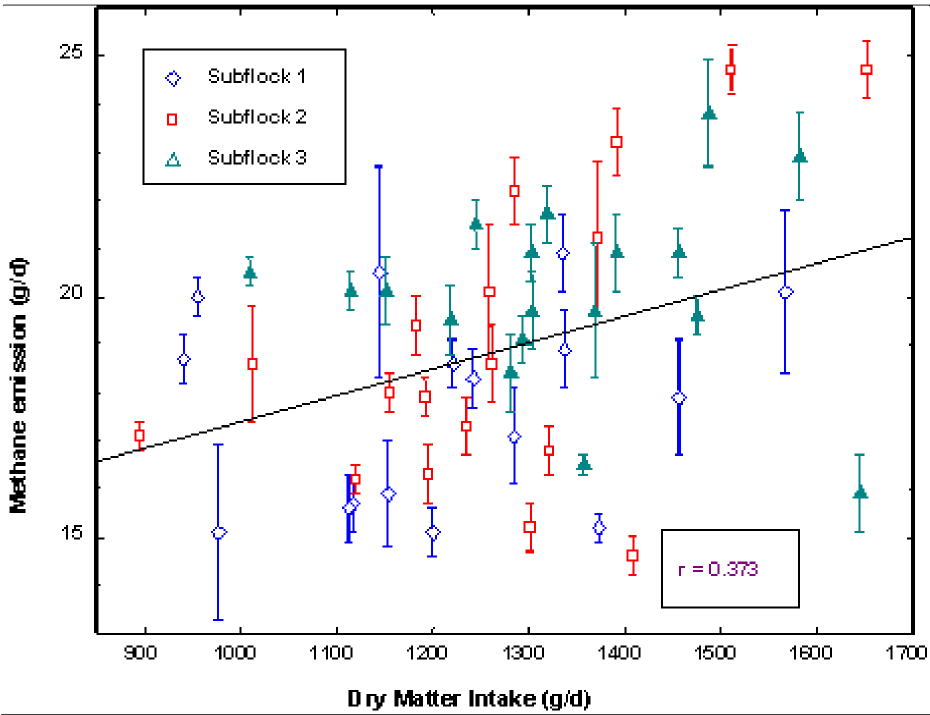
D The relationship between feed intake and methane emissions

The link between methane, nitrous oxide and carbon emissions from agriculture and productivity has been studied for many years, but only recently in context of the climate related externalities produced by the emissions themselves.

There has been a substantial amount of research undertaken in New Zealand on the relationship between methane emissions and animal production. This is not surprising, given that NZ is the only developed economy to include agriculture in its national emissions reduction scheme; arguably, it had little choice (if it were to introduce such a scheme) as agriculture accounts for up to 60 per cent of NZ total emissions.

The research in NZ indicates that the relationship between methane emission and feed intake is positive, but emissions between animals are highly variable (Blaxter & Clapperton, 1965; Kirchgessner et al, 1995; Lassey *et al*, 1997). An example of this relationship is shown in Chart D1, using data from sheep grazing fresh pasture in New Zealand, where the absolute amount of methane emitted increases as intake increases ($r=0.373$; $P<0.05$) (Lassey *et al*, 1997). The notable thing about this relationship is that approximately 87% of the variation in methane emission is between animals, suggesting that differences in DM intake *per se* accounted for about 13% of the variation in methane emission.

Chart D1 **Methane emissions versus DM intake in a group of 50 sheep grazed on the same pasture (n=5)**

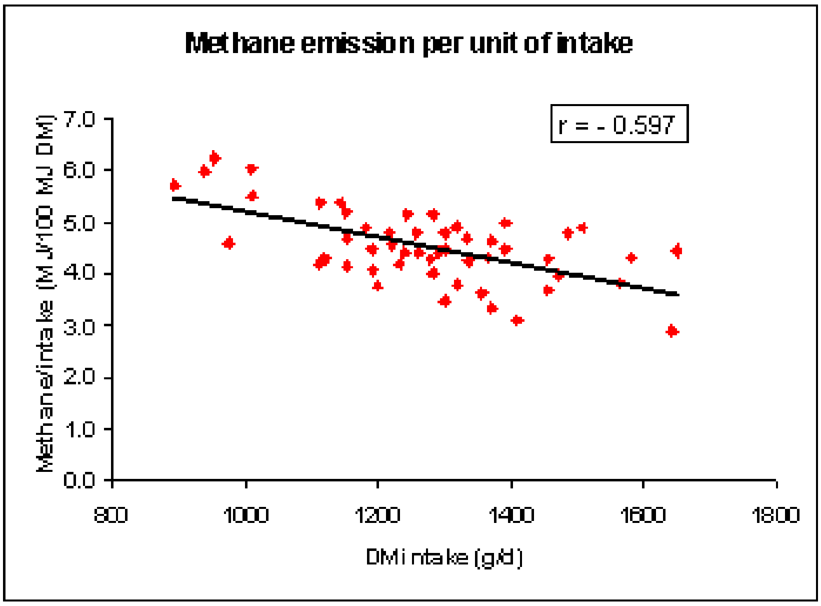


Data source: (New Zealand Ministry of Agriculture and Forestry, 2009)

However, while the relationship between intake and emissions is positive, the rate of emissions per unit of intake declines as more feed is consumed per animal. That relationship is stronger (r=-0.597; P<0.01) than that for total intake and emissions (r=0.373; P<0.05):

> This is a well established relationship for sets of data where animals are fed the same diet at both restricted and ad libitum intakes (Armstrong, 1964; Blaxter & Clapperton, 1965; Johnson & Johnson, 1995). This suggests that for efficient animal production and reduced methane emission it is advantageous to feed animals well above maintenance intake (New Zealand Ministry of Agriculture and Forestry, 2009).

Chart D2 **Methane emissions per unit of feed intake plotted again DM intake in sheep grazing the same pasture**

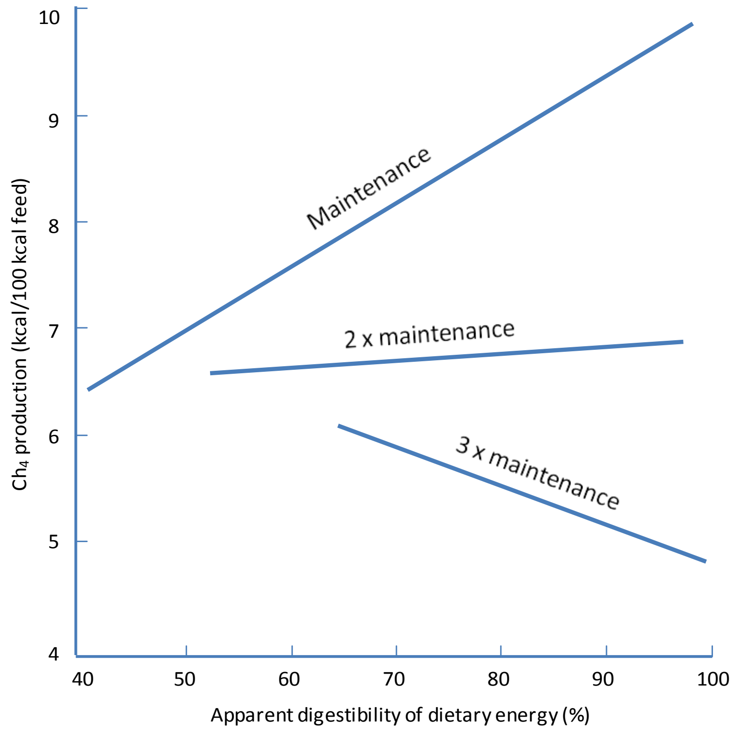


Data source: (New Zealand Ministry of Agriculture and Forestry, 2009)

The relationship between feed intake and emissions is also dependant on the quality of the feed consumed. Higher quality feed, measured as apparent digestibility of feed consumed, produces less methane when broken down in the rumen. The relationship between feed intake, productivity of the animal and feed quality is demonstrated in Chart D3. At maintenance, the level of methane emitted rises as digestibility increases. But as feeding exceeds maintenance levels, emissions per unit of feed fall as feed quality rises.

At maintenance levels of feeding, animals are assumed not to be producing meat or milk and only minimal quantities of fibre. Therefore, at this level of feeding, the emissions per unit of product produced are theoretically infinite. As feed intake rises, emissions per unit of production fall dramatically.

Chart D3 **The relationship between digestibility, methane emissions and different levels of feeding**



Data source: (New Zealand Ministry of Agriculture and Forestry, 2009)

Table D1 **Summary of the abatement potential assumptions for animal management options for dairy cows**

Activity	Production improvement (%)	CH4 reduction (%)	Notes
Concentrate	14	7	
Maize silage	7	-2	
Propionate precursors	15	22	
Probiotics	10	7.5	
Ionophores	25	25	
Bovine somatatrophin	17.5	10	
Genetic improvement-production	7.5-22.5	0	Cumulative effect over years
Genetic improvement-fertility	3.25-11.25	2.5-7.5	Cumulative effect over years
Transgenic offspring	10	20	

Data source: *(Moran, et al., 2008)*

E Options valuation and decision tree analysis

The material in this attachments is adapted from earlier work done by ACIL Tasman for CSIRO (##Reference to Overview Report 2006).

The application of the real options approach to investments in research and development is relatively new, with relatively few case studies. The more formal approaches to value options have endeavoured to use the Black-Scholes formula for estimating the option value of research. This approach is complex and often limited by data availability. Furthermore, the potential for R&D to deliver 'lumpy' outcomes, in the form of a major breakthrough can seriously violate some of the assumptions underpinning the Black-Scholes approach, which has its origins in financial markets where volatility is usually driven by the collective impacts of myriad small shocks. ACIL Tasman has adopted a more pragmatic approach whereby a real options model is set within the structure of a decision tree to enable the possibilities and risks associated with research projects to be explored.

A decision tree maps the sequence of decision and chance nodes which define the project under consideration. The decisions emanating from a decision node represent the options available to the decision maker. The chance nodes identify where an external event will influence the project, and assign probabilities to each outcome. The outcomes need to be specified as discrete possibilities, even if this means approximating a continuous outcome.

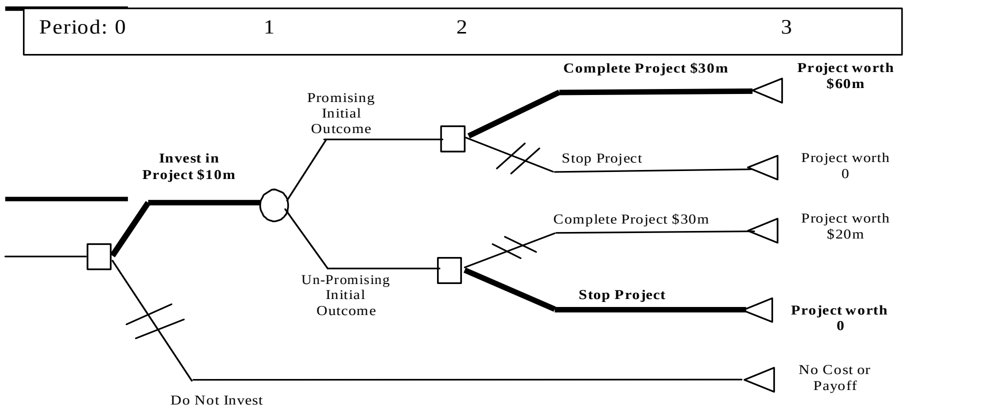
Decision tree analysis corrects some of the inadequacies of NPV calculations because it recognises that only with the resolution of uncertainty will the most appropriate decision be revealed. It does not pre-commit to a decision in the first time period, and instead identifies an array of options.

Figure 5 shows the structure of a decision tree for a simple project. In the diagram, squares denote decision points and a circle denotes a chance point. The project involves an initial decision about whether to start a project, which costs $10 million, and a later decision whether to complete the project or abandon it. Completing the project costs a further $30 million. Before making the second decision, managers are able to observe the initial outcomes, and determine whether these are favourable.

Once the tree has been laid out, decision analysis solves the tree from right to left, in principle working down each branch, to find the best possible decision at each point. One decision rule commonly used is to select the decision which offers the best average value, where average is a weighted average of the present values by their probabilities.

At the decision point in period 2, the value of completing the project is 60/1.1 less 30 = $25.54 million, which is the discounted worth of the project less the cost of completing the project. If the project is stopped at this point, its value is zero.

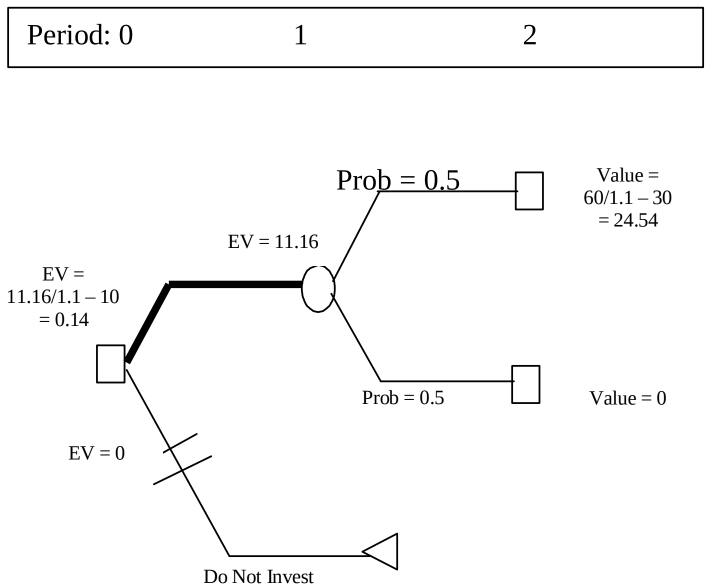
Figure 5 **Decision tree structure**



Weighting each of these outcomes by their respective probabilities and discounting by one period gives the expected value in period 1 of investing in the initial project, [0.5 × 24.54 + 0.5 × 0]/1.1 = $11.16 million. Discounting this value back a further period and comparing with the initial cost of the project suggests that it would be worthwhile undertaking, but only just.

Figure 6 shows this process of rolling back the decision tree to determine the optimal initial decision.

Figure 6 **Rolled back decision tree**



A criticism of decision trees is that they can quickly become 'bushy' and complex. However, good quality software available for decision tree analysis can, to a large extent, overcome this problem. The complexity that remains is typically a reflection of complexity inherent in the decision problem.

F Impact of extra 'irons in the fire'

The material in this attachments is adapted from earlier work done by ACIL Tasman for CSIRO (##Reference to Overview Report 2006).

What follows is somewhat theoretical but in fact it affords powerful insights into some of the key dimensions of option value offered by MLA research programs and, in particular, the RELRP. The discussion opens up a practical approach to addressing the counterfactual relevant to assessing value attributable to CSIRO involvement.

To make these ideas clearer – and to establish a basis for credible assessment of value, we consider a somewhat artificial example of how extra irons in the fire deliver a different outcome.

Suppose there are two ways of a attacking a problem – and suppose for the moment that either, if it succeeds, will deliver an equally valuable solution. Both approaches have good prospects, but the time taken to deliver the solution is unknown. Approach A is proceeding. The question is: why bother with Approach B? We develop a basis for addressing this question below.

F.1 Distribution of time to discrete success

A wide range of real world phenomena, including in relation to R&D, failure of equipment and occurrence of some natural phenomena, can be modelled under the assumption that the probability of a discrete event occurring in a given time interval (say 1 year) is reasonably constant. For example, consider an R&D program that is systematically trawling through hundreds of candidate gene sequences, rumen microbe patterns or potential feed supplements, looking for a high impact pattern that could underpin a methane abatement strategy. Assume the assessment of each will take on average a certain amount of time and that there are fixed resources directed at the exercise. A structure along these lines would appear to align well with this constant rate of success assumption.

Where this assumption applies, it is possible to infer the statistical distribution of the time taken to achieve a breakthrough. The appropriate distribution function is the exponential function (defined below). For now, we assume that both Approaches A and B have this characteristic – that the time till 'success' can be approximated by an exponential function. We later argue that this assumption can be relaxed substantially while still allowing robust conclusions regarding the impact of adding extra irons to the fire, but this as a working assumption makes formal modelling of research prospects and outcomes more tractable.

F.2 Identical independent distributions

Accordingly, to make the example concrete and tractable, suppose the distribution of time till success, T, for both Approaches A and B is the same, and follows a simple exponential distribution defined as follows:

$$\text{Prob}\{T<t\} = 1 - \exp(-\lambda t)\}, t>0$$

We know that the mean of this distribution is 1/ λ, so that, for example, for:

$\lambda = 1$, mean time to success = 1 year;

$\lambda = 0.2$, mean time to success = 5 years

Given this assumption, we can also calculate the probability of a breakthrough in any one year, assuming the problem has not already been 'cracked'. This probability is 1-exp(-λ). If is 1, then this probability is 1-exp(-1), or about 63% – a fairly optimistic assumption for most research. With λ at 0.25, the mean time to success becomes 4 years and the probability of a breakthrough in any one year is about 22 per cent. Varying the single parameter allows a fair bit of flexibility to set a distribution broadly in line with expectations.

If both Approaches A and B are independent of each other (likely to be a reasonable assumption if both approaches are either trawling through a wide range of candidates or trawling through different candidates), each with this distribution, it is trivial to establish that the distribution of the time till the first of the two approaches succeeds is also an exponential distribution, this time with parameter 2λ, and a mean time till success of 1/(2λ).

In this case, having the extra iron in the fire halves the mean time till the problem is solved, even though the second approach had no better prospects than the first.

More generally, for effectively all meaningful and non-trivial distributions of time till success, the extra iron *must reduce* the mean time till success. An even stronger statement is possible in that the two irons strategy is necessarily statistically dominant, not just for the means but for all percentiles of the distribution. Running the two investments systematically shifts the distribution of the time till success forward.

###Chart of shift in distribution curves

F.3 Non-identical independent distributions

A simple extension of this is to assume that the two approaches have different mean times till success – in reality, a far more plausible situation if the two distributions are seen as relating to the counterfactual and to the RELRP as distinct programs. Approach A follows a distribution with parameter λ_1 and mean time till success of $1/\lambda_1$, and Approach B has parameter λ_2.and mean time till success of $1/\lambda_2$.

Again it is trivial to show that the time till the first success follows an exponential distribution, this time with parameter $(\lambda_1 + \lambda_2)$. The above identical distribution case is a special case of this result. Mean time till first success is then $1/(\lambda_1 + \lambda_2)$ – which must be less than the mean time till success of either approach independently.

So if Approach A has a mean time till success of, say, 2 years, and approach B has a mean time till success of 4 years, then adding Approach B to Approach A reduces the mean time till success from 2 years to 4/3 years – a reduction of one third in the time till the problem is solved by the more promising of the two approaches on its own.

Of course, the cost of solving the problem has gone up – though not necessarily by the full cost of Approach B. This is because it may well be possible to abandon the remaining research as soon as one approach delivers (or even earlier, once it is clear that the approach will deliver fairly quickly). These higher costs need to be justified, and in this case the justification would need to lie in the value of having a solution on average 8 months earlier than would otherwise be the case.

The assumption of an exponential distribution makes the example concrete, but is not essential. As a general proposition, adding another independent line of attack, with some prospects for success within the range of possible times till success of the existing approaches, must reduce the mean time till success.

F.4 Non-independent distributions

Suppose both approaches depend critically on the one hypothesis. If it is true, both will deliver and if false neither will deliver. In this case, there may be little benefit in adding the extra iron to the fire unless it has other desirable attributes. You would be better backing the approach that can be expected to reach a landing earliest. However, two different lines of attack on this key hypothesis could well be justified if they are fairly independent, and there will be significant luck that determines how long the search takes.

Furthermore, should the research be heavily dependent on trawling through prospects in a time consuming way – 'looking for a needle in a haystack' – the extra iron in the fire can still deliver substantial benefits in the form of improved prospects of early delivery. Again, such an approach will bring forward the mean time till the 'needle' is found, and also bring forward all of the percentiles of the distribution of the time till discovery.

On the other hand, suppose we know that only one of the two approaches can succeed. If one will work, the other will fail, because each relies on an assumption that is not compatible with the success of the alternative approach. In this case, adding Approach B to Approach A is quite dramatic in its effects. The mean time till success of Approach A is in fact infinite, given the non-zero chance of it ever delivering, as is the mean time till success of approach B. However, the mean time till success of the composite of the two is finite and may well be quite small.

What is happening here is that the combination approach has eliminated the risk of total failure to find a solution. With less stringent assumptions but including some chance of failure, it is straightforward to demonstrate the proposition that extra irons in the fire will usually boost the chances of ultimate success, as well as lowering the mean time till success.

Of course, an alternative would be to back one of the two approaches long enough to determine if it really is promising – and if not to switch to the alternative. This is a classic options strategy. It has the effect of lowering the chances of wasting resources on an unsuccessful approach (backing both in parallel guarantees that one of the approaches being backed will fail – we just do not know which) but will not deliver the same level of bringing forward of the time till a successful strategy is found. There is a cost/time trade-off here that would need to be weighed.

In relation to the RELRP, the interactions are not as extreme as this but there may be some 'negative correlation'. For example, there might be two approaches, both of which would ultimately work by modifying rumen microbes. One appears likely to be much cheaper than the other and it would never make sense to implement both, as the impacts do not add. However, continuing to explore the higher cost approach might make sense if there is a chance the lower cost approach would not succeed. The 'extra iron in the fire' could provide insurance against this risk, and in doing so may substantially improve (at a cost) the time till a successful outcome is achieved.

A broad proposition to emerge from the above examples is the robust conclusion that, while there is uncertainty about whether and when specific research initiatives will succeed, adding an extra iron to the fire will bring forward the distribution of the time till a successful breakthrough is achieved. This is true provided the extra iron has some prospects for success, even in the event that the other approach will fail. It is even true if there is a non-zero chance that none of the approaches will succeed – so that the mean time till success is infinite. Adding an extra iron still reduces the mean time till success in the event that one of the approaches would eventually succeed.

Again, of course, the costs of adding the extra iron needs to be weighed against these benefits – in some circumstances, keeping the extra iron in reserve in the event that the other research is not panning out may be the better strategy.

F.5 Multiple approaches

Of course, there may already be several approaches being pursued. What then of adding one more? The same principles apply. The several existing approaches imply a distribution of time till success (and possibly an overall probability that the portfolio of these approaches will ever succeed). Adding one more will, under quite broad assumptions, reduce the mean time till success in the event that one of the approaches will eventually succeed, and under reasonably broad assumptions increase the chances of ever solving the problem. This fact drives value from adding the extra approach.

However, the more approaches there are already, and the more diverse and prospective these approaches, the less will be the value of adding one more. There are 'diminishing returns to scale' and, conceptually at least, there will be an optimal level of attack, involving a mix of approaches but stopping when the extra value from adding the next most promising approaches falls short of the expected extra cost of doing so.

However, in the case of RELRP, these marginal returns seem most unlikely to diminish towards zero unless the counterfactual includes substantial, Australia-focused research. This is because of the way in which RELRP is likely to add diversity to the overall research activity – and in particular to deliver not just prospects for an earlier science breakthrough, but also capability likely to allow earlier translation of the science in feasible farm strategies relevant to Australian conditions.

F.6 Diversity and 'hybrid vigour'

The earlier comments regarding the benefits of different approaches can be given explicit meaning in the context of portfolio theory. However, the basic proposition that comes through is that adding to the diversity of the package of approaches is likely to deliver more value than effectively duplication an approach already being pursued – though even this can sometimes be justified by big enough problems or opportunities where there are skill and cultural differences, or for reasons of sheer serendipity (as in the case of needing to trawl through multiple possibilities for supplements etc).

A feature of RELRP is the way in which it almost necessarily delivers this diversity relative to the counterfactual, as a result of its focus on trials in relation to Australian herds, pasture species and soil and climatic conditions. These targets for science research may be no more prospective than analogous targets from NZ, the US etc. However, they are different and for this reason they may result in an earlier breakthrough. But more importantly, if there is a breakthrough, then all that has been learnt from trials focused on Australian conditions, and all the capability developed by Australian researchers working in these conditions, can be expected to embed a set of options for early adaptation and implementation.

This type of diversification has a structural impact on forward expectations in relation to cost effective methane mitigation opportunities for Australia. Realistically, RELRP probably offers a modest enhancement to the overall prospects for early success with the science, coupled with a large enhancement to the prospects for early adaptation to Australian conditions.

F.7 Adoption impacts

Poor rates of take-up have killed the economics of many a good science breakthrough – even where technical adaptation to local conditions has been achieved. Sound investment planning and justification must address, preferably long before the development costs have been incurred, the question of whether an innovation successfully delivered from a research program will deliver enough take-up to justify the costs and risks.

The effect of slow take-up is to defer the benefits – which as result get discounted more heavily. It can also increase the chances of another innovation arising before high take-up has been achieved, implying greater risk of 'obsolescence'.

The above discussion is highly relevant here. If a feature of RELRP is to improve the likelihood or timing of delivery of capabilities that are particularly well suited to Australian conditions, then this could support earlier and more rapid adoption.

Nonetheless, it is appropriate to look at the features of particular lines of attack on methane abatement, and to assess their prospects for early adoption. Adoption of other rural R&D innovations has important lessons here. For example plant genetic improvements, which can be embedded in available seed varieties, can achieve very rapid take-up. They involve little if any modifications to farm systems – where the need for modification commonly proves a major deterrent to rapid adoption. By analogy, innovations that allow for 'aggregation' of mitigation benefits into other inputs already in demand could favour rapid adoption relative to farm level changes that require new systems for monitoring and reporting. These types of considerations are highly relevant to consideration of where RELRP might achieve the greatest gains.

F.8 Modelling the advancement options

ACIL Tasman has developed for this review a simple spreadsheet system that allows modelling of the nature of these advancement options as part of an approach for valuing the options. This spreadsheet allows explicit assumptions to be made regarding the prospects of both the RELRP and the wider counterfactual portfolio of innovation strategies. Under the assumptions made, this allows estimation of a time series of probabilities that an effective innovation has been delivered by RELRP and would not otherwise have been available at that point in time.

Of course, the input parameters for such modelling will be highly subjective and the overall approach involves simplifying assumptions that depart somewhat from reality. However, the model allows testing of sensitivity of option values to different assumptions about the prospects and timing of both the CSIRO and the counterfactual approaches to the problem/opportunity. As such, this modelling can provide guidance that is relevant both to judging the value of the RELRP and to considering possible modifications to the RELRP to improve its impact and/or value for money.