# final report

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**Breeding for reduced greenhouse gas intensity of Australian livestock production**

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# Abstract

This report outlines the nature of the business case and path to market for research into genetic improvement of ruminants as a tool for reducing enteric methane emissions, and is intended to inform the development of future strategic and tactical research investments in this area in Australia. Two approaches are recommended. The first is a short term approach which targets reductions in greenhouse gas emissions intensity using existing selection criteria, but with use of new selection indexes that incorporate new weights for methane reducing traits. The long run approach depends on research to develop new selection criteria for enteric methane emissions expressed per unit of feed eaten. Commercial drivers for these initiatives would benefit from integration of genetic strategies into a Carbon Farming Initiative program although consumer demand captured through vertical supply chains could also be important.

# Executive Summary

While there is confusion around the definition of methane traits for genetic improvement, this can be resolved by considering methane emissions intensity as a broad breeding target affected by a large number of traits including those selected historically, as opposed to the trait *methane yield* which is a new trait under development. *Methane yield* is defined as methane output adjusted for the associated level of feed intake.

Emissions intensity is already being improved by genetic selection although there are opportunities to accelerate this by encouraging faster rates of current genetic progress, and by giving more weight to those existing traits in economic selection indexes which can contribute most to reductions in emissions intensity.

The impact of changes (both historical and future) in individual traits on emissions intensity has not yet been adequately quantified for the Australian beef and sheep industries.

There are numbers of potential commercial drivers for improvement in emissions intensity that could be facilitated by the actions of MLA. Engagement with both domestic and international retail sectors on opportunities to include genetic merit for methane emissions intensity in supply contracts could be considered. There are also opportunities to prioritise traits with favourable emissions intensity when it comes to developing improved recording and genetic evaluation methods. The challenges in terms of mounting a case that selection for reduced emissions intensity should form the basis of a Carbon Farming Initiative project will be satisfying the additivity criterion, and the fact that gross farm emissions may not decline with an improvement in emissions intensity.

Development of selection criteria for methane output which do not allow for the fact that high methane output is associated with high feed intake and high productivity is pointless, as the opportunity costs of any sort of incentivisation scheme for this trait will be very high relative to alternative methane reduction policy options.

Further research is required to develop and refine selection criteria for *methane yield* which is methane yield adjusted for the associated level of feed intake.

Basic research into the understanding of the *methane yield* trait is warranted, as it will provide confidence and integrity when it comes to inclusion of the trait in any future Carbon Farming Initiative project.

Applied research into *methane yield* should be very high priority and needs to focus on developing portable recording devices that are capable of measuring both methane output and associated feed intake on a standard diet. Portable recording devices are critical to achieve widespread and cost-effective measurement of *methane yield* in industry selection candidates and their relatives. They will also be crucial for any field scale validation studies required to meet Carbon Farming Initiative project criteria.

Applied research on methane yield needs to be closely integrated with existing genetic improvement structures. In particular, the Beef and Sheep Information Nuclei are highly relevant to industry, and are well-structured for research into new traits.

Attempts should be made to evaluate methane yield traits directly on popular industry sires. While measurement in these mature animals appears unconventional, the target phenotype is expressed in mature animals (breeding cows and ewes), and there will be substantial savings in time taken to validate traits because these sires will have mature daughters in breeding flocks and herds.

Policy makers need to be aware of the medium- to long-term nature of the breeding for reduced *methane yield* option. In the meantime, it would be highly advisable to investigate in more detail

potential scope and operational aspects of a Carbon Farming Initiative project initially targeting *emissions intensity* but ultimately targeting reduced *methane yield*. If transaction costs for the scheme would be high, and research breakthroughs prove to be problematic in the next few years, a review of the overall strategy in relation to *methane yield* would be highly advisable.

**Summary of recommendations**

1. That MLA assesses the opportunity costs to producers of selection for reduced gross farm methane output using current Australian selection criteria (for beef cattle and sheep) and compares these with other abatement options including direct incentives to farms with low profit per unit of methane emissions to incentivise them to reduce the extent to which they farm ruminants.
2. That the Emissions Intensity GHG values are computed for traits in selection indexes used in the Australian beef and sheep industries; these can be used to quantify the historical impacts of selection and to monitor ongoing benefits in terms of Emissions Intensity.
3. That MLA works with the organizations responsible for providing the genetic improvement schemes to the Australian sheep and beef industries to investigate the opportunities to modify the selection indexes to improve Emissions Intensity.
4. That MLA actively communicates with both domestic and international retail sectors the potential opportunity to source product from suppliers of slaughter livestock that are derived from animals that have been genetically identified as having reduced methane emissions intensity.
5. That MLA undertakes research to identify which existing selection criteria are most powerful for the reduction of methane emissions intensity and that these traits be considered for preferential research and development into improving their recording and genetic evaluation.
6. That MLA recognizes that there is a strong case for further underpinning research to develop new practical selection criteria for measuring *methane yield*, and supports such research.
7. That MLA works to ensure that research into methods for field measurement of methane output is closely associated with complementary research into how feed intake can be recorded at the same time, so as to facilitate development of a genuine *methane yield* trait with highly portable measurement options.
8. That MLA develops some provisional operational costings of a model CFI project supporting genetic reductions in *methane intensity* and *methane yield* separately for beef cattle and sheep.
9. That a group of sires that have been or are being widely used in the industry is identified, and that these are screened for *methane yield* (on a common diet) and the progeny of the selected extreme sires are then recorded to estimate the realized heritability of the trait (and potentially to be used in a deep phenotyping study to seek potential correlated traits).

# Background

MLA and the Commonwealth Government of Australia have invested in underpinning research for genetic improvement of ruminants as a tool for reducing enteric methane emissions. This report outlines the nature of the business case and path to market for this research, and is intended to inform the development of future strategic and tactical research investments in this area in Australia.

Research to date has identified ambiguities and gaps in the definitions and protocols for defining traits for reductions in Methane emissions. In addition to inconsistencies across research groups in the definition of the Methane trait, there are also fundamental higher level questions as to whether Methane should be reduced on per animal, per hectare, or per unit of product basis.

Notwithstanding the issues around definition of traits, and the target endpoint, there are issues of whether genetic reductions in methane emissions are feasible. Both the challenge of motivating farmers to select animals with genetic merit for low methane production, and technical considerations as to whether targeted traits can be improved contribute to the questions around feasibility. It is therefore informative to consider some other challenging traits that have historically been introduced as potential selection criteria within ruminant livestock breeding programs, to better understand critical factors leading to their success and or failure.

This report starts out by addressing, in detail, a number of critical aspects that drive interpretation of the value of genetic traits influencing methane yield. This leads to a clear distinction between emissions intensity and gross farm emissions as metrics of methane output, both of which are identified as being rational metrics from various perspectives. Opportunities to accelerate genetic progress in both metrics are discussed from both technical and business case perspectives. This then leads on to some suggestions regarding novel research approaches and implications for policy makers. Recommendations to MLA are provided throughout the report, and a summary of recommendations is included.

# Approach

## Overview

The foundation of any genetic evaluation and improvement scheme is critically dependent on four key factors:

- a suitable phenotype,
- establishment of relevant genetic parameters,
- the definition of pedigree of individual selection candidates so that suitable performance records taken on relatives can improve the accuracy of selection,
- the capacity to select and use elite individuals.

For beef cattle and sheep in Australia, there are long established structures for genetic improvement, including breeding studs which sell genetically-improved sires to commercial farmers, as well as breed societies, research organisations, databases, and genetic evaluation systems which support the activities of the breeding studs.

In order for a new trait or breeding direction to be manifested within this existing structure, there must be confidence in the following factors:

1. that the new trait or breeding direction is scientifically sound and robust,
2. that it is possible for a breeding program to make meaningful genetic progress in the new trait or breeding direction,
3. that commercial producers/farmers will receive financial incentives for purchasing and mating bulls and rams that are superior for the new trait or breeding direction than they otherwise would have been,
4. that financial incentives received by commercial farmers will motivate a switch in their ram and bull buying behaviour such that they seek out different sires in such a way that breeders are then motivated to make meaningful genetic progress in the new trait or breeding direction.

Points 1 and 2 are issues that relate to the science of breeding for reduced methane emissions, while points 3 and 4 are issues that relate to the business case required for change to actually occur. While this suggests a clear separation, a fundamental outcome of this report is that the science and business aspect issues are intrinsically intertwined.

## Terminology

For clarification, we will refer to a number of different aspects of Methane output. These are defined explicitly in the Table below.

| | |
|---|---|
| **Farm level** | |
| Gross farm methane yield | The total emissions from a farm over a one year period. |
| Methane emissions intensity | Emissions from a farm over a one year period divided by a measure of farm product output over the same period. |
| **Trait level** | |
| Methane yield | The amount of methane output from an animal per unit of feed consumed around the time of the methane measurement |
| Methane output | The amount of methane output from an animal without any consideration of the amount of feed eaten. |

# Base Definitions

We believe it is very important to partition reductions in methane yield into four defined categories as follows:

a. improved productivity leading to emissions dilution – e.g. through improved production per unit of productivity (i.e. the breeding animal);
b. improved system efficiency - e.g. through fewer replacements required leading to lower emissions from the carrying of pre-reproductive females;
c. more feed-efficient animals – e.g. through higher efficiency of conversion of feed to product;
d. lower emission per unit of feed – through a more efficient rumen digestive system

Each of these needs to be considered in more detail. Changes in many traits have an indirect impact on methane emissions because they impact on either the total feed intake, or the feed efficiency, or on the efficiency of the whole farm system. For example, any trait change that results in fewer replacements being reared will lead to a reduction in emissions associated with replacements. Because of this, assumptions about how the numbers of animals and replacements on a farm change in response to genetic trait changes become very important. There are three simple and common alternative assumptions made about how farm scale responds to trait changes as follows:

a. Constant farm output
b. Constant amount of farm feed utilised
c. Constant number of breeding females

Further, the effects of a change in a genetic trait on methane emissions can be quantified in at least two ways:

a. Gross methane yield - the total amount of methane output of a farm, or
b. Methane emissions intensity - the amount of methane output of a farm expressed in proportion to some unit measure of farm output (such as feed production or product output).

Appendix 1 considers the detailed interactions between the four types of changes in traits, the three definitions of farm scale, and the two different emissions metrics. The impacts of the various trait changes are summarised in Table 1 below.

**Table 1**. Summary table of favourable (+) or unfavourable (-) impacts of alternative emissions influencing trait changes on two alternative methane emissions measures (blank cells denote neutral impacts; see Appendix 1 for rationale).

| | **Gross farm methane output** | | | | **Methane emissions intensity** | | |
|---|---|---|---|---|---|---|---|
| **Trait improved** | Fixed output | Fixed feed | Fixed breeding females | | Fixed output | Fixed feed | Fixed breeding females |
| **a. Productivity trait** | + | | - | | + | + | + |
| **b. System efficiency** | + | | + | | + | + | + |
| **c. Feed efficiency** | + | | + | | + | + | + |
| **d. Emissions per unit of feed** | + | + | + | | + | + | + |

Three key points are evident from this summary:

- The "***Emissions per unit of feed***" category of traits is the only one which improves (reduces) gross farm methane output under the assumption of a fixed feed resource;
- Selection for productivity traits increases gross farm methane emissions output per breeding female because more feed is required to realise the productivity gains;
- All of the trait types relating to methane emissions are favorable in terms of their impact on emissions intensity.

It is of relevance that intensification (a management equivalent to genetic improvement of productivity) is widely-recognised in the literature as leading to reductions in emissions intensity. Within a pastoral setting, the results of Alcock and Hegarty (2011)[1] suggest that a *fixed feed definition* of farm scale might be appropriate for farms at current optimum stocking rates, while a *fixed number of breeding females definition* is appropriate for farms currently at sub-optimal stocking rates, and which would move to more optimal stocking rates with genetically more productive animals with higher feed requirements. While micro-economic theory of the firm would suggest that these definitions are a little simplistic for valuing farm traits, in the long term, consideration of a fixed feed resource is probably most relevant when evaluating trait impacts on gross methane yield from extensive ruminant livestock farming systems. The argument is

[1] Alcock, D.J. and R.S. Hegarty (2011). "Potential effects of animal management and genetic improvement on enteric methane emissions, emissions intensity and productivity of sheep enterprises at Cowra, Australia." Animal Feed Science and Technology **166**: 749-760.

particularly strong when impacts are modeled at the level of an industry, or country, rather than at the level of individual farm business.

# Perspectives on Methane Emissions

The existence of two mainstream measures of methane emissions (**gross emissions** versus **emissions intensity**) is somewhat problematic, given that genetic changes in productivity traits (which typically dominate genetic gains in breeding programs for extensive ruminants), have unfavourable effects on the former, and favourable effects on the latter. Rationalisation of this conundrum can be helped by considering emissions from four different perspectives.

**Perspective 1.** The supermarket buyers' perspective - In this instance, a consumer may wish to purchase a product which has low methane emissions associated with it. It would seem rational to compare different lines of the same product in terms of emissions intensity. In other words, this would involve a comparison of the quantity of emissions associated with each particular product.

**Perspective 2.** The producer/farmer perspective - Under a perfect carbon market, the logical approach for the producer or farmer is to treat emissions as a cost as would be the case with any other cost trait (such as the replacement rate, or the costs of managing animal health). In such a context, the focus is on profitability – the production of GHG can be treated simply as a component of the cost side of the breeding objective and duly incorporated in the selection index. Hence a profitability-based approach for the producer will focus on the same outcome as that desired by the end-consumer above.

**Perspective 3.** The FAO perspective - In this instance, the growing protein demands of very large numbers of people increasing their purchasing power from a low base mean that food security and satisfying food demands are at least of comparable importance to reducing greenhouse gas emissions. Given that the only option to generate food from large areas of grazing lands unsuitable for other forms of food production is through grazing ruminants, the intensity measure of emissions is much more attractive than attempting to reduce gross emissions per farm or per area of land.

**Perspective 4.** The Kyoto perspective - When a broad view is taken of the risk of GHG emissions contributing to deleterious climate change, reductions in gross emissions are considered to be key to mitigation of this risk. This has become manifest as country-level targets for GHG emission reductions. Reductions in emissions intensity do not obviously contribute to the aspirations of individual countries to find least-cost options for reducing emissions. A reduction in gross farm emissions offers a much more straight-forward target, albeit one that would limit gains in productivity.

Thus we have three clearly rational perspectives that justify an emissions intensity measure of methane emissions (the supermarket perspective, the farm profitability perspective and the FAO perspective), and an alternative rational perspective that justifies gross farm methane output as a measure of methane emissions. The conundrum therefore leads to two rational, but quite distinct, business case propositions for breeding to reduce methane emissions.

The issues of perspective and bases for valuing methane emissions traits have also been addressed recently by van Arendonk (2011). From his study, a recommendation was made that emissions traits should be evaluated on the basis of emissions intensity, rather than on profit per animal. Interestingly, they also showed examples where trait weightings would be identical if based on maximising profit subject to a constraint on total level of emissions, such as when assuming a fixed number of animals on the farm. While we agree with the attractiveness of the emissions intensity focus, the arguments of van Arendonk (2011) overlook an alternative rational business case around reducing gross farm emissions.

# Business Case - Reducing Emissions

The above discussions summarise the conundrum presented by the Kyoto approach versus those that approach the issue from the perspective of the supermarket buyer or the producer or from the perspective of meeting world food demand (as per FAO). There are essentially three breeding options:

1. selection for a reduction in methane emissions per animal focusing on new methods of measuring methane output;
2. selection for a reduction in ***emissions intensity*** (methane per kg of product) using both historic and new selection criteria;
3. selection for a new trait defined as ***methane yield*** per kg of feed consumed on a standardised diet.

In this section we proceed to make the case for approaches 2 and 3 above. The ***Emissions Intensity*** approach is a short-run opportunity, while ***Methane Yield*** requires a long run approach with wider national benefits. However first we address the issue of the focus in breeding and selection.

## ***Defining the focus in breeding & selection***

A robust business case requires that it must make economic sense to the producer, as without this, it will be society who pays directly for the impacts that it requires from the producer (through subsidies or higher food prices). Hence a valuable approach, in order to ensure a clear focus, is to ask two questions. The first is:

> *What would I have to believe to justify incorporating an Emissions Factor in breeding and selection decisions?*

In essence, to answer this question involves definition of the return on investment required given the risk profile of the change in selection policy. To define the key factors necessitates a robust bio-economic model that incorporates both genetic and economic parameters that will then enable definition of the scale of change that is required to make a significant positive financial impact at the level of the individual producer.

The second question asks:

> *Where are the pressure points or most vulnerable points in this system?*

This question helps define those potential points of failure which would threaten the system, and hence highlights the key areas for research. In the present context, the system is probably most vulnerable around the establishment and characterisation of the phenotype and the genetics of that phenotype.

## ***Breeding for lower gross farm methane production***

Unfortunately, it is unlikely that genetic selection for reduced emissions intensity will help a country reduce its Kyoto obligations. It is also unlikely that selection for a lower *Net Feed Intake* (NFI) in a pasture situation will reduce gross emissions as producers will either utilize the 'saved' feed to improve productivity per animal (if this is indeed achievable) or alternatively increase stocking rates in order to utilise the feed. In fact by increasing stocking rate, it may actually have the perverse effect of increasing gross emissions and emissions intensity.

There is a further conundrum to consider, in that breeding for lower *gross farm methane output*, even via an expanded index, can actually discourage approaches that will improve productivity. Hence if the focus is on gross methane output, then there is the likelihood that significant financial incentives will be required because of the inherent antagonism with farm profitability. In fact, a strong case can be made that it would be much cheaper to pay producers who operate farms with high emissions per unit of productivity to cease farming or to reduce production. Therefore we believe that it is unwise to advocate selection for reduced gross emissions per animal over and above selection for reduced emissions per unit of feed.

Due to the correlation between overall productive efficiency and food intake[2], direct approaches to reduce food intake would result in lower productivity per animal, lower farm profit and increased emissions intensity. Such a strategy would have a high opportunity cost to producers, particularly those with high profitability per unit of emissions, and there would be much more cost-effective alternatives to reduce GHG emissions from sheep and beef cattle than the subsidies (or enforced profit reductions) that would be required to construct a tangible business case around breeding for less productive animals with lower methane emissions per farm.

Selection index work for Merino sheep in Australia has already illustrated the problem of including penalties for gross farm system emissions in selection indexes (Cottle et al. 2009[3]). Because of the almost certain antagonism between gross farm system emissions and productivity, a huge carbon price operating with a perfect carbon market (i.e. perfect measurement and payment system for carbon) would be required to justify inclusion in selection. Finding least-cost options for reducing agricultural greenhouse gas emissions is an important focus of policy makers, and this is often addressed using Marginal Abatement Curves as discussed by Moran *et al* (2011)[4].

Hence the response to the question, *what would I have to believe (in respect of incorporating an emissions factor),* is that given a focus on *gross farm methane output,* major distortions will result. This would likely require significant financial inputs (subsidies) to ensure that the overall outcome was achieved.

**Recommendation** – that MLA assesses the opportunity costs to producers of selection for reduced gross farm methane output using current Australian selection criteria (for beef cattle and sheep) and compares these with other abatement options including direct incentives to farms with low profit per unit of methane emissions to incentivise them to reduce the extent to which they farm ruminants.

## ***Why a focus on Emissions Intensity?***

Given the above discussion, and the potential costs of implementing an approach targeting gross methane output per animal, it is our view that the immediate practical solution is to target a self-incentivising approach that will actually encourage producers to adopt procedures that will actually reduce GHG emissions while not compromising their businesses. Therefore we

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[2] A consequence of genetic improvement in productivity per head has been an increase in feed intake such that the maintenance cost of the animal is spread over a higher output of product.

[3] Cottle, D, van der Wef, J and Banks, R. (2009). IS METHANE PRODUCTION LIKELY TO BE A FUTURE MERINO SELECTION CRITERION? Proc. Assoc. Advmt. Anim. Breed. Genet. 18:516-519.

[4] Moran, D. and Wall, E. (2011). Livestock production and greenhouse gas emissions: Defining the problem and specifying solutions. Animal Frontiers. July 2011, Vol. 1, No. 1. pp 19-25.

advocate a short-term approach to breeding for reduced methane based on emissions intensity. Essentially this will result in a reduction in emissions per unit of product produced.

## ***The potential impact of breeding for a reduction in Emissions Intensity***

Reducing emissions in ruminant livestock farming is set to become a further cost on livestock producers. However ignoring the issue may incur a greater cost in situations where reductions in emissions are recognized in official GHG accounting systems and actually reduce the direct cost to those producers who utilize the new breeding knowledge. In considering the issue, we will take the view that is likely that the benefits will accrue to those producers who do utilize superior genetics.

Hence a key issue is to seek to develop and apply a breeding system that will minimize this additional cost, and at the same time maintain the focus on improving profitability through genetic progress. There are some opportunities to achieve better gains in emissions intensity by changing current breeding goals, and these opportunities come at minimal cost to changes in rate of improvement in farm profitability. Such gains can come about through shifting selection emphasis modestly from traits which improve farm profitability without significant gains in reduced emissions intensity, towards traits which still improve farm profitability, but also reduce emissions intensity.

An example comes from the work by Ludemann *et al* (2012)[5] who assessed the impact of including Emissions Intensity (EI, including both methane and nitrous oxide) in the selection protocol for dual-purpose sheep in New Zealand. The current dual-purpose selection index (DPO) was compared with novel indexes (DPE) incorporating EI. They showed that index-based selection methods that incorporated productivity traits were far more effective in improving profitability while reducing emissions intensity (expressed per kg of product sold – lamb carcase weight) than approaches which sought the maximum reduction in emissions. In this respect, their models showed that the annual decline in emissions intensity (EI) improved by 13% compared with the current DPO with virtually no change in the farm profitability response at a C price of $25 per tonne (DPE25) and improved by 40% with a 3% reduction in profitability at a C price of $100 per tonne (DPE100). This is in marked contrast to the situation where the emphasis was on EI alone where the annual reduction in emissions intensity was two-fold that of the DPO index but the profit response was halved. The data are summarised in Table 2 below.

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[5] Ludemann, C., Byrne, T, Sise, J. Amer, P and McEwan, J. (2012). Selection indexes offer potential to reduce greenhouse gas emissions per unit of product for New Zealand sheep farmers. International Journal of Agricultural Management (IJAM). Under review.

**Table 2.** The effect of different selection indexes on GHG intensity in sheep production systems in New Zealand (extract from the paper of Ludemann *et al*, 2012)

| | DPO | DPE25 with C price of $25/t | DPE100 with C price of $100/t | EI alone |
|---|---|---|---|---|
| **Farm profit response ($NZ per lamb)** | $0.818 | $0.816 | $0.793 | $0.404 |
| **Reduction in GHG intensity reduction as a percentage of total lamb GHG emissions** | -0.59% | -0.67% | -0.83% | -1.19% |

The above analysis provides evidence that the opportunity costs to farmers of genetic changes in emissions intensity are minimal where the current breeding objective is targeting profitability, and it can be expected that this is very highly correlated with emissions intensity.  It is also very important that the gains in emissions intensity that come about through breeding are accurately quantified.

A further important and highly relevant development in the work of Ludemann et al. (2012) relates to the technical challenge of combining farm profit index weights on a per animal scale with farm profit index weights on the emissions intensity or unit of product scale. This issue was resolved using algebraic derivation. Appendix 2 presents an Appendix from Ludemann et al. (2012), which shows how standard emissions ratios for a farm can be used to quantify how changes in biological traits such as number of offspring per female, farm output per offspring, as well as emissions per offspring and breeding ewe will impact on farm emissions intensity. Thus, the assessment of the gains in emissions intensity or the assessment of new opportunities is a relatively straight-forward task, with some modifications to existing industry models and software.

Hence the response to the question, *what would I have to believe (in respect of incorporating an emissions factor),* is that the selection indexes can be tweaked to improve emissions intensity with only very minor impacts on profitability. Therefore it seems that the introduction of a minor change in the selection focus could deliver useful benefits.

**Recommendation** – that the Emissions Intensity GHG values are computed for traits in selection indexes used in the Australian beef and sheep industries; these can be used to quantify the historical impacts of selection and to monitor ongoing benefits in terms of Emissions Intensity.

## ***Making genetic progress***

As highlighted above, the second central question is:

*Where are the pressure points or most vulnerable points in this system?*

This is best considered in the context of a genetic evaluation scheme where there are two core issues in establishing such a scheme: firstly the availability of an appropriate **phenotype** on which to base genetic analysis, and secondly, knowledge of the genetics of the trait derived from the phenotypes and the population genetic relationships. In the particular case of Emissions Intensity, there is a belief that the heritability of the trait will be relatively low[6].

In order to progress, the phenotype must include both Methane Emissions and Food Intake (and ultimately Nitrogen Use Efficiency of the individual animal). Both traits are difficult to measure in grazing settings. While a number of methods are being used of have been proposed, they all suffer from the same problems. Progress in phenotyping of individual animals is being made and genetic analyses are being performed[7] but this is slow due to the range of problems including:

- scale - in terms of the number of animals required to generate sufficient phenotypes – this is exacerbated when the medium- to longer-term target must be the application of genomic selection approaches to the selection of animals;
- complexity - of the phenotype in terms of the actual measurements required and the practicalities of measurement; for example, as noted in the recent International Workshop Report[8] live weight/ carcase weight is being used as a proxy for feed intake);
- timescale - of measurement required (hours to days to repeated measures over time);
- appropriateness of the phenotype - in that the actual phenotype of interest is that of the adult breeding female rather than the growing animal.

Given the issues outlined above, it is apparent that the development of indicator traits is critical.

## ***Could we make faster progress in breeding for reduced Emissions Intensity?***

Given the situations outline above, we need to ask how could we make faster progress in delivering reduced GHG emissions. While the work of Ludemann *et al* (2012) shows that the impact of a focus on animal efficiency and profitability will result in a reduction in emissions intensity (in terms of product output) and that this can be tweaked to increase the rate of progress, the issue is to look at ways to enhance this further. Methane output is a consequence

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[6] A very high-level analysis of the Herd Report to MLA (Herd R 2011, Report on MLA Project B.CCH.1006)

[7] Herd R 2011. Report on MLA Project B.CCH.1006

[8] Shackell GH & JC McEwan 2011. International Workshop: Enteric $CH_4$ mitigation using animal selection, genetics and genomics. New Zealand Government

of microbial breakdown of feed and therefore the opportunity lies in defining the extent of the phenotypic variation in methane production and then dissecting that variance to identify areas which can be targeted.

For example, the current approaches assume that live weight and live weight gain or carcase weight gain (or milk production or wool growth) are essentially proxies for food intake (feed requirements for maintenance and product). They take no account of individual variation in the actual output of methane per unit of food intake. There is evidence of phenotypic and genetic variation in this trait, and hence this provides an opportunity to target a reduction in emissions per unit of food intake. The approach targets the most efficient animals in terms of both productivity and the efficiency of feed utilization reflected in emissions that are the consequence of the digestion of the feed that is consumed.

**Recommendation** – that MLA works with the organizations responsible for providing the genetic improvement schemes to the Australian sheep and beef industries to investigate the opportunities to modify the selection indexes to improve Emissions Intensity.

## ***What are the likely commercial drivers of genetic improvement in emissions intensity?***

Because improvements in emissions intensity are reasonably synergistic with improvements in farm profitability, there are numbers of potential commercial drivers for improved emissions intensity. These are as follows.

1. Existing profitability drivers - farmers and breeding programs are already striving to improve the rate at which they improve profitability.
2. Supermarket supply arrangements - whereby farmers are required to be using Bulls and Rams that meet a minimum requirement for their overall genetic merit of emissions intensity as evaluated using historic selection criteria. Because genetic evaluation systems are run independently with substantial genetic links among breeding flocks and herds, it should be relatively easy to audit the quality of a breeder's recording system and the genetic merit of rams and bulls sold to commercial farmers could be tracked through an administrative process not dissimilar to existing premium supply relationships that already exist for groups of farmers.
3. Targeted support of trait research and recording - whereby traits with a highly favourable impact on emissions intensity are identified and prioritised such that they are recorded and so that genetic evaluations for these traits become more accurate. Increasing the relative accuracy of breeding values for targeted traits results in higher rates of genetic progress in these traits at the expense of other traits. An illustration of this option has

been given in the context of modifying genomic selection strategies to improve the robustness of cattle by Amer (2011)[9].

4. A direct subsidy from government such as an auditable system that could be addressed via the Australian Carbon Farming Initiative (CFI). The challenges in terms of mounting a case that selection for reduced emissions intensity should form the basis of a Carbon Farming Initiative project will be satisfying the additivity criterion, and the fact that gross farm emissions may not decline with an improvement in emissions intensity.

**Recommendation -** That MLA actively communicates with both domestic and international retail sectors the potential opportunity to source product from suppliers of slaughter livestock that are derived from animals that have been genetically identified as having reduced methane emissions intensity.

**Recommendation -** That MLA undertakes research to identify which existing selection criteria are most powerful for the reduction of methane emissions intensity and that these traits be considered for preferential research and development into improving their recording and genetic evaluation.

# Methane Yield

## Methane yield as a defined phenotypic trait

Reduced emissions per unit of feed intake can be advocated as a medium- to long-term breeding target. From both the global and individual country perspectives, the prize from this is very large, because there is an opportunity to reduce agricultural emissions from current levels. The impact of reducing emissions per unit of feed is shown in Appendix 1 (summarised in Table 1 above) to result in reduced gross farm emissions, and reduced emissions intensity, irrespective of what assumptions are made about changes in farm scale factors in response to any change in a genetic trait.

For clarification, we define an animal that performs favorably for the trait *methane yield* as one which emits less methane per kg of feed eaten than its contemporaries due to genetic differences in rumen function processes and digestion. This is different from an emissions intensity focus based on methane per kg of feed at a systems level.

While there are statistical issues with defining a ratio trait that require care, these are not insurmountable. Many traits with analogous definitions are successfully included in livestock

[9] Amer, P. (2012). Turning science on robust cattle into improved selection decisions. Animal 6:4, pp 551–556

breeding programs (e.g. feed conversion ratio in pigs and poultry, carcase yield traits such as saleable meat per kg of carcase). We believe there are substantial benefits from defining a selection criterion for methane after some form of adjustment for feed intake around the time of methane measurement. The alternative of selecting against gross methane output will inevitably be dominated by the strong association between methane output and productivity, and thus, any selection effort applied directly to methane output will come at very high opportunity cost of lost productivity.

The opportunity costs to farmers of genetic changes in *methane yield* are likely to be greater than the low opportunity cost of selecting for emissions intensity using historic selection criteria. They come because breeders must switch selection pressure away from traits which are currently increasing profitability (or saleability where there is low uptake of scientific genetic improvement tools), in order to make improvements in reducing *methane yield*. In the absence of accurate on-farm measurement and a perfect carbon market, farmers receive no profitability benefits from reduced *methane yield*. The more emphasis placed on *methane yield* (i.e. striving for a quick solution), the greater will be the opportunity cost (i.e. there will need to be a greater trade-off in profitability per unit gain in *methane yield* if a large proportion or all of selection pressure is put on emissions per unit of feed). This is an inherent characteristic of multi-trait selection indexes and which is exacerbated when there are unfavourable genetic correlations at play. However, moderate gains can usually be made in new traits, without too much trade-off in progress in old traits. This is especially so if there turns out to be a favourable association between *methane yield* and farm profitability (for example, animals with low *methane yield* may be utilising the feed better, and therefore also be more productive per unit of feed - perhaps for animals fed a high quality diet). However the outcome is not as good if there turns out to be an unfavourable association between *methane yield* and farm profitability (e.g. animals on a low quality diet have low *methane yield*, but also have lower voluntary feed intakes (VFI), and therefore they compromise their inherent productivity because their VFI is relatively low).

**Recommendation** – that MLA recognizes that there is a strong case for further underpinning research to develop new practical selection criteria for measuring *methane yield*, and supports such research.

## Methane phenotypes

There is currently a lot of work under way targeting the measurement of methane. We broadly categorise these as follows:

- chamber systems where methane output and amount of feed consumed of a highly standardised diet are measured with high accuracy,

- field systems that measure methane output, but which do not measure feed intake.

Chamber systems have very high fixed costs, and the focus is on highly accurate recording protocols of short duration. In terms of genetics, their likely role will be in terms of validation of field systems, and perhaps also in terms of deep phenotyping (discussed further below). In contrast, a number of new field systems for measuring methane are undergoing field trials. While these have the potential to record much larger numbers of animals for repeat records without expensive animal transport costs and health risks, they typically suffer from the absence of associated feed intake measurements. In fact, the measurement of feed intake on pasture remains a key limitation to the definition of methane yield in grazing ruminants.

Ongoing evaluation of these measurement systems is required in terms of:

a. how relevant are the measures taken in the context of the rational business case models discussed here,
b. how practical and cost-effective will it be to incorporate the measures on the scale necessary to bring about meaningful change in industry breeding programs,
c. how heritable are the traits, and will we be able to predict the merit of selection candidates with meaningful accuracy, and
d. is there sufficient genetic variation in the traits to facilitate measureable changes within a 5 to 10 year time frame.

For chambers, some positive results are starting to emerge in relation to heritability and trait variation, but there are serious concerns in relation to practicality. It seems inevitable that field measurement systems will be required in addition to chamber measurements of methane.

For field measurements, there is still very limited evidence about heritability and extent of genetic variation. While some show potential for wide scale *in situ* measurement, there are substantial numbers of questions as to whether methane output measurements on their own in the absence of associated feed intake records will be sufficient to provide a selection criteria that is not highly antagonistic to genetic merit for productivity. This concern has been highlighted by the earlier discussion in this report in relation to the business case.

Assuming that good progress has been made in developing field measurements for methane output, the required major breakthrough in terms of field measurements is to be able to measure feed intake at the time of methane measurement. Because of the inherent variability of pasture, even field measurements may require feeding of controlled diets, with feed weighing systems and methane sniffers. There will be huge advantages from highly portable systems. Bull and ram breeders will be able to circumvent the costs as well as physical and disease risks associated with sending valuable breeding livestock to a central facility. Such costs and risks are highly likely to have been a major factor in the decline in industry interest in residual feed intake recording.

**Recommendation** – That MLA works to ensure that research into methods for field measurement of methane output is closely associated with complementary research into how feed intake can be recorded at the same time, so as to facilitate development of a genuine *methane yield* trait with highly portable measurement options.

## The business case for methane yield

Selection of animals for reduced *methane yield* will constitute a significant opportunity cost for both farmers and breeders. In contrast, national benefits could be substantial if meaningful genetic improvements in *methane yield* in the breeding sector were disseminated widely across the industry. There is a somewhat stronger case for advancing genetic progress in *methane yield* into a specific Carbon Farming Initiative approach than there is for improvement of emissions intensity using historic genetic selection criteria.

Further detailed investigation would be required as to how breeding for reduced *methane yield* could be developed into a CFI project. However, we see key characteristics of the project as follows:

- convincing science replicated both nationally and internationally supporting the technical creditability of *methane yield* as a robust selection criteria;
- convincing support for the hypothesis (using both research and commercial farm animal resources) that animals with favourable genetic merit for *methane yield* would lead to farms with lower farm level methane emissions;
- development of an audit system, to check participating bull and ram breeders for their integrity in terms of general quality of pedigree and data recording for the *methane yield* trait;
- development of an additional audit system to ensure that bulls and rams purchased by commercial farmers correspond to selected individuals with breeding values for *methane yield* that meet all necessary criteria;
- development of a system of reimbursing commercial farmers who have purchased favourable *methane yield* bulls or rams with associated and quantified direct and opportunity costs; direct costs would be attributable to higher market premiums being required to purchase qualifying bulls, while opportunity costs would relate to the

anticipated lower genetic merit of these bulls for other farm profitability traits from which selection pressure would have been diverted onto selection for methane yield.

Recommendation - That MLA develops some provisional operational costings of a model CFI project supporting genetic reductions in *methane intensity* and *methane yield* separately for beef cattle and sheep.

# Novel Research Approaches Targeting Methane Yield

## Specific objectives

### ***The value proposition for producers***

Discussion around the value proposition necessitates a consideration of the first basic question:

> *What would I have to believe to justify incorporating an Emissions Factor in breeding and selection decisions?*

The issues to be addressed in addressing this question include the factors that will influence the value proposition to producers which include:

- the potential for genetic gain,
- the trade-offs with other facets that contribute to profitability,
- the return on investment required given the risk profile of the change in selection policy (recognising the need to select the sires that will produce the replacement breeding stock which are fundamental to the producer's farm operation).

It is then important to address the second basic question:

> *Where are the pressure points or most vulnerable points in this system?*

This helps define those potential points of failure which would threaten the system, and hence highlights the key areas for research.

All genetic evaluation and improvement schemes are critically dependent on four key factors:

- a **suitable phenotype** that can be scored relatively accurately on a moderate number of individual selection candidates (a few hundred might be sufficient in breeding schemes with highly structured genetic multiplication tiers) or alternatively a phenotype (less accurate) that can be scored easily and quickly on relatively large numbers of animals (thousands) including the relatives of selection candidates;

- the establishment of a set of relevant **genetic parameters** that will provide the basic information to assess the opportunity to make genetic progress – this requires a reasonable degree of genetic variation in the trait which is defined in terms of the genetic standard deviation;
- the capacity to **select and utilise elite individuals** for the trait, without excessively compromising genetic progress in other economically-important traits, and a breeding program that enables a rapid turnover of generations to minimise the generation interval;
- a simple means of **defining the pedigree of the individuals** in both the study population and in the population which will select, breed and utilise the superior animals.

From phenotype to genetic parameters: dissecting the phenotypic variance

In considering *methane yield*, the phenotype is potentially problematic. It requires the accurate measurement of feed intake and the measurement of $CH_4$ production. Thereafter progress demands a system to collect the relevant data. The time pressure on making progress precludes the more traditional data collection phase (often coupled with selection lines) in favour of the rapid generation of a reasonably robust set of genetic data. In this context, Appendix 3 (see Appendix Table 3) and the background explanation provides a way of thinking about the sources of variation that make up the observed phenotypic variation in a trait such as *emissions intensity*. The phenotypic variance ($\sigma^2_p$) can be considered as being made up of a number of components, some of which may be amenable to definition or estimation, as:

$$\sigma^2_p = \sigma^2_G + \sigma^2_d + \sigma^2_S + \sigma^2_R + \sigma^2_M + \sigma^2_E$$

where $\sigma^2_G$ is the additive genetic variance (including both additive ($\sigma^2_A$) and non-additive genetic variance), and the variance associated with other 'definable' effects includes: that due to diet or nutrition - $\sigma^2_d$, that due to physiological state - $\sigma^2_S$, that due to the direct effect of the ruminal microbiota - $\sigma^2_R$, the permanent maternal effect - $\sigma^2_M$; $\sigma^2_E$ is the residual variance. There is also likely to be a considerable range of interactions of varying importance, most of which are likely to be very difficult to resolve. The major purpose would be to dissect the variance in order to assess the relative scale of the variance associated with each major source.

Can selection lines offer novel insights?

The value of selection lines for research around a single trait can be contentious. They can offer novel insights but the cost-benefit is not always clear.

On the one hand, they offer researchers the opportunity to assess and define a phenotype, and to identify potential adverse consequences of selection. On the other hand, the relevance or practical applicability of any results may be questionable in reality given that an intensive selection approach will probably select individuals which are atypical of the wider population, especially where extreme phenotypes are selected and the lines are not replicated. In addition the time and cost to establish selection lines means that attention is diverted away from the basic target of the work – its practical application.

Deep phenotyping

Deep phenotyping refers to the analysis of a manageable number of individuals to define their phenotypes in greater depth than is usually achievable. The value lies in the leads it provides for identifying traits that are potential candidates for correlated traits. They are often a practical alternative to selection lines in that extreme individuals can be used. A practical approach is work with the progeny of the extreme sires bred as part of a realised heritability project (which is outlined below).

## Alternatives

While the approaches outlined above all have their appeal, by necessity, each would be a slow and somewhat expensive process. However we note that the collection of data is already underway with progeny testing and selection lines being used in Australia and/or New Zealand.

In considering the needs for urgency and the need for a commercially-relevant route to market, we propose a potential lower-cost alternative that will enable rapid characterisation of the capacity to make genetic progress, and at the same time provide a route to market for sires that will accelerate progress in the trait.

### ***Estimating the realized heritability of Emissions Intensity***

The proposed approach involves estimation of the realised heritability of the trait outlined below.

Alternative 1 – young potential sires:

- Screen a population of males (say 100 potential sires) all fed the same diet in a controlled feeding situation for *emissions intensity* ($CH_4$/unit of feed intake)
- Select the 5 highest and 5 lowest for *emissions intensity*
- Progeny test (PT) these 10 males recording both male & female progeny for the trait at a range of different ages and estimate the realised heritability of the trait.

It is essential that the estimate of heritability is derived as the paternal half-sib estimate, given the potential for permanent maternal effects associated with the population of microbiota derived from maternal transfer (hence there is the risk that any effects resulting from the maternal transmission of gut microflora will appear as maternal heritability).

This option is not dissimilar to the early phase of establishment of selection lines. However, numbers or animals are modest, they are unlikely to be of immediate industry relevance, and there are considerable time delays in waiting for daughters to be evaluated once they have become breeding females.

Alternative 2 – established sires:

- Screen a population of elite males which already have progeny that are available now
- Record the progeny of the most extreme sires for the trait (this would include both the young male and female progeny and the their mature daughters - breeding ewes or cows)
- Estimate the realised heritability of the trait.

While it is acknowledged that the screening of adult males (especially bulls) will be a non-trivial exercise, it will take advantage of the fact that daughters will already be available. Hence it will reduce the time taken to realise an impact and also recognises the reality that the vast majority of emissions come from breeding females.

While it is unconventional to record phenotypes on mature bulls and rams, it is important to remember that the ultimate goal of selection on a *methane yield* trait is to reduce emissions from breeding cows and ewes which are responsible for a substantial majority of ruminant emissions, and are themselves mature animals. Having a standardised protocol (i.e. standardised diet fed for a sufficient adaptation period) and expressing methane output relative to feed intake may be sufficient to at least partly offset the fact that the mature bulls and rams would not be evaluated within the same contemporary group.

## ***A commercial model***

There is the potential to integrate genetic evaluation into the actual industry use of sires through a retrospective progeny test assessment of sires that have already been used (Alternative 2 above) . This approach has the advantage that it is directly and commercially relevant as the progeny of these sires are already available. There are advantages in screening the available sires and then screening the progeny of extremes to provide an estimate of the realized heritability (as in Appendix Table 2.1), especially given that it is feasible to assess the progeny across different ages and physiological states. In addition, the mature phenotype of the sires is likely to be highly relevant (so long as the genetic correlation between males and females is high) as much of the GHG intensity of a ruminant production system is actually due to emissions from adults used for breeding.

This approach is potentially amenable to integration with current beef (BIN) and sheep (SIN) information nucleus structures. Phenotypes could be recorded on the sires contributing to the BINs and SINs and validation measurements could be taken at the information nucleus sites. Until a portable system is developed for measuring *methane yield* it would be necessary for sires to be phenotyped at a central facility. This will only be practical for a subset of sires, as many owners will be reluctant to subject their elite breeding animals to risks of physical accidents and exposure to disease.

**Recommendation -** that a group of sires that have been or are being widely-used in industry is identified, and that these are screened for *methane yield* (on a common diet) and the progeny of the selected extreme sires are then recorded to estimate the realized heritability of the trait (and potentially to be used in a deep phenotyping study to seek potential correlated traits).

# Implications for Policy Development

We have identified two clearly different business case models for reduced methane. The first involves a better understanding and some modification to historic selection criteria that are already widely used in bull and ram breeding sectors. This model is best driven by market forces, although there is a valuable role for MLA to play in communicating and facilitating this option.

Simple selection criteria based on gross methane output are unlikely to contribute to a viable methane reduction business case because of inherent and unfavourable associations between gross methane yield and productivity.

Policy development should focus on developing and incentivising systems for reducing *methane yield* defined as methane output per unit of feed intake. While the potential scope of benefits from this approach is high, much research is still required, and it needs to be accepted that the opportunity is unlikely to be realised for some years. Research on basic trait understanding, development of portable field recording devices capable of measuring both methane output and associated feed intake of a standardised diet, field scale population studies including records taken on both selection candidates and breeding females are all required. However, it would be highly advisable to also investigate in more detail potential scope and operational aspects of a Carbon Farming Initiative project targeting reduced *methane yield*. If transaction costs for the scheme would be high, and research breakthroughs prove to be problematic in the next few years, a review of the overall strategy would be highly advisable.

# Lessons from Other Traits

Here we consider progress in three traits with complex and/or expensive measurement requirements and potentially vague business cases that have had various impacts on sheep and beef cattle breeding industries in Australasia. These include residual feed intake (RFI, sometimes referred to as Net Feed Intake, NFI) in the Australian beef industry, meat yield in the NZ sheep industry, marbling in the Australian beef industry and Worm Egg Count (WEC) traits in both the NZ and Australian sheep industries. Some commentary on developments in these traits is now provided, with reference to the relevance of observations to the potential development and use of a methane yield trait.

## Residual Feed Intake (RFI)

An overview of residual feed intake has recently been provided by Arthur et al. (2010)[10]. Of note is the extensive amount of business case and cost benefit studies on the value of this trait to the industry. These studies suggest RFI is a highly valuable trait. However, adoption has been poor, and is currently declining. This pattern of adoption is not unique to Australia. Significant factors contributing to low rates of adoption of RFI may be as follows:

- costs of recording are high;
- inconvenience of recording is high - animals have to be transported to recording facilities
- risk associated with recording is high, there is a risk of elite breeding animals being injured or exposed to infectious diseases;
- commercial bull buyers do not understand the complex trait definition;
- commercial bull buyers do not comprehend in profitability terms, the implications of more feed-efficient cattle, because most feed consumed is in the form of pasture which is only limiting in certain seasons and years;
- market failure means that feed efficiency savings at the feedlot level are not passed back to commercial bull buyers, let alone the commercial bull sellers who have to invest in residual feed intake recording.

The implications for the business case for a methane yield trait are as follows:

- reliance on a central recording facility adds substantial cost and inconvenience that is highly detrimental to uptake;

[10] Arthur, P, Herd, R and Basarab, J. (2010). The role of cattle genetically efficient in feed utilisation in an Australian carbon trading environment. AFBM Journal vol 7 no 2. pp 5 - 14.

- a CFI initiative should focus on changing behaviour at the bull/ram buyer, bull/ram seller interface in order to directly incentivise bull/ram sellers to make the necessary investments in recording; this could circumvent problems with commercial farmers not understanding the trait, drastically reduce transaction costs (compared with trying to monitor changes in emissions on commercial farms), and avoid issues of market failure through the supply chain;
- factors beyond a pure quantitative genetics assessment need to be considered when considering the business case.

## Meat yield in NZ sheep

Meat yield is a moderately- to highly-heritable trait, but there is not a great deal of within breed genetic variability. Simple selection criteria (ultrasonic scanning for muscle and fat depth) have been available for many years, although most selection focus has been on reducing fatness so as to avoid penalties for overfat carcasses as industry average carcase weights have increased over time. More advanced selection criteria involving computed tomography (CT) scanning and progeny testing to estimate yields of high value cuts have also been available, but until recently, adoption of these measurement options in NZ has been limited. Yield-based grading systems were mooted in the NZ sheep industry for many years, but their recent introduction by a subset of NZ sheep meat processors has led to an explosion of performance recording for meat yield traits.

The implications for the business case for a methane yield trait is that when commercial farmers see concrete commercial rewards for genetic improvement traits, this can rapidly translate into changes in buying behaviour which rapidly motivates increased investment in relevant recording by a broad cross section of breeders.

## Worm egg count (WEC) in sheep

This trait is a complex trait in that economic benefits of reduced WEC manifest themselves as production benefits across the whole flock due to reduced pasture contamination, rather than due to direct production or cost saving benefits to the low WEC animal itself. A key foundation driver of the business case is that the efficacy of anthelmintic treatment will decline over time to catastrophic levels in the absence of alternative parasite management and control options. The trait is quite inconvenient to measure because it involves deliberate exposure of selection candidates to moderate levels of parasitic challenge which would otherwise be controlled through anthelmintic treatment. Despite substantial investment in selection lines, fundamental trait research, and demonstration trials, adoption and penetration of this recording technology has remained relatively modest. In NZ, there have been mixed messages from scientists, with one group advocating breeding for parasite resilience, which is the ability of the sheep to withstand parasitic challenge and maintain good health and productivity, while others advocate selection for resistance. In New Zealand resilience is a substantially different trait to WEC.

The implications for the business case for a methane yield trait are as follows:

- there needs to be a clear demonstration to farmers of the commercial value of trait improvements to them;
- there needs to be clear and consistent messages from science as to what the appropriate trait is;
- for wide penetration of a new trait recording option, the commercial case must be concrete and near term; and
- only a subset of breeders are prepared to take a punt on an uncertain future outcome.

# Time Lines and Risks

Table 3 below identifies major tasks, and assigns them a priority and a timeframe for impact.

**Table 3**. Prioritisation and timelines

| Major task | Priority | Timeline to Impact | Comments |
|---|---|---|---|
| Quantify impact of existing traits on emissions intensity | High | 1-3 years | This generates short-term outcomes and creates a pipeline model for long-term impacts |
| Basic research into understanding the methane yield trait | Moderate | 7+ years | This could lead to improved lower cost phenotypes in the future and would assist acceptance of improved genetics of methane yield in a CFI project |
| Development of portable measurement devices for methane yield including feed intake | High | 3-7 years | This is required to facilitate active genetic selection in breeding industries |
| Validation of portable measurement devices using chamber experiments | High | 3-7 years | This will be required to facilitate acceptance of improved genetics of methane yield in a CFI project |
| Validation of portable measurement devices using realised heritability studies | High | 3-7 years | This will be required to facilitate acceptance of improved genetics of methane yield in a CFI project |
| Deployment of portable measurement systems for methane yield including feed intake into industry breeding structures such as in elite breeding flocks and herds, and within BIN and SIN structures | Moderate | 3-7 years | Contingent on efficacy of portable measurement devices following validation |
| Provisional operational costings of a model CFI project supporting genetic reductions in *methane intensity* and *methane yield* separately for beef cattle and sheep | High | 3-7 years | This will help guide measurement technology and policy development to maximise the chance of a successful CFI project linked to genetic selection for methane yield. |

# Appendix 1. Interactions between types of trait change, farm scale definitions, and emissions metrics

## Background

In this appendix we consider the interactions between four different types of trait change:

1. Improved productivity leading to emissions dilution – e.g. through improved production per unit of productivity (i.e. the breeding animal);
2. Improved system efficiency - e.g. through fewer replacements required leading to lower emissions from the carrying of pre-reproductive females;
3. More feed-efficient animals – e.g. through higher efficiency of conversion of feed to product;
4. Lower emission per unit of feed – through a more efficient rumen digestive system ;

together with three different constraints on farm scale factors when quantifying trait changes:

a. constant farm output;
b. constant amount of farm feed utilized;
c. constant number of breeding females; and

the effects a change in a genetic trait on methane emissions which can be quantified in at least two ways:

a. gross methane yield - the total amount of methane output of a farm; or
b. methane emissions intensity - the amount of methane output of a farm expressed in proportion to some unit measure of farm output (such as feed production or product output).

## Improved productivity leading to emissions dilution

Output traits such as breeding female reproductive rate and offspring growth rate typically dominate selection indexes for beef cattle and sheep. Their calculated effects on emissions are highly dependent on assumptions about farm size changes in response to trait changes.

### 1a. Constant farm output

If farm output is assumed to be constrained, then productivity trait improvements lead to a requirement for fewer productive units and hence lead to cost savings. Thus, productivity gains would lead to a reduced requirement for feed for maintenance of breeding females and their replacements, and consequently, reduced gross methane emissions and reduced emissions intensity. This is analogous to the way in which productivity gains improve methane emissions intensity, by diluting cow maintenance and replacement methane emissions with more product output.

### 1b. Constant feed available

Under constant feed availability or utilisation, gross farm emissions are effectively fixed by the fixed amount of feed, and so increases in productivity can only improve emissions intensity via the dilution of static emissions with more output.

### 1c. Constant number of breeding females

With a constant number of breeding females, then following a productivity trait change, feed requirements of the farm system will inevitably be higher because extra production inevitably requires more feed to sustain it. Thus, when a constant number of animals is assumed, productivity gains increase gross farm emissions. However emissions intensity improves, because the constancy of breeding females does not prevent the dilution of maintenance feed requirements of breeding females and their replacements.

## System efficiency

### 2a. Constant farm output

If an assumption is made of a constant level of farm output over time as traits change, then traits that result in an increase in yield lead to fewer animals and reduced emissions. In fact, the trait change values for gross methane yield under the assumption of fixed farm output are identical to those for methane emissions intensity.

2b. Constant feed available

Under an assumption of constant feed availability to the farm, then traits that reduce feed requirements for replacements (i.e. system efficiency traits) will result in an increase in the number of productive animals farmed, so that gross methane emissions will remain static (i.e. these traits have zero benefits for reducing gross emissions). However with more animals, output may well increase when system efficiency traits are improved and so feed efficiency traits contribute emissions intensity benefits but do not reduce gross emissions under the assumption of constant feed available.

2c. Constant number of breeding females

When it is assumed that the number of breeding females on a farm will not change over time as a result of genetic improvement, then system efficiency traits reduce the requirement for replacements and therefore improve both emissions intensity and reduce gross farm emissions.

## More feed efficient animals

It is a reasonably comfortable assumption that any trait that reduces feed intake will reduce farm methane emissions.

3a. Constant farm output

Under the assumption of constant farm output, more feed-efficient animals will have both lower gross emissions and also lower emissions intensity.

3b. Constant feed available

Under the assumption of constant feed availability, a larger number of more feed-efficient animals would be farmed, resulting in constant gross emissions. However, there would be greater output from the extra animals, and so emissions intensity would improve.

3c. Constant number of breeding females

With the same number of more feed-efficient breeding females, or more feed-efficient offspring, gross emissions would be reduced, and emissions intensity would also be reduced.

## Lower emissions per unit of feed

Irrespective of the farm size factors, lower emissions per unit of feed result in both reduced gross farm emissions, and reduced emissions intensity.

# Appendix 2 - Quantifying emission intensity impacts of conventional trait changes

This appendix presents an equation taken from Ludemann et al. (2012) which takes standard emissions ratios for a farm and uses these to quantify how changes in biological parameters such as number of offspring per female, farm output per offspring, as well as emissions per offspring and breeding ewe will impact on farm emissions intensity.  It is straight forward to define how conventional genetic traits in sheep and beef farming systems impact on these biological parameters. Then for a specified base level of product output on the same unit scale as the farm profit breeding objective (e.g. product output per breeding female or product output per unit of feed) and taking an assumed carbon price, it is possible to define emissions intensity economic values on the same scale as the existing farm profit breeding objective.

Equation to estimate the change in EI (in GHG per kilogram of lamb cwt sold) from a one unit change in a trait (EI value)

$$B_o \cdot \left(\frac{l(g)}{\Sigma y(g)} - \frac{\Sigma e(g)}{\Sigma y(g) \cdot o(g)}\right) - B_y \cdot \frac{\Sigma e(g)}{\Sigma y(g) \cdot y(g)} + B_l \cdot \frac{1}{y(g)} + B_w \cdot \frac{1}{\Sigma y(g)}$$

$$= \text{[Trait g' GHG}_{(\text{Intensity})}\text{ value in kg CO}_2\text{e per kg lamb carcass sold}$$

Whereby:

$B_o$ is the amount by which the number of offspring per breeding female changes as trait g changes by 1 unit.

$B_y$ is the amount by which the amount of farm output per offspring changes as trait g changes by 1 unit

$B_l$ is the amount by which emissions per offspring change as trait g changes by 1 unit

$B_w$ is the amount the emissions per breeding female changes as trait g changes by 1 unit.

And:

$l(g)$ is the amount of lamb emissions per offspring

$\sum y(g)$ is per ewe product output i.e. an increase in emissions per breeding female increases emissions intensity according to the amount of output per breeding female

$\frac{l(g)}{\Sigma y(g)}$ is the offspring emissions per unit of product from a breeding ewe i.e. more emissions per unit of product

$\sum e(g)$ is the total lamb and ewe emissions expressed per ewe in the flock

$o(g)$ is the number of offspring per breeding female as a function of trait g

$\frac{\Sigma e(g)}{\Sigma y(g)}$ is the average emissions intensity for the farm

$\frac{\Sigma e(g)}{\Sigma y(g) \cdot o(g)}$ is the average emissions intensity for the farm expressed per offspring from a breeding female i.e. extra offspring with output dilutes emissions intensity

$\frac{\Sigma e(g)}{\Sigma y(g) \cdot y(g)}$ is the average emissions intensity for the farm expressed per unit of output from offspring i.e. extra output per offspring dilutes farm emissions intensity per unit of product

$y(g)$ is the amount of farm output per offspring as a function of trait g i.e. an increase in emission per offspring increases emissions intensity according to the amount of output per offspring

# Appendix 3. Resolving the Phenotypic Variance

**Appendix Table 3.1.** Potential approaches to resolution or dissection of the phenotypic variance equation

| | Variance associated with | Approach | Comments |
|---|---|---|---|
| **1** | $\sigma^2_p$ – phenotype | Primary or basic phenotype for *emissions intensity*: measure feed intake (indoors) & $CH_4$ production. Record large numbers of parameters in order to define the potential for development of correlated markers that will enable large numbers of individuals to be screened. | The identification of a trait or traits that correlate with emissions intensity and can be used to screen large numbers of individuals is fundamental to progress. |
| **2** | $\sigma^2_G$ – total genetic effect | This includes genetic effects due to both non-additive (dominance, etc) and additive effects | Practically it is very difficult to account for non-additive genetic effects in analyses of animal data so that these are ignored in most cases (the exception is where there are known effects usually associated with major gene effects) |
| | $\sigma^2_A$ - additive genetic effect | Screen a population of males (say 100 potential sires) all fed the same diet in a controlled feeding situation. Select the 5 highest & 5 lowest for $CH_4$ intensity ($CH_4$/unit of feed intake). Progeny test (PT) these 10 males recording both male & female progeny for the trait at x different ages & estimate the realised heritability of the trait | It is essential that $h^2$ is derived as the paternal half-sib estimate, given the potential for permanent maternal effects associated with the population of microbiota derived from maternal transfer. It may be feasible to conduct this PT retrospectively (at least in part) by screening a group of males with progeny that are available now & then recording progeny of identified extreme sires for the trait at x different ages; essentially this is a mature male phenotype and takes advantage of what is available immediately. |
| **3** | $\sigma^2_d$ - diet or nutrition | Screen the sire population above on a range of diets to define $CH_4$ intensity; in practice 3 or 4 diets are likely to be adequate that cover the following broad classes of feeds – low quality roughage such as low quality hay (say 9 MJ ME/Kg DM), good quality pasture (say 11 MJ ME/Kg DM) and a high concentrate pelleted diet (say 11 MJ ME/Kg DM) | This would generate phenotypic correlations across feed classes and provide an indication of the likely scale of variance due to diet. While all diets should be fed *ad lib*, there is a case for (some?) animals to be fed at restricted levels to assess the potential scale of any effect due to the level of nutrition; there would also be an opportunity to assess the efficiency of utilisation of dietary nitrogen (through both urinary & faecal N losses) and to assess the impact of factors that might impact on N efficiency (post-ruminal protein), especially on the low quality diet. |
| **4** | $\sigma^2_S$ - physiological state | Record the PT female progeny for the trait at different physiological states including: growing non-pregnant, pregnant, lactating, adult non-pregnant ages & estimate the realised heritability of the trait (estimated from males on one diet as per #1 above) | While it would be preferable to record all female progeny in each physiological state, the scale required may prove problematic, although all animals will be recorded as growing animals. The phenotypic correlations across the different physiological states will provide an indication of the scale of the effects. |
| **5** | $\sigma^2_R$ - direct effect of ruminal microbiota | The potential scale of the effect can be estimated by research involving transfer of rumen contents form one animal to another; this would be done with a number | Practically, in a genetic evaluation sense, these effects will be indistinguishable from one another and will be combined; however the proposed research will provide an indication of the likely scale of, and the relative size of, the two effects; as |

| | | | |
|---|---|---|---|
| | | of individuals on different diets | the numbers of animals that have been assessed increases, the potential to resolve the effects will be enhanced |
| **6** | $\sigma^2_M$ - permanent maternal effect | | |

# Appendix 4 - Detailed Overview of the Carbon Farming Initiative

The two main initiatives of the Australian government in response to climate change for land based industries are:

- Carbon Farming Initiative (CFI), and
- Carbon Farming Futures (CFF).

The CFI is a carbon offsets scheme that will enable farmers and other land managers to access carbon markets. Farmers and land managers will be able to generate carbon credits for taking action to reduce emissions and store carbon. These credits can be sold to other businesses and individuals wanting to offset their carbon pollution.

The CFF program complements the CFI by funding research, development and on-ground demonstration of innovative ways of reducing emissions and storing carbon while improving farm sustainability. The program will also support extension and outreach activities to help farmers and land managers benefit from carbon farming.

Both initiatives will be briefly summarised in this chapter and selected parts will be evaluated in more detail in the later parts of this report.

The information has been gathered and collated mainly from these websites:

http://www.daff.gov.au/climatechange

http://www.climatechange.gov.au

## Carbon Farming Initiative

The Carbon Farming Initiative (CFI) is an Australian Government scheme to help farmers, forest growers and land managers earn income from reducing emissions like nitrous oxide and methane through changes to agricultural and land management practices. The initiative will achieve this by:

- establishing a carbon crediting scheme
- developing methodologies for offset projects
- providing information and tools to help farmers and land managers benefit from carbon markets
- investing in a CFI Communications Program
- investing in a Biochar Capacity Building Program

Participation in the CFI is voluntary; farmers and landholders can choose whether or not to be involved. Legislation to underpin the CFI was passed by Parliament in 2011 and the scheme has now commenced and is operational.

### *Carbon crediting scheme*

These rule and regulations will be the basis for the carbon crediting scheme and developing on farm methodologies for emissions offset activities. Landholders undertaking activities that conform to an approved methodology will generate carbon credits. These carbon credits could then be sold on domestic or international carbon markets.

### *Methodology development*

Landholders and Indigenous Land Managers undertaking projects to credit offsets will need to use an approved methodology in order to participate in the carbon offset scheme.

All offset methodologies are assessed by the Domestic Offsets Integrity Committee (DOIC), an independent committee of experts, to ensure they lead to real and measurable emissions reductions. The Committee brings a range of expertise to these assessments, including science, technology, legal, methodology development and greenhouse gas measurement approaches.

The Government is continuing to work with stakeholders to develop further methodologies for submission to the DOIC.

### ***Communications Program***

The Carbon Farming Initiative (CFI) Communications Program will invest $4 million from 2011–12 to 2013-14 to provide farmers, land managers and their key influencers with credible, clear and consistent information on the CFI.

Part of the program will provide targeted grants to each of the 56 Natural Resource Management (NRM) regions. This will see Regional Landcare Facilitators (RLFs) work closely with farmers, Indigenous Australians and other land managers to identify how they can participate in and benefit from the opportunities created by the CFI and carbon farming.

### ***Biochar Capacity Building Program***

A further $2 million through the CFI is being provided for a Biochar Capacity Building Program which will provide farmers and land managers with a better understanding of biochar and its role in mitigating greenhouse gas emissions. The Biochar Capacity Building Program will support research, on–ground demonstration of biochar and the development of offset methodologies to provide additional options for landholders to contribute to reducing Australia's carbon pollution.

Biochar is a soil amendment that is produced by the burning of organic matter such as wood or crop waste in a low oxygen environment. Biochar has the potential to mitigate Australia's greenhouse gas emissions while benefiting agricultural production.

## Carbon Farming Futures

The Australian Government's "Securing a Clean Energy Future" plan, released in July 2011, has been developed to reduce greenhouse gas emissions to an acceptable level and drive investment in renewable energy. The Plan contains four elements

- carbon price
- innovation in renewable energy
- energy efficiency and
- **action on the land (Land Sector Package)**

Direct emissions from agriculture are excluded indefinitely from liability under the carbon price mechanism. However, the land sector currently represents 24 percent of Australia's total greenhouse gas emissions with methane and nitrous oxide emissions being the main contributors.

Over $1.7 billion **of carbon revenues** will be invested in the land sector in the next six years through funding programs – most of which are ongoing. The land sector measures are:

- **Carbon Farming Futures** ($429 million over six years) – Funding measures to help farmers and other landholders to benefit from carbon farming. Comprises five elements
    - Filling the Research Gap ($201 million over six years) - commences in 2011/12.
    - Converting research into methodologies ($20 million over six years) - commences in 2012/13.
    - Action on the Ground ($99 million over six years)

  - o Refundable Tax Offset (RTO) (over three years) to provide 15% RTOs for new eligible conservation tillage equipment installed between 1 July 2012 and 30 June 2015.
  - o Extension and Outreach ($64 million over six years)
- Biodiversity Fund ($946 million over six years) - Support for projects that establish, restore, protect or manage biodiverse carbon stores. Commences in 2011/12.
- Indigenous Carbon Farming Fund ($22 million over five years) - support Indigenous participation in the Carbon Farming Initiative. Commences 1 July 2012.
- Regional Natural Resource Management Planning for Climate Change Fund ($44 million over five years) - Support for regional natural resource management (NRM) organisations to incorporate climate change mitigation and adaptation components into existing regional NRM plans. Commences 1 July 2012.
- Carbon Farming Skills ($4 million over five years) - Funding available for training and accreditation of carbon brokers and aggregators so landholders have access to credible, high quality advice and carbon services. Commences 1 July 2012.
- Carbon Farming Initiative Non-Kyoto Carbon Fund ($250 million over six years) - Government purchase of land sector abatement that is not counted towards Australia's emissions targets under current accounting rules. Commences 1 July 2013.
- Land Sector Carbon and Biodiversity Board - Establishment of a permanent, expert board to provide advice on implementation of the measures.

Out of all the programs we will focus on the Carbon Farming Fund. The CFF program has four main components as below.

**Filling the Research Gap ($201 million)**

The government will invest in new and innovative ways for Australian land managers to reduce emissions or store carbon. This will include funding to engage scientists and independent experts to investigate ways of improving soil carbon.

The fund will target emerging technologies and innovative management practices by engaging more scientists and independent experts to improve soil carbon, reduce emissions from livestock and crops, and enhance sustainable agriculture practices.

Surveys of common practice in agricultural industries across different regions will be undertaken to help identify activities that go beyond common practice and could be eligible for credits under the CFI, and to target research to where it will be most effective.

**Converting research into methodologies ($20 million)**

This research will be converted into estimation methodologies for use in the CFI. This will include the development of practical, low cost estimation and reporting tools for farmers and land managers that store or reduce carbon across various landscapes and production zones.

**Action on the Ground ($99 million)**

New research findings will be tested and demonstrated on-farm, ensuring that laboratory results can be replicated in real farming situations. Regional land managers and research, industry and farming organisations will be able to access grants to implement innovative management practices to reduce emissions and store carbon, including demonstrating new ways of increasing soil carbon.

This measure includes support for *conservation tillage farming*. Farmers will be able to claim a 15 per cent refundable tax offset for new eligible conservation tillage equipment installed and ready for use between 1 July 2012 and 30 June 2015. Participants in the scheme will have to assist in soil carbon research.

**Extension and Outreach ($64 million)**

The program will enable information and support to be provided directly to land managers to help them integrate emissions abatement and carbon management into land and farm planning. The program will fund additional extension officers. Funding will also be available for a range of extension and outreach activities, including workshops and field days, to be delivered through existing extension networks across Australia.

## Eligible and excluded activities

The Carbon Farming Initiative (CFI) allows landholders to earn carbon credits for reducing emissions or storing carbon on their land.

For an activity to be eligible under the CFI, it must:

- be within the scope of the CFI
- be covered by an approved CFI methodology
- be on the Positive List, and
- not be on the Negative List.

### ***Scope of the Carbon Farming Initiative***

The CFI covers projects that occur in the agriculture and land use sectors, as well as projects to reduce emissions from legacy landfill waste.

The following four types of projects could be eligible under the CFI, provided they are covered by a methodology, on the positive list and not on the negative list.

1. Agricultural emissions avoidance projects

   Projects that avoid emissions of:

   a. methane from the digestive tract of livestock
   b. methane or nitrous oxide from the decomposition of livestock urine or dung
   c. methane from rice fields or rice plants
   d. methane or nitrous oxide from the burning of savannas or grasslands
   e. methane or nitrous oxide from the burning of crop stubble in fields, crop residues in fields or sugar cane before harvest
   f. methane or nitrous oxide from soil.

2. Landfill legacy emissions avoidance projects

   Projects that avoid emissions of greenhouse gases from the operation of a landfill facility, to the extent to which the emissions are attributable to waste accepted by the facility before 1 July 2012.

3. Introduced animal emissions avoidance projects

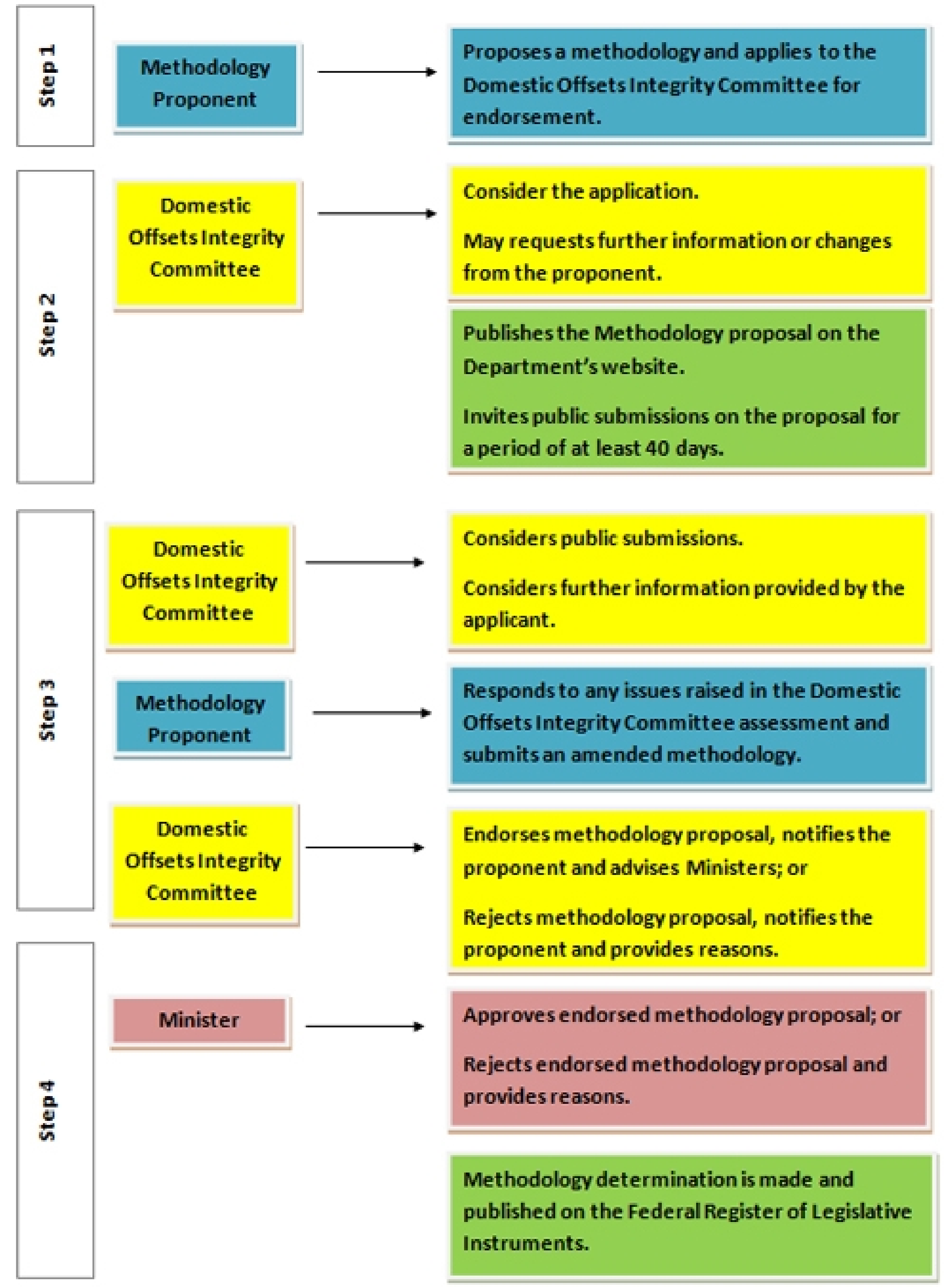
   Projects that avoid emissions of methane from the digestive tract of an introduced animal or emissions of methane or nitrous oxide from the decomposition of introduced animal urine or dung.

4. Sequestration offsets projects

   Projects that remove carbon dioxide from the atmosphere by sequestering carbon in living biomass, dead organic matter or soil; or remove carbon dioxide from the atmosphere by sequestering carbon in, and avoid emissions of greenhouses gases from, living biomass, dead organic matter or soil.

## ***CFI Methodologies Approval Process***

The following graph summarises the full process to establish a methodology and will be described in more detail below:




Offset projects established under the Carbon Farming Initiative will need to use methodologies approved by the Government. These contain the detailed rules for implementing and monitoring specific abatement activities and generating carbon credits under the scheme.

Methodologies may be developed by private proponents and industry associations as well as government agencies.

An independent expert committee, the Domestic Offsets Integrity Committee (DOIC, click here for details, especially Dr Keating), has been established to assess offset methodologies and advise the Minister for Climate Change and Energy Efficiency on their approval.

The Committee will consider the public comments and any technical advice sought in making its recommendation to the Minister for Climate Change and Energy Efficiency.

The Minister for Climate Change and Energy Efficiency will decide whether or not to approve the methodology. Approved methodologies will become legislative instruments.

Once the legislative instrument is made project proponents may apply to the CFI Administrator for approval of a project using the methodology.

The following methodologies are currently under consideration by the DOIC (click here for an up to date list):

- Avoided emissions from diverting waste from landfill for process engineered fuel manufacture
- Management of large feral herbivores (camels) in the Australian rangelands
- Savanna burning

The following methodologies are currently approved (click here for an up to date list):

- Capture and combustion of landfill gas
- Destruction of methane generated from manure in piggeries
- Environmental plantings

<u>Methodology development</u>

The Department of Climate Change and Energy Efficiency and the Department of Agriculture, Fisheries and Forestry are working with industry to develop offset methodologies that have broad application.

Technical working groups comprising representatives of expert and practitioner groups have been established by the departments to review current scientific knowledge, determine any requirements for additional research and finalise methodologies under each work stream. These methodologies are expected to be rolled out progressively.

<u>Submitting a methodology for assessment</u>

The Domestic Offsets Integrity Committee is accepting methodologies for assessment.

Applications for assessment of proposed Carbon Farming Initiative methodologies must be prepared in accordance with the Guidelines for Submitting Methodologies using a provided template.

The key points from these guidelines are (click here for more details):

- Intellectual Property:

  Any entity that submits an application for assessment of a draft methodology as part of the CFI warrants that they own or have a licence to use all of the relevant intellectual property rights in the application submitted.

- Carbon Farming Initiative methodologies

  CFI methodologies must relate to eligible abatement activities and will need to contain:

  - a description of the abatement activities
  - a description of the greenhouse gases and emissions sources and sinks affected by a project

  - o procedures for determining a baseline which represents emissions and removals that would occur in the absence of the project
  - o procedures, including models, for estimating or measuring abatement relative to the baseline
  - o project-specific data collection and monitoring requirements, and
  - o any additional reporting and record keeping requirements which are specific to the project and not included in the CFI legislation.

- Offsets integrity standards

  The environmental integrity of the scheme will directly affect consumer confidence and the amount that buyers are willing to pay for CFI credits. For this reason, it is important that abatement credited under the CFI meets internationally recognised offsets integrity criteria designed to ensure that abatement is real and verifiable. These integrity criteria include:

  - o **Additional**—a project must result in abatement that would not have occurred in the absence of the project's expected returns from the sale of CFI credits. There would be no reduction in emissions as a result of the CFI if the project activity is already in widespread use by landholders.
  - o **Permanent**—permanence is an important characteristic of abatement projects involving the removal of carbon from the atmosphere and its long-term storage in plants, soil or other carbon sinks. There would be no real abatement if carbon were to be stored and subsequently released to the atmosphere. For practical purposes, biological carbon stores are generally considered permanent if they are maintained (on a net basis) for at least 100 years.
  - o **Accounting for all emissions sources and sinks**—all emissions sources and sinks directly or indirectly affected by the project must be identified and accounted for. This is also referred to as avoidance of leakage. There would be no real abatement if a project's emissions reductions or removals were nullified or replaced by a consequential increase in emissions elsewhere.
  - o **Accounting for variability**—many bio-sequestration activities are subject to a high degree of variability as a result of natural climatic or production cycles. Abatement estimates will need to be adjusted to account for variations that are likely to occur in carbon stores over a 100 year period.
  - o **Measurable and verifiable**—abatement must be credibly measured or estimated to ensure each offset credit represents one tonne of carbon dioxide equivalent ($CO_2$-e) of emissions reduction or removal. Data collection, estimation and modelling approaches must be consistent over time and enable abatement estimates to be verified. Conservative assumptions, numerical values and procedures must be used to ensure that abatement and other claims are not over-estimated. Projects must be audited by an independent, qualified third party.
  - o **Internationally consistent**—estimation methods must be not inconsistent with (but need not necessarily be the same as) the methods applied in compiling Australia's National Greenhouse Accounts (as detailed in the National Inventory Report), where relevant, and internationally agreed methodologies and reporting practices adopted by the United Nations Framework Convention on Climate Change (UNFCCC).
  - o **Supported by peer-reviewed science**—where emissions estimation methods are not the same as those used for Australia's National Greenhouse Accounts,

scientific evidence used to support the estimation methods must be peer-reviewed.

## ***The Positive List***

The CFI includes an additionality test to ensure that carbon credits generated by CFI projects can genuinely offset the emissions produced by the person who buys the credit. To pass the additionality test, a project must not be required by law and the activity must be on the positive list.

The Positive List identifies activities that are deemed to go beyond common practice in the relevant industry or environment.

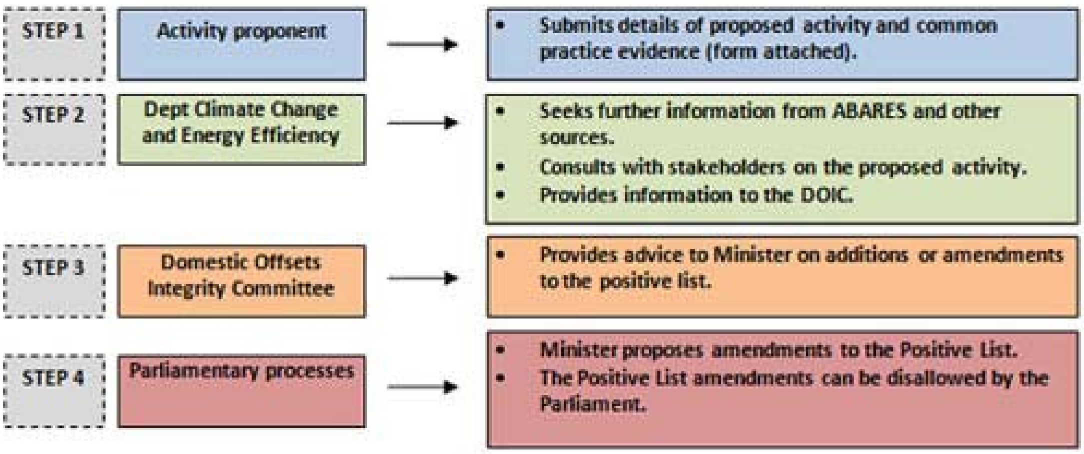
To stress this again: Under section 41 of the *Carbon Credits (Carbon Farming Initiative) Act 2011* (Cth), ACCUs will only be issued for *additional* abatement, which means that ACCUs will **not** be available for:

- projects that are required by law (regulatory additionality which will be assessed on an individual project basis), or
- activities that are common practice and already widely adopted.

The Australian Government will review the Positive List periodically with a view to keeping the list current in light of technological developments and the latest scientific research.

It is important to note that each CFI project must use an approved methodology (see above) that sets out the baseline against which abatement is measured. The baseline is an estimate of what would happen in the absence of the project. Measuring abatement against a baseline ensures that only improvements beyond what would otherwise occur can be credited under the CFI.

The following graph is the summary of the administrative process for the Positive List:




The key points from the positive list guidelines are (click here for more details):

The common practice assessment will take account of the following factors:

- The activity under assessment
- The relevant comparison group
- Take-up rate and take-off point
- Circumstances where penetration rate is low

### ***The Negative List***

The Negative List identifies activities that are excluded from the CFI in circumstances where there is a material risk that the activity will have a material adverse impact on one or more of the following:

- the availability of water
- the conservation of biodiversity
- employment
- the local community, and
- land access for agricultural production.

The Negative List is intended to manage risks that are not addressed by existing regulations and planning regimes, and will change over time as new risks are identified or mitigated.

Activities on the Negative List will be tightly defined and take account of options to avoid or mitigate risks. This ensures low-risk projects aren't excluded from participating in the CFI, and also creates an incentive for project proponents to adopt best practice risk management.

Some activities may not pose risks when undertaken by only a few landholders in a particular area, but would have impacts when undertaken on a broad scale. These activities may not be on the list to begin with; but would be added before they reach a threshold where adverse impacts could occur.

## Carbon Faming Futures

This section provides details around the three up and running programs of the CFF. The Department of Agriculture, Fisheries and Forestry is responsible for delivering these three components of the Carbon Farming Futures program, see below. Two programs haven’t commenced yet, “converting research into methodologies” and “Refundable tax offset”. The Department of Climate Change and Energy Efficiency (DCCEE) is responsible for the development of methodologies. Treasury is responsible for delivering the 15% tax offset.

The Carbon Farming Futures program will provide $429 million to ensure that advances in emissions reduction technologies and techniques will continue the evolution of management practices in the land sector towards emissions reduction and improved productivity. These advances will allow farmers and other landholders to benefit from the economic opportunities of the Carbon Farming Initiative (CFI).

### ***Filling the Research Gap***

Filling the Research Gap is a component of Carbon Farming Futures and will invest $201 million to support research into emerging abatement technologies, strategies and innovative management practices that reduce greenhouse gas emissions from the land sector, sequester carbon and enhance sustainable agricultural practices.

Filling the Research Gap will build on research undertaken through the Climate Change Research Program. Projects will target current research gaps around abatement technologies and practices. Research priorities are reducing methane emissions, reducing nitrous oxide emissions, sequestering carbon and improving modelling capability. Research projects will draw on industry, scientific and government sectors to ensure that:

- sufficient expertise and experience is brought together to achieve outcomes that will make a difference
- commercial realities are taken into account to improve the transition from applied research to demonstration of commercial applications.

Research projects will target current research gaps around abatement technologies and practices. It is expected that the results of research activities will be published in peer–reviewed scientific literature.

Research outcomes will underpin the development of new abatement methodologies that land managers can use to participate in the Carbon Farming Initiative (CFI). The CFI voluntary carbon offsets scheme allows participating land managers to earn additional income from reducing emissions and storing carbon in the landscape.

Research could include cattle genetics and feed alternatives to reduce livestock methane emissions and waste management strategies, new fertiliser technologies and management strategies to reduce soil nitrous oxide emissions, and new crop species to build soil carbon.

A number of practical difficulties exist in accurately measuring emissions in the agriculture sector. Improving measurement techniques would assist in producing better estimates to inform mitigation strategies. DCCEE has primary carriage of maintaining and developing Australia's national emissions inventory. The Carbon Farming Futures program will seek to complement, not duplicate, the DCCEE work program in this area. Research on managing emissions will be reflected, over time, in refinements to emission factors and measurement techniques utilised by the national emissions inventory.

Priorities for the first funding round focus on improving understanding of the sources, scale and cause of agricultural emissions, and quantifying the effectiveness of management practices aimed at reducing emissions. This will contribute to abatement opportunities under the CFI.

Research priorities for funding round one of the Filling the Research Gap program are:

- reducing methane emissions
- reducing nitrous oxide emissions
- increasing soil carbon
- improved modelling capability.

This information will be used to underpin the CFI additionality test and development of offset methodologies.

## ***Priority 1: Reducing methane emissions***

Agriculture produces around 60 percent of Australia's methane emissions, the majority coming from livestock. Through the CCRP, researchers have been investigating various measurement techniques (e.g. tracer gas devices and open path laser technology) as well as strategies to reduce methane emissions from ruminant animals.

Animal breeding, biological controls, dietary supplements and alternative forage sources as abatement activities are all methods that have been trialled so far under the CCRP. However, further research is required to build on current knowledge and develop practical technologies for producers.

Further research is needed to:

- investigate a wider range of farming practices and develop new methods by which landholders can reduce methane emissions
- better understand the role of soils in greenhouse gas fluxes
- better understand how to reduce greenhouse gas emissions through manure management
- convert current technologies around methane reduction into practical solutions for landholders.

## ***Priority 2: Reducing nitrous oxide emissions***

Nitrous oxide is a significant greenhouse gas as it is 310 times more potent than carbon dioxide. Through the CCRP researchers have been investigating different methods for reducing nitrous oxide emissions. Preliminary results suggest that nitrous oxide emissions can be reduced in a number of ways, including strategic irrigation management (timing and amount of water applied), using legume crops to build up soil N (rather than using nitrogenous fertiliser), and using fertiliser breakdown inhibitors.

Further research is needed to:

- investigate a wider range of farming practices and develop new methods by which landholders can reduce nitrous oxide emissions
- better understand the interactions between carbon and nitrogen and their influence on productivity and greenhouse gas emissions
- improve our understanding of nitrous oxide emissions under a range of soils and production systems to underpin methodology development
- better understand the role of soils in greenhouse gas fluxes.

## ***Priority 3: Increasing soil carbon***

Through the CCRP researchers have started to examine various management practices and their impact on soil carbon levels. The CCRP has also developed a national standard for measuring soil carbon and provided key data to improve the National Carbon Accounting System.

Further research is needed to:

- investigate and verify a wider range of alternative methods of increasing soil carbon
- examine the problems with measuring and monitoring carbon in Australian soils and investigate practical solutions
- better understand the long–term viability of sequestering carbon in soil as an emissions management practice
- better understand the interactions between carbon and nitrogen and their influence on productivity and greenhouse gas emissions
- develop robust soil carbon methodologies
- better understand the role of soils in greenhouse gas fluxes.

## ***Priority 4: Improved modelling capability***

Improved modelling capability is required to better estimate levels of abatement and carbon sequestration in response to different management practices. Improved modelling will also lower the costs of implementing offset methodologies and help quantify the likely financial rewards for land managers under the CFI.

Improved modelling supports the first three research priorities identified above. Projects are encouraged to utilise site specific data collected around methane, nitrous oxide and carbon sequestration to build the capacity of existing models and integrate all sources and sinks in a whole farm systems context to evaluate the net mitigation benefit of various technologies and management practices.

Modelling improvement activities should aim to ensure that the resulting data is of a kind and standard that allows it to inform Australia's National Greenhouse Gas Accounts. This will ensure that, over time, research under the Filling the Research Gap may be reflected in refinements to Australia's National Greenhouse Gas Accounts or used to develop CFI methodologies.

## ***How the Program Will Operate***

Filling the Research Gap funded projects will be selected through a competitive grants process. Proposed work can be up to a maximum of three years. Within the funding limits of the program, there is no limit on the amount of funding a project may apply for.

Applicants are required to submit an application for funding and meet all eligibility and other requirements set out in the guidelines.

Proposed work will be carried out over a period of up to three years (2012–13 to 2014–15). Program funds are available across four financial years (2011–12 to 2014–15), with the first payment initiated by the signing of the funding deed. Future payments will be made in increments on the completion of milestone activities as specified under the funding deed.

Applicants' in–kind contributions are required and cash contributions are expected. In–kind contributions must be directly related to the eligible costs of delivering the activities of the project and can include salaries of staff for the time they are involved and other costs incurred for the duration of the project. Contributions (both cash and in–kind) should be listed in the project budget.

Successful applicants will be required to submit regular progress reports (at least every six months) under the milestones in the funding deed. These reports will cover the activities, outputs and outcomes along with all necessary information required to verify results (i.e. evidence of achievement). Successful applications will also need to identify methods for communicating outputs and outcomes to Australia's land managers as well as to relevant science and policy communities.

Key Dates – Funding Round 1

The table below presents anticipated key dates for the first year of funding for the Filling the Research Gap program. Subsequent rounds will be announced in future years.

Anticipated key dates for the first year of funding

| **Milestone** | **Anticipated Dates** |
|---|---|
| Guidelines available and application period open | November 2011 |
| Applications close | 3 February 2012 |
| Assessment of applications, refining of selected projects, endorsement and approval | Early April 2012 |
| Funding deed signed by both parties and initial payment made | June 2012 |

Who Is Eligible?

Applicants must be an Australian company, business, research organisation, government agency or department, for example:

- Australian business with an Australian Business Number
- Rural Research and Development Corporation
- National or state primary industry organisation
- Australian, state or territory or local government agency or statutory corporation
- Australian tertiary education institution
- Australian Cooperative Research Centre

- Australian public sector research agency
- Australian private research organisation.

Click here for more details.

## Action on the Ground

Action on the Ground is a component of Carbon Farming Futures and will invest up to $99 million of grant funding in on-farm projects over six years. Action on the Ground is designed to enable on-farm trial and demonstration of practices and abatement technologies to reduce agricultural greenhouse gas emissions and/or increase carbon sequestered in soil.

Action on the Ground on-farm projects will create new opportunities for landholders and farmers to participate in the Carbon Farming Initiative (CFI) by trialling and demonstrating outcomes from research programs including, but not limited to, the Climate Change Research Program and the Filling the Research Gap program. Projects under Action on the Ground will ensure that research results can be practically applied on the ground in real farming situations.

This will be achieved by supporting landholders, research, industry, non-government, government and farmer 'care' 'grower' groups/organisations to come together to trial and demonstrate management practices and technologies on-farm that can reduce agricultural greenhouse gas emissions and/or increase carbon sequestered in soil.

### ***Guidelines***

Action on the Ground is an ongoing program that will invest $99 million during the first six years (2011-12 to 2016-17) to assist landholders trial and demonstrate ways to reduce agricultural greenhouse gas emissions and/or increase carbon stored in soil.

These guidelines are for the first round (round one) of the Action on the Ground program covering 2011-12 to 2014-15. Round one will provide funding of up to $25 million. Future funding rounds will be announced at a later stage and will build on the outcomes of research into ways to implement innovative management practises to achieve sustainable outcomes, reduce agricultural greenhouse gas emissions and boost soil carbon stores. Projects will test the relationships between different management practices and emissions levels/carbon stores, which will enable knowledge transfer and promote broader uptake of land sector abatement activities.

Successful applicants under round one of Action on the Ground may also be eligible to apply for funding under future rounds of Action on the Ground. Applicants will be required to demonstrate that their application to either extend the term of and/or vary the scope of their project is consistent with future round guidelines and that they have complied with requirements of their existing Funding Deed.

Action on the Ground is seeking applications from groups of landholders, research, industry sectors, non-government, government and farmer 'care' 'grower' group/organisations to undertake on-farm projects to:

- demonstrate that research outcomes, including, but not limited to, outcomes of research undertaken through the Climate Change Research Program, can be practically applied on-farm to reduce agricultural greenhouse gas emissions and/or increase carbon stored in soil under a range of farming practices, geographic and climatic conditions
- trial and demonstrate innovative farming practices and/or abatement technologies that can be practically applied on-farm to reduce agricultural greenhouse gas emissions and/or increase carbon stored in soil.

Priorities for Action on the Ground are:

- **Reduced methane emissions**

- **Reduced nitrous oxide emissions**
- **Increasing carbon stored in soil**
- **Reduce greenhouse gas emission and/or store carbon in soil through the application of innovative practices and/or abatement technologies**

How the Program will Operate

Projects to be funded under the Action on the Ground program will be selected through an open competitive grants process.

Applicants are required to provide cash/in-kind contributions. Contributions must be directly related to the eligible costs of delivering the activities of the project and can include salaries of staff for the time they are involved in the project. Contributions should be listed as part of the project budget in the application.

Key Dates - Round One

Table 1 below presents anticipated key dates for the first round of funding of the Action on the Ground program. Subsequent rounds will be announced in future years and information on these will be available on the department's website.

| **Milestone** | **Anticipated Dates** |
|---|---|
| Action on the Ground guidelines released | December 2011 |
| Application submission period opens | 11 January 2012 |
| Application submission period closes | 8 February 2012 |
| Assessment period | February/March 2012 |
| Announcement of Action on the Ground projects | March/April 2012 |
| Commencement of successful projects with first payment – on signing the Funding Deed | April/June 2012 |
| Project milestones – project payments dependent on project activities as defined in the Funding Deed being achieved | To be defined in the Funding Deed |
| Final project payment – paid on submission of project final report | To be defined in the Funding Deed |

Applications are sought from landholders, research, industry sectors, non-government, government and farmer 'care' 'grower' group/organisations and/or consortiums to undertake on-farm projects.

Action on the Ground grants are targeted towards the Australian agricultural sector. To be eligible, the applicant must be an Australian legal entity at the time the application is lodged.

Applications for funding through the *Action on the Ground* program must meet the following requirements:

Applicants must seek to trial or demonstrate agricultural greenhouse gas emission reductions or carbon sequestration as a result of specific management practices and/or technologies under one or more of the *Action on the Ground* priority areas.

Proposed works must be undertaken on-farm in Australia.

Eligible Activities

Examples of some activities that would be eligible for funding include practises and/or technologies that seek to address Action on the Ground priorities (Section 2 – Purpose of the Action on the Ground program) through on-farm projects' that trial and demonstrate:

- animal management and feed strategies that can reduce methane emissions
- management strategies to reduce soil nitrous oxide emissions including the use of chemical inhibitors
- planting, rotation, cropping or grazing practices to either reduce agricultural greenhouse gas emissions from soil and/or increase carbon stored in soil
- on-farm management practices and abatement technologies to reduce agricultural greenhouse gas emissions from agricultural wastes
- other practices and abatement technologies that can be demonstrated on-farm to have the potential to reduce agricultural greenhouse gas emissions and/or increase carbon stored in soil.

Ineligible Activities

Examples of project activities that would be ineligible to receive funding through Action on the Ground include activities that:

- do not address any of the identified Action on the Ground priorities (Section 2 - Purpose of the Action on the Ground program)
- are already being undertaken by the applicant and funded through other Commonwealth programs
- seek funding to undertake subsequent devolved funding of projects. All entities receiving funding to deliver on-farm activities as part of a project must be identified in the application.
- have costs associated with either the development of a Carbon Farming Initiative methodology or implementation of a project under a Carbon Farming Initiative methodology
- focus on reduction of greenhouse gas emission associated with on-farm fuel use and/or power consumption
- aim to develop on-farm greenhouse gas emissions abatement plans without significant farm based activities that implement practices to reduce agricultural greenhouse emission and/or store carbon in soil.

Click here for more details.

## Extension and Outreach

The Extension and Outreach program is a component of Carbon Farming Futures and will invest $64 million over six years to support coordinated communication activities to provide technical information and support for farmers and other land managers to participate in the Carbon Farming Initiative (CFI) and benefit from carbon farming.

Extension and outreach activities will motivate landholders to explore opportunities to participate in the CFI carbon offsets market, by providing technical information and support about integrating carbon management into farm planning; new research and farm techniques for the property and farm business; and enhancing productivity and environmental sustainability.

The CFI is a voluntary carbon offsets scheme that will create productivity, economic and environmental benefits for farmers, forest growers and land managers who reduce greenhouse gas emissions and / or store carbon in the landscape.

The Extension and Outreach program will also supply up to date information about the Carbon Farming Futures (CFF).