GREENHOUSE AND AGRICULTURE WORKSHOP SERIES


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Introduction

In 1999, Greenhouse gas emissions from agriculture accounted for 20.5% of total national net emission (AGO, 1999). Dairy cattle contribute to around 12% of livestock emissions and 2% of total national emissions, by emitting greenhouse gases with high global warming potentials. Agriculture is unique, in greenhouse terms, when compared with other Australian industries, as the non carbon dioxide gases methane and nitrous oxide make up the majority of its emissions profile. These two gases are very potent greenhouse gases with methane having a global warming potential 21 times that of carbon dioxide and nitrous oxide 310 times.

Australia is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC) which aims to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous human induced changes to the global climate system (AGO, 1998). Australia has taken an active involvement in negotiating and have since signed the Kyoto Protocol (to the Framework Convention on Climate Change). If this Protocol is ratified, it will commit Australia to a legally binding limit on its future greenhouse gas emissions (AGO, 1998).

Responding to the provisions of the Kyoto Protocol will therefore present a number of threats and opportunities for agriculture. The agricultural industries need to be proactive to develop mechanisms that limit greenhouse gas emissions and adapt to climate change impacts in a way that minimises any dislocation and costs and at the same time make the most of any commercial opportunities.

To assist this process, the Standing Committee on Agriculture and Resource Management (SCARM) has developed a combined Commonwealth and State Government Work Program to:

“provide the facilities for a joint government and industry consultation to improve the knowledge base for greenhouse issues in agriculture and provide a suite of appropriate strategies to farmers for emission reductions”.

The first phase of the Work Program involves a Greenhouse and Agriculture National Workshop Series, which was developed to engage nine key agricultural sectors to discuss the range of greenhouse issues relevant to their sector industry. The agricultural sectors involved are

- Extensive Grazing sectors:
  - Beef cattle; and
  - Sheep.
- Intensives Livestock:
  - Dairy;
  - Lot Feeders; and
  - Pork Industries.
- Field Crops:
  - Cotton;
  - Grains;
  - Rice; and
  - Sugar.

\(^1\) Australian Greenhouse Office
The Dairy Workshop was held in Melbourne on 23 July 2001. The specific aims of the workshop were to:

- Share the latest climate change and greenhouse effect information with industry and other stakeholders;
- Identify options to reduce greenhouse gas emissions; and
- Prioritise areas where action is required.

The question posed to participants at the start of the workshop was:

**What are the key mechanisms available to the dairy sector to reduce net greenhouse gas emissions?**

The second phase of the SCARM Work Program will involve the implementation of a number of specific projects to address particular industry needs, such as providing the research necessary to fill important gaps in our understanding of greenhouse gas emission reduction options and/or communication and extension activities.

There were twenty-two participants from industry, science and government who attended the workshop. A list of these participants and their contact details is provided in Attachment A.

**Format of the Workshop**

The morning session of the workshop consisted of presentations by both industry representatives and producers who provided information to participants on dairy greenhouse emissions and abatement issues. The presentations are summarised in this paper. After each presentation participants were able to ask questions and discuss any of the information provided in that presentation.

The afternoon workshop session further identified and explored options on mechanisms to reduce greenhouse gas emissions and also to identify strategic directions for the dairy sector.

**Presentations**

**Richard Habgood**
**Victorian Department of Natural Resources & Environment (NRE)**

Richard Habgood welcomed workshop participants by providing a background to the dairy industry and information on the

- National Greenhouse and Agriculture Workshop Series;
- Victorian Governments response to greenhouse;
- Dairy industry profile and
- Victorian Department of Natural Resources and Environment’s (NRE) Greenhouse Strategy for Agriculture.

The Standing Committee of Agriculture and Resource Management (SCARM) Working Group on Greenhouse initiated this national workshop series in response to the National Greenhouse Strategy’s module 6.9 ‘Reducing greenhouse gas emissions from agricultural production.’ The workshop series aims to engage agricultural sectors about their greenhouse gas abatement opportunities and identify what work needs to be
carried out to enable agriculture to be in a position to respond to greenhouse gas abatement. This workshop series is a joint State and Commonwealth Government initiative. Hassall & Associates has been engaged to coordinate the workshops and their proceedings. The Australian Greenhouse Office (AGO) has personnel involved in these workshops. Australia is the only country in the world to have set up an office specifically aimed to examine the country’s response and approach to Greenhouse gas abatement, being the AGO.

Habgood identified why the dairy industry and agriculture as a whole should be concerned with greenhouse. He stated that humans are significantly contributing to greenhouse gas emissions and global warming. He went on to say that agriculture was a significant contributor being the second highest emitter, responsible for 20.2% of total net emissions, with the main source being methane and nitrous oxide.

Livestock accounts for 66.7% of agricultural emissions with the major contributors being:
- Dairy (8.1%);
- Beef (38.4%); and
- Sheep (17.2%).

Habgood also suggested the potential economic costs that greenhouse gas abatement may pose on the agricultural sector could be high.

The Intergovernmental Panel on Climate Change (IPCC) have a general consensus that global warming and climate change is a reality. The Framework Convention for Climate Change (FCCC) committed countries to seriously investigate capping their emissions. In particular, the Kyoto Protocol (1997), which was to be discussed in Bonn the week following this workshop, shows that capping emissions is not a matter of IF but WHEN and HOW.

The Victorian Government takes climate change and global warming seriously and has established a greenhouse policy unit within NRE. This policy unit developed a discussion paper in August 2000, which will be used to help to develop the Victorian Greenhouse Strategy, and is to be released late 2001.

Habgood provided a snapshot of the Australian dairy industries. He described Australia as small producers on the world scene but major traders in dairy products. Australia and New Zealand produce milk at a substantially lower cost than other countries because the milk is produced off pastures and forages. He estimated Victorian production totals are approximately 80% of total Australian production. Dairy farms are located in areas of high rainfall. Approximately 50% of Australian milk production is exported, 28% domestic manufacture and 20% domestic milk market.

The Dairy Sector has also carried out work in this area, including:
- Dairy Production Report to CRC for Greenhouse Accounting, Eckard et al (2000);
- Dairy Greenhouse Emissions, Report for Dairy Research and Development Corporation by McCrabb (2000); and
- Decision Support Tools proposal, with Dairy Research and Development Corporation.

The Victorian Grazing Industries held a workshop in November 2000 with the aims to have:
- Better quantification of current emissions;
• Need for a common framework to assess impact and guide research;
• Development and education;
• Identify and pursue opportunities to reduce greenhouse gas emissions;
• An understanding of farm versus catchment solutions;
• Policy mechanisms necessary to drive change;
• Scope for complimentary solutions with other environmental/ ecological issues;
• Models to communicate with targeted audiences;
• An understanding of potentially negative impacts from possible greenhouse gas emission controls; and
• An understanding of the impacts of climate change.

The work program for 2001-02 NRE’s greenhouse strategy for agriculture aims to better define the emission status for Victorian agricultural industries, identify feasible options and projects to reduce emissions and describe impact of climate change and strategies for adoption.

Martin Teasdale
Greenhouse Challenge

Martin Teasdale opened by establishing that there is international consensus that global warming and climate change is occurring, that the Australian Government has recognised that greenhouse is an issue and they are looking to identify the best action to take.

As a result of global warming and climate change, Teasdale presented the biggest potential changes that will impact inland systems to be soil erosion, increased dryland salinity, more frequent extreme weather events and reduced pasture and animal production.

Agriculture is the second major source of emissions in Australia. Teasdale suggests that this presents Australia with significant challenges and opportunities for agriculture.

Australia has internationally committed itself to reducing greenhouse gas emissions. In international negotiations, Australia is encouraging the use of flexible mechanisms to offset greenhouse gas emissions, emissions trading and the involvement of developing countries.

Australian Government has allocated $1 billion of resources to greenhouse related National Action. National Action encompasses the following programs and strategies
• National Greenhouse Strategy (agreed at the State and Commonwealth level);
• Greenhouse Gas Abatement Program;
• Greenhouse Challenge;
• Bush for Greenhouse (enhancing the growth of sinks);
• Renewable Energy;
• National Carbon Accounting System; and
• Land based sector:
  o Sustainable land management;
  o Native revegetation;
  o Plantations and Farm Forestry;
  o Agricultural management practices; and
  o Rumen modifier research.
Dairy cattle contribute to around 12% of livestock emissions and 2% of total national emissions. Teasdale identified emission reduction opportunities for agriculture, which include:

- Reducing Energy Use;
- Reducing Livestock Methane Emissions;
- Manure Management / Use of Biogas;
- Improvements in Animal Husbandry;
- Reduction of Biomass Burning; and
- Conservation Cropping.

Methane production depends on feed characteristics and amount eaten. Potential methane emission reduction options include:

- Rumen and/or feed manipulation;
- Selection for high net feed-use efficiency;
- Greenhouse and agriculture;
- Significant opportunities and challenges; and
- Opportunities for greenhouse outcomes, economic interests and provision of environmental services.

Richard Eckard
University of Melbourne / Agriculture Victoria

Richard Eckard presented information on the current research and abatement options for the dairy industry based on three recent activities:

- Workshop discussions on Greenhouse issues in the grazing industries workshop held in November 2000; and
- Research carried out by Eckard, McKenzie, Mundy & McCaskill on Best Management Practices (BMP) for Nitrogen fertiliser use in dairy.

The dairy sector emits the following greenhouse gases: methane (CH₄), carbon dioxide (CO₂) and nitrous oxide (N₂O).

Methane
Eckard noted that about 90% of methane emitted by ruminants comes from the fermentation in the rumen. Eckard also suggests that even though total greenhouse gas emissions from the dairy sector is less than 2% of national net emissions, the trends of methane emissions from dairy farming has increased by approximately 22% since 1990 and is projected to increase by approximately 44% by 2010. The dairy industry should therefore not be complacent about their greenhouse gas emissions.

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2 This summary is from a combination of Richard Eckard’s presentation at the workshop and the paper “Greenhouse Gas Sources and Sinks, and Impacts of Potential Management changes on Greenhouse Gas Emissions and sequestration from Dairy Production Systems in Australia. Workshop proceedings CRC for Greenhouse Accounting (2000)
Eckard questioned the current methodology used in the National Greenhouse Gas Inventory (NGGI) for measuring methane from ruminants. He noted that New Zealand data suggests that emissions are between 80 to 96kg CH$_4$/head/year (Lassey et al) whereas the Australian NGGI would report 134kg methane/ head/ year under the same conditions. This is a significant difference and suggests that the NGGI methodology should be verified and improved to give confidence of the estimates for the grazing sectors.

Another quantification issue where Eckard suggested further work to be carried out is related to emissions from dairy effluent ponds. Currently there is very limited data in Australia and New Zealand.

Eckard identified options to reduce methane emissions from the dairy sector. These options are shown in Table 1.

### Table 1 – Options to Reduce Greenhouse Gas Emissions from Dairy

<table>
<thead>
<tr>
<th>Option to reduce greenhouse gas emissions</th>
<th>How</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce animal numbers</td>
<td>Reduce animal numbers</td>
<td>Reduction in animal numbers. Deregulation will impact on an initial reduction in cow numbers. Generally cow numbers are likely to continue to increase and production will move to more temperate areas.</td>
</tr>
<tr>
<td>Reduce the emissions from the animal</td>
<td>Improve the efficiency of livestock performance that results in reduced methane emissions per litre of milk produced.</td>
<td>This can be done by feeding livestock highly digestible feed such as grain or high quality pasture. The production of grain and higher quality pasture may decrease emissions from the cow but it does not take into consideration the emissions produced in producing/transporting the grain or producing higher quality pasture.</td>
</tr>
<tr>
<td></td>
<td>Rumen modifiers</td>
<td>It suppresses feed intake and suppresses acetate production, which results in reducing the amount of hydrogen released. Monensin has shown methane emission reductions but research suggests that the decrease in emissions may be short-lived. The future use of this option is uncertain.</td>
</tr>
<tr>
<td></td>
<td>Forage processing</td>
<td>The grinding and pelleting of forages can decrease methane production. This option has the potential to decrease emissions by 40% but there is likely to be high costs and not be appropriate in a pasture-based industry.</td>
</tr>
<tr>
<td></td>
<td>Dietary Fats</td>
<td>Can reduce methane through biohydration of unsaturated fatty acids, enhanced propionic acid production and protozoal inhibition This option has the potential to reduce emissions up to 37%. This option has potential for further research.</td>
</tr>
</tbody>
</table>
**Option to reduce greenhouse gas emissions**

<table>
<thead>
<tr>
<th>Option</th>
<th>How</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defaunation</td>
<td>Removing protozoa from the rumen reduces methane emissions. This may be as a result of a decreased methanogen population, altered pattern of fatty acid production or increased partial pressure of oxygen on the rumen.</td>
<td>Eckard suggested that this option can reduce methane emissions by approx. 20% but has also been identified to increase milk production. This would be a win-win for the producer. There are currently no agents available and requires further research.</td>
</tr>
<tr>
<td>Acetogenic bacteria</td>
<td>Encourage acetogenic bacteria to perform the function of removing the hydrogen instead of the methanogens. Acetogens convert CO₂ and H₂ to acetate, which the animal can use as an energy source.</td>
<td>Currently this is being researched in New Zealand. Eckard suggested that some collaborative research on this could be instigated.</td>
</tr>
<tr>
<td>Vaccination</td>
<td>The vaccine stimulates antibodies in the animal that are active in the rumen against methanogens.</td>
<td>CSIRO are carrying out research in this area.</td>
</tr>
</tbody>
</table>

**Nitrous Oxide**

Eckard said that there are two main areas of nitrous oxide emissions from the dairy sector. The highest source of change in nitrous oxide emissions is as a result of a significant increase in the use of nitrogen fertilisers in the dairy sector. More than 60% of dairy farmers are using nitrogen fertilisers and this is likely to increase. However, the single largest source of nitrous oxide is from urinary deposition and is thus related to stocking rate increases.

Nitrous oxide emissions are increased in warm water logged soils. Therefore, summer flood irrigated pastures are likely to have high nitrous oxide emissions. Eckard suggests that this should be investigated and quantified, as emission factors used in the NGGI methodology do not account for approximately one third of the national dairy industry. He estimated that in flood irrigated pasture emissions of nitrous oxide are likely to be greater than 75kg N₂O + N₂-N/ha per year, whereas in a dryland pasture it is likely to be between 7 and 12kg N₂O + N₂-N/ha per year. Eckard suggested that research into nitrogen management and irrigation management be carried out.

Opportunities and issues identified by Eckard for reducing nitrous oxide emissions include:

- Methods for reducing denitrification from flood irrigated pastures should be researched, including options for manipulating N₂O: N₂ ratios;
- Techniques for quantifying nitrous oxide emissions for the National Greenhouse Gas Inventory, or providing more regionally and industry specific emission factors;
- Irrigation techniques and systems for their emission characteristics (including the timing of irrigation); and
- Develop and encourage the use of best management practices of nitrogen fertiliser and effluent management specifically for reducing greenhouse gases.
Eckard summarised by suggesting the following actions:

- Develop better quantification of current emissions;
- Identify options for reducing methane from grazing herds;
- Gain a better understanding of the nitrous oxide emissions from flood irrigated pastures;
- Provide industry with a simple Greenhouse accounting framework or self auditing tool that can be used on-farm;
- Develop a greenhouse profile for the dairy industry;
- The self-auditing tool will allow us to carry out some case studies (“what-if” scenarios); and
- Identify synergies with other environmental issues (eg biodiversity, Environmental Management Systems and salinity initiatives).

Eckard also identified relevant research projects, including:

- Best Management Practices (BMP) for nitrogen in intensive pasture production systems (Richard Eckard);
- Soil, water and nitrogen dynamics under perennial and annual pastures (Bob White);
- Nitrous oxide from legume-based pastures in south eastern Australia (Ian Galbally);
- A Vaccine for methane mitigation in ruminants (Dr Sue Baker, CSIRO Livestock Industries); and
- Acetogens: (Dr Keith Joblin, AgResearch New Zealand and Dr Gerard Fonty, NIAR, France).

Athol V. Klieve  
Beef Industry Institute, Agency for Food and Fibre Sciences, Queensland Department of Primary Industries

Athol Klieve opened his presentation by outlining that global warming was regarded as detrimental to the long-term sustainability of the planet. He said that Australia has internationally agreed to reduce its contribution to global warming by reducing emissions of carbon dioxide and methane. Klieve said that 14% of the total greenhouse gas emissions are from livestock production and that in Queensland 80% of the total greenhouse gas emissions from the agricultural sector are enteric methane from sheep and cattle. The Dairy sector can account for 8% of enteric methane production (1996).

Klieve noted that animal production produces more greenhouse gas per $GDP than other activities and without identified reductions, the agriculture sector could be vulnerable to punitive measures (eg “carbon tax”). He identified that ABARE calculated that a “carbon tax” would reduce livestock production by 8% at 2010 and production costs would increase. This could be expected to have major negative impacts on rural economies, rural community viability and rural employment.

Klieve identified that methane was produced as a by-product of digestion by cattle and sheep. Effectively, it could be regarded as wasted feed material and energy that could be available for animal production. Methanogenesis is a microbiological mechanism to prevent hydrogen (from the fermentation of feed) building up in the rumen. Methanogenesis predominates in the rumen of cattle and sheep. There are alternatives to methanogenesis, such as reductive acetogenesis, that exist and predominate in other
ecosystems (e.g. rat caeca and termite hindgut). Reductive acetogenesis produces acetate instead of methane and acetate can be used by the animal as an energy source.

Klieve noted that reductive acetogenesis could contribute an energetic gain from feed of 4 to 15%. If three quarters of the methane generated could be channelled into animal product, then 10% of greenhouse gas emissions could be permanently eliminated. Klieve said that at the same time approximately $150 million worth of production annually (calculated as beef cattle equivalence) could be generated by Queensland’s primary producers alone. He noted that this would reverse the “carbon tax” scenario and could be expected to have significant positive impacts on rural economies, rural community viability and rural employment.

Klieve identified several strategies that could be used to reduce methane generation, these strategies include:

- **Nutritional strategies**
  - Improved efficiency of feed utilisation. Klieve said that this option has limited scope and has been pursued for the past 50 years as “production research.” He is not sure how much further, in terms of meaningful reductions in methane emission, we can progress with this approach.

- **Specific feed additives.** Klieve suggested that this option is showing promising results:
  - Additives that reduce available hydrogen could reduce methane formation; and
  - Additives that kill or inhibit protozoa or methanogens, such as oil based products (e.g. sunflower or coconut) are showing encouraging results.

- **Direct manipulation of microbial ecosystems:**
  - Reducing numbers of methanogens. Klieve said that this can be done by chemical means and may be possible using a range of bio-control strategies.

- **Reducing numbers of protozoa.**

- **Providing alternative means of removing hydrogen:**
  - Increase reductive acetogenesis by replacing methanogens with competitive acetogens.

- **Ruminal oxidation of methane by methanotrophic bacteria.**

Klieve said that the existence of both bacteria and archaeal viruses was well known. These viruses are obligate pathogens capable of rapidly killing and lysing their hosts. This can lead to dramatic reductions in population density over a short time period. A number have been isolated, including archaeal viruses from the rumen. Klieve noted that there had been very few serious attempts to use microbial viruses as bio-control agents and none of these studies were with methanogens.

Klieve identified that there was considerable interest in using bacteriocins from rumen bacteria to manipulate the rumen ecosystem. He said that Nisin was a very well known bacteriocin widely used as a preservative in the food industry and, when used as an alternative to monensin, was found to reduce the emission of methane from rumen contents by 36%.

Klieve said that the protozoa provide a habitat for 20% of rumen methanogens. These methanogens are thought to contribute up to 37% of total methane emissions. Klieve
noted that it had been demonstrated that ruminants without protozoa produce less methane and therefore the elimination of protozoa offers another opportunity to indirectly reduce rumen methane emissions.

Klieve identified that there has been a lot of good ideas put forward for reducing methane from livestock that should be pursued. However, very little was currently being undertaken. The Rumen Ecology Unit at the Queensland Department of Primary Industries is undertaking a pilot study (funded by private enterprise) to investigate the use of a feed additive to reduce emissions. The preliminary results indicate a 25% reduction in methane is possible and further funding was being sought to continue development. He also identified that funding was being sought to implement an innovative program to investigate a range of bio-control and reductive acetogenesis strategies.

Klieve was aware of, but also skeptical of, the CSIRO vaccine strategy. He said that this was the only major strategy being undertaken in Australia at the present time. However, he felt that the project used unproven technology and that there was certainly no guarantee of success. In the interests of bringing a balance to the debate on the vaccine strategy, Klieve listed half a dozen technical constraints (including the diversity of uncultured methanogens in the rumen and the likely fate of antibodies in the rumen) that would need to be overcome for any immunological strategy to be of success. He also pointed out that even if those constraints could be overcome, the maximum extent to which the vaccine strategy could reduce emissions was 20% or less.

Klieve concluded by suggesting some take home messages. He said that enteric methane from cattle and sheep is the single largest source of greenhouse gas emissions from the agricultural sector. Klieve identified that there are many strategies and potential strategies that should be investigated in order to reduce methane emissions and that no single strategy will be applicable to all farming systems. He said that, currently, only one potential abatement strategy is being developed (the vaccine), whereas a multi-directional approach should be pursued to maximise chances of success. If the vaccine strategy fails then there is, at present, no fall back position and even the success of this strategy would still leave 80% of emissions unabated. This leaves Australia’s livestock industries exposed to further risk in the future. He believed that if Australia is serious about abating methane emissions then more needs to be done.

Tom Denmead
CSIRO Land and Water, Canberra

Nitrous oxide (N\textsubscript{2}O) is a colourless, odourless gas with an atmospheric concentration of about 315 ppb and is increasing at close to 1 ppb/yr. It is a greenhouse gas with a global warming potential of about 310 molecule for molecule, absorbing 250 times as much radiation as CO\textsubscript{2}. Nitrous oxide has a 120 year lifespan in the atmosphere and is eventually destroyed in the stratosphere, where it then plays a part in ozone chemistry.

Oceans and soils are natural sources of nitrous oxide. There are two main man-made sources – nitrogen fertiliser use and (management of) animal wastes. Other man-made sources include catalytic converters, biomass burning and adipic acid (used in manufacture of nylon). Overall agriculture is the source for between 80 and 90% of all nitrous oxide emitted into the atmosphere.

According to Denmead global pastures and animal grazing contribute 28% of all man-made nitrous oxide emissions. It is formed naturally in soils by microbial action (during
the conversion of the nitrogen mineral to nitrate, and by denitrification of nitrate under anaerobic, waterlogged conditions). Fertilisers and legumes increase the soil nitrogen pool. Legumes can increase nitrous oxide emissions from pasture soils by about 2 or 3 times. Animal wastes (urine and dung) greatly increase the soil nitrogen pool in grazed pastures (a sheep urine patch contributes 400kg N/ha at the surface). The National Greenhouse Gas Inventory (NGGI) has algorithms for estimating nitrous oxide production which are based almost wholly on extrapolating results of chamber experiments to the field scale. Denmead suggests that there is a need to extend the database through direct measurements at larger scales.

There are several methods of measuring nitrous oxide emissions. Denmead describes both the bottom-up and top-down methods. Chamber, mass-balance and line source experiments are bottom up methods\(^3\). The top-down approaches, namely Flux-gradient and Convective Boundary Layer (CBL) techniques, involve inferring paddock and regional-scale emissions from atmospheric signatures. This can be done for areas of between 2Ha to 104Ha.

Denmead notes that all of the methods except for the Chamber Method can be used to measure methane emissions simultaneously.

Denmead suggests two main areas that could be used as nitrous oxide mitigation strategies:

- Match the nitrogen supply with plant demand (this requires soil and plant tests for nitrogen fertiliser requirements and split applications of nitrogen fertilisers); and
- Tighten nitrogen flow cycles (through the integration of animal and crop production).

The use of advanced fertiliser techniques include:

- Controlled release fertilizers;
- Deep fertiliser placement;
- Foliar fertiliser application;
- Use of urease and nitrification inhibitors; and
- Match fertilizer type to precipitation.

Denmead also suggests the optimisation of irrigation and drainage to avoid denitrification could be achieved by using spray irrigation instead of flood irrigation of pastures. He suggested keeping the water filled porosity to less than 70% would assist this process.

Denmead suggested future areas where further research is required:

- Reducing uncertainties relating to the emission factors used in the NGGI.
- Reducing spatial and temporal variability of measuring nitrous oxide, which is high (e.g. soil variations in N\(_2\)O emission can vary 10-fold within 10 metres, emissions can vary 10-fold with changes in soil moisture status and emissions persist for a long time (up to 10 years)).
- Increasing certainty regarding strategic planning, modelling and inventory estimation; and
- Undertaking high quality measurement program, using a range of techniques extending to the paddock scale and using long time scales.

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\(^3\) The Chamber method is used for measuring emissions from soils and is carried out by placing enclosures over the soil and measuring the rate of nitrous oxide increase in the headspace. Typically, the chamber size is about 1m\(^2\) and soil variability is very large. The Mass-balance and line-source experiments uses direct field measurements created by a known number of animals in a known space or grouped in a known geometry. Denmead suggests that this is appropriate for a few cattle but difficult with large samples.
Summary of Workshop Discussions

Workshop participants were asked to identify the top three strategic directions or priorities that the dairy industry requires to reduce net greenhouse gas emissions. The participants suggested that a strategic approach for the dairy sector was required and identified 6 key areas that the industry should concentrate on. Figure 1 highlights the top priorities which are further discussed below.

Figure 1: Top strategic Priorities

- Ensure a strategic approach is taken for Dairy Sector to reduce GG emissions
  - Develop an Action plan that includes R&D activities and the following
  - Raise awareness and promote practice change to dairy producers and industry
  - Improve the quantification of GG Emissions from dairy
  - A better understanding of different management options on GG Emissions and develop BMP guidelines
  - Develop modelling tool that can estimate GG emissions to on farm
  - Feedback measures into BMP
  - Create baseline data
  - Improve the accuracy of N2O measurements
  - Rumen Management
  - Effluent methane Utilisation
  - Soil Management
  - Irrigation Management
  - Develop modelling tool that can be used to measure on farm
  - Note: GG refers to Greenhouse gases

Three of these key areas were further examined at the workshop discussions and potential further action was identified. The following is a summary of the groups’ findings and actions.

Improve the quantification of greenhouse gas emissions from the dairy sector

Participants identified the needs for baseline data to improve the accuracy of greenhouse gas emission measurements, particularly for nitrous oxide and methane. Participants suggested that greenhouse gas emissions should be quantified for the cow, soil (dry and irrigated), effluent and farm operations. Sink opportunities should be identified. There is also a need for quantifying greenhouse gas emissions at various scales for the dairy sector including on farm, catchment and whole of industry.
Develop a better understanding of the different management options for greenhouse gas (mostly methane) abatement and develop best management practices.

Participants identified four main areas of farm system management that should be investigated for the greenhouse gas abatement potentials/characteristics. These areas are:

- Rumen management;
- Irrigation management;
- Effluent methane utilisation; and
- Soil management.

These options are discussed in the following section. Information developed from these areas should be used to develop best management practice (BMP) guidelines for greenhouse gas abatement. Other areas that should be examined and incorporated in BMP guidelines include:

- Fertiliser management and the possibilities for reducing nitrous oxide emissions;
- The production of seed on farms may reduce transport emissions;
- On farm energy consumption, i.e. pre-cooling of milk via heat exchange;
- Optimal stocking rates to minimise methane/unit milk;
- The effects of feed additives on CH$_4$ emissions (including chemicals, oilseeds); and
- Bio-control options, for example bacteriocins, viruses and protozoal removal. These options would include an alternative method of removing hydrogen from the rumen, such as reductive acetogenesis.

**Rumen Management**

Participants identified that there is a large error percentage in estimating emissions from the rumen (±20%) but the overall emissions were high and need to be clarified. Issues requiring clarification as part of rumen management include:

- Examining whether there are regional emission differences;
- Identifying greenhouse gas emission between different feedbase and forage;
- Quantifying the effects of feed additives on methane emissions. Available options include chemicals and oil seeds and possible future options are bio-control and alternative hydrogen sinks;
- Identifying the greenhouse gas emission impact of feed supplements;
- Investigating whether there are breeding options for cows that emit less greenhouse gases;
- Investigating the effects of the stage of lactation and time of year on methane production (this is likely to be closely linked to changes in feed quality);
- Better measurement methods including measurements that can be carried out in the paddock; and
- Input to refining the National Greenhouse Gas Inventory (NGGI)

The participants recommended two options for reducing emissions that could be applied immediately:

- Balancing rations – forage base, supplements and stage of forage growth; and
- Adjusting stocking rate (which will require some investigation of optimal stocking rates to minimise methane/unit of milk).
Irrigation management

According to Eckard et al (2000), the greatest loss of nitrous oxide is from irrigated dairy pastures. Workshop participants identified the need to quantify the impact of different irrigation practices. This information and existing research on the different irrigation practices and their influence on nitrous oxide emissions should be used to develop BMP. An understanding of the linkages between irrigation management and fertiliser application and their combined impact on nitrous oxide emissions should be investigated. The participants suggested that information was available about irrigation techniques but the size of the effects were unknown.

The participants in this group identified the strong need for extension activities to distribute BMP developed with greenhouse gas abatement. However they also questioned the costs of implementing changes and the penalties likely to be imposed on farmers i.e. what incentives are there for farmers to make the changes? Are there benefits other than greenhouse gas abatement benefits – such as increasing water use efficiency?

Effluent methane utilisation

Participants suggested that a desktop review or audit be carried out on Australian and international research on effluent management utilisation. They also suggested that a cost benefit analysis be carried out on the effluent management options in terms of greenhouse gas abatement and costs for producer to implement.

Develop whole farm emissions modelling and decision support tools to assess impacts of change

The participants suggested the aims of decision support tool should be to:
- Quantify change of outputs compared with change in farm practice;
- Quantify benefits to producers; and
- Identify gaps in knowledge.

Participants suggested that the existing framework should be accepted for use at farm, regional, state, national and industry-wide scales. There should be some desktop work carried out on identifying what is currently known. Information on the following should be collated:
- Fertiliser input;
- Cow feed management;
- Soil management;
- Effluent management; and
- Seasonal impacts.

The tool should be used for benchmarking, auditing, conducting sensitivity analyses, identifying sources and sinks and understanding information at different scales (paddock, farm, region etc).
Communication and Extension

Participants suggested that there is a need to identify current level of knowledge of the industry and producers. This information can then be used to address the gaps and measure the change of knowledge over time. Participants felt that there should be a two stage process starting with a clear, simple and farmer-friendly information to get the message out. Then extension officers should help explain the detail to those most interested. The second stage is where farmers start to distribute the information amongst themselves through their own experiences or demonstrations and fields days. This second stage aims to give the producers ownership of the methods and therefore they are more likely to adopt changes to their practices. The participants suggested that the message should join with other environmental issues such as environmental management systems.
**Key messages from Workshop**

The dairy industry has already carried out some work on greenhouse gas abatement options. This workshop built on previous activities by generating valuable discussions and identifying gaps in activities in Australia. Overall, the participants felt that a strategic coordinated approach was paramount.

**Research and Development**

The Participants identified several areas where research and development is required, these are:

- To better quantify greenhouse gas emissions from dairy and refine the measurement techniques to improve the confidence of the data to the industry;
- Develop a better understanding of the greenhouse gas emissions of different management options and their greenhouse gas emission characteristics;
- Identify management options that reduce greenhouse gas emissions for the four management areas identified (rumen management, irrigation management, effluent reuse and soil management. For example, at the workshop there were several options identified for reducing emissions from the rumen eg reducing the populations of methanogens and protozoa. The participants felt that more than one option should be researched).

Some of the research requirements identified by participants are required across the livestock sector generally. Information required that is unique to dairy, compared with other livestock workshops (sheep and beef), relates to irrigation management and this information is required by other sectors, such as the field cropping sectors.

Participants suggested a whole farm emission-modelling tool be developed to identify sources and sinks on farm. The model should incorporate results of the greenhouse gas abatement characteristics of management options and be used at farm and industry scales.

The participants put particular emphasis on encouraging adoption of best management practices by the industry. To do this best management practices for greenhouse gas abatement should be developed, and incorporated with other environmental issues.

**Communication and Extension**

There is a need to identify the gaps in the industries knowledge of greenhouse issues and then educate the industry on these gaps. However, the participants felt that the information that is currently known and the proposed research should be packaged and communicated to the producer and industry. There will be a need to update producers and industry on options and research results as they become available.

**Institutional Impediments**

Institutional impediments were identified specifically relating to the research and development organisations. Participants felt that the research and development activities should be carried out collaboratively. This can be difficult as many of the research organisations are seen to compete for funding.

Governments, both Commonwealth and State and Territory, need to work together to ensure that the same messages are delivered and similar activities are carried out constructively. Participants identified that there needed to be a coordinated approach for agricultural industries and across the States and Territories.
Further Information and References

Agriculture, Fisheries and Forestry Australia (www.affa.gov.au)


Australian Greenhouse Office (www.greenhouse.gov.au)


CSIRO Atmospheric Research & Sustainable Ecosystems (www.csiro.au)


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