NSW GOVERNMENT | Industry & Investment

Background Paper
climate

I&I NSW – PROFITABLE, ADAPTIVE AND SUSTAINABLE PRIMARY INDUSTRIES IN NSW

Background Paper - climate

This paper reports on Climate Change Priority Actions and was prepared for the NSW Department of Primary Industries Board of Management.

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Authors

Jason Crean
Helen Fairweather
Ron Hacker
Bob Martin
Brad Mullard
James Scandol
Helen Scott-Orr
Rob Young

Addressing Climate Change: Priority Actions for NSW DPI
Executive Summary

Introduction

Following a facilitated workshop in October 2007 a cross divisional working group identified a range of priority actions for DPI to address the significant challenges posed by climate change. Members of the working group are listed in Attachment 1. The accompanying full report outlines the logic behind the actions summarised here.

The programs cover the three broad themes of climate change:

1. Assessing the ***impacts*** of climate change on primary producers;
2. Developing ***adaptation and transition*** strategies to help primary producers cope with those impacts or transition to alternative activities where impacts are likely to exceed their coping ability; and
3. Developing options to ***mitigate*** greenhouse gas emissions.

This executive summary outlines the objectives of each theme, the recommended actions to achieve those objectives and the outcomes expected from implementing those actions.

In preparing the report four broad areas of activity emerged under each theme:

1. Developing new biophysical knowledge

Quantifying the socio-economic implications of climate change and actions to address it

2. Developing information, education and training programs for a range of stakeholders and
3. Policy development

The priority actions are presented as a series of programs which cover:

Impact

- Quantifying the projected impacts of climate change on primary industries
- Monitoring those impacts

Adaptation and Transition

- Options for production systems (agriculture, plantation forestry, aquaculture and mining) to adapt to climate change
- Options for natural and wild harvest systems (native forests and wild harvest fisheries) to adapt to climate change
- Biosecurity responses for all primary industry sectors
- Emergency management responses across all primary industries
- Preparing communities for change

Mitigation

- Developing cost effective accounting methods
- Reducing methane emissions from ruminant livestock
- Reducing nitrous oxide emissions from agriculture
- sequestering carbon in agriculture and forest soils
- sequestering carbon in forests and in forest products
- Reducing DPI's own greenhouse footprint
- Bioenergy
- Reducing emissions via clean coal
- The role of emissions trading

Cross - Cutting

- Socio-economic assessment
- Information, education and training
- Policy

Actions are presented as a series of programs which are numbered using an alpha-numeric system ("I" is the prefix for "*Impacts*"; "A" for "*Adaptation and Transition*"; "M" for "*Mitigation*"; and "C" for "*Cross Cutting*"). This numbering provides a cross reference to the recommended programs in the main report.

The recommended programs are outlined in full below.

Impacts Theme

Objective: *Provide knowledge to inform decision making regarding the impacts of climate change on primary industries in NSW*.

This theme involves statistical and dynamic modelling as well as experimental studies to quantify the projected impacts of climate change on primary industries, assess the capacity of primary industries to cope with those impacts and monitor changes due to climate change in order to inform the development of climate change policy and adaptation strategies.

Program I1: Forecasting future climate change impacts on primary industries.

Project I1.1: Develop expertise in the application of downscaled global circulation model outputs to simulation models and other analyses of primary industries.
This project will develop the necessary expertise to apply the results from Global Circulation Models (GCMs) to issues associated with primary industries in NSW. The downscaled results will be presented in a form that is accessible to researchers and policymakers and will include documentation of uncertainties and caveats.

Note: this project will use the outputs from GCMs developed by CSIRO, the Bureau of Meteorology and others and apply them to determine impacts on primary industries in NSW. DPI will not undertake GCM modelling.

Project I1.2: Define the coping range/resilience of key production systems in each primary industry sector.
This project will predict the susceptibility of key production systems to forecast changes in climate variables (eg carbon dioxide, temperature, rainfall, evaporation, stream flow). The activities in this project will include both experimental and modelling work and will have linkages to projects in the adaptation themes. These projects will be at a production system scale (e.g. crop or forest type, estuaries, etc).

Project I1.3: Apply models and climate change data sets to forecast the impacts of climate change, their probability of occurrence and their resultant consequence on primary industries production systems.
This project will link the land use monitoring data (from *Project I2.1*) and the results of research on the susceptibility (including the coping range) of primary production (from *Project I1.2*) to changes in climate variables. By linking the probabilistic climate scenarios to this spatially explicit information, regional risk assessments (at various time-points in the future) will be generated. More detailed models will be able to capture the varying ability of systems to adapt to gradual or sudden changes in climate variables.

Project I1.4: Forecast the impacts of climate change on aquatic ecosystems.
This includes consideration of decreased or more variable flows in rivers (and thence estuaries), increased sea level, increased temperature, increased ocean acidity and changed recruitment patterns. The outcomes from this project will feed directly into program 10 (*adaptation strategies for wild harvest fisheries*).

Project I1.5: Estimate the biosecurity risks associated with climate change.
Risk-based methods will be applied to address biosecurity issues including consideration of the likely behaviour of both endemic and exotic pests and diseases. This will be similar to *Project I1.3* but focus on biosecurity issues only for agriculture, forestry and fisheries.

Project I1.6: Forecast the expected changes in Emergency Management support that is likely to result from climate change.
There will likely be shifts in extreme weather events (eg fire, flood, drought, extreme heat) that will affect EM in NSW. DPI will work closely with the State Emergency Management Committee Climate Change Working Group to examine these issues.

Program I2: Monitoring the Impacts of Climate Change on NSW Primary Industries

Project I2.1 Spatial monitoring of land use and coastal geomorphology.
This project will develop an understanding the current status of the primary industries resource base for informing the spatial extent and magnitude of climate change impacts. Inputs include remotely-sensed data (aerial photography and satellite imagery) as well as spatially explicit sampling of terrestrial and aquatic ecosystems. The project will include the identification of indicators that can be used to validate predictive models. Although this project will have a spatial/mapping focus, it will be closely linked to time-series project (*I2.2* below).

Project I2.2 Time series of production indicators and climate indices.
This project will collate and report time-series data for validating predictive models and provide a direct understanding of climate changes that are occurring. This will inform the predictive models in Impacts Program 1 as well as the adaptive responses being developed by the *Adaptation and Transition* Theme. Other statutory responsibilities of DPI for forest and aquatic resources (including the likely integration of climate change issues with the state-wide MER program) will be addressed within this project. This project must be capable of distinguishing the synergistic effects of non-climate stressors (pollution, inappropriate land use, exotic pests, modification / loss of aquatic habitat) from climate change impacts.

Note: Evaluating the socio-economic impacts of climate change
It is critical to provide an assessment of the socio-economic impacts of climate change on primary industry sectors at both the industry and enterprise unit scale. Such analyses are required for all themes in this report (*Impacts; Adaptation and Transition;* and *Mitigation*). For simplicity, socio-economic assessment is presented as *Cross Cutting Program C1*, towards the end of this document.

Note: Communication, education, extension and training to address climate change
This is a critically important aspect of addressing climate change. As with socio-economic assessment, this is a cross cutting theme that is outlined in more detail in *Cross Cutting ProgramC2*, towards the end of this document.

Note: Developing policy to address climate change
A range of policy issues are outlined throughout the climate change strategy. In terms of impact assessment, key policy issues include:

- coordinating national action on climate change (through COAG, PISC and the NSW Climate Changes CEOs)
- securing the resources necessary to implement this strategy

As with other cross cutting issues, policy issues have been aggregated (with issues such as setting emissions targets and emissions trading) and are presented in *Cross Cutting Program C3*, towards the end of this document.

Outcome of the Impacts Theme:
Impacts of climate change on primary industries in NSW quantified, evaluated and communicated to key stakeholders.

Adaptation and Transition Theme

Objective: *To provide options for primary producers to adapt their operations to the anticipated future climate in which they will operate and inform the process of transition for industries unlikely to cope with the magnitude of expected changes.*

Based on the projected impacts of climate change on primary industries (from the "*Impacts*" theme), the "*Adaptation and Transition"* theme will identify options to increase the flexibility and resilience of primary

production systems and the capacity of wild harvest systems to adapt to those impacts. It will also inform policy decisions to facilitate transition (structural adjustment) for those industries unlikely to be able to cope with the expected rate of change.

Production Systems (agriculture, plantation forestry, aquaculture and mining)
This work will be field based predominantly but the results will be tested for application to future climates by using the same models applied to impact assessment.

Agriculture

Program A1: Adaptation strategies for the livestock industries

This program will include a range of projects aimed at building greater flexibility and resilience into livestock management systems, and understanding the natural capacity of pasture resources to adapt to the expected rate of change. It will include projects related to:

- pasture pre-breeding to achieve greater resilience to extreme climatic conditions
- multi-species pasture or pasture-crop systems for greater continuity of production and increased flexibility
- fodder conservation, storage and feedout strategies that maximise opportunities of high feed availability events and reduce impact of low feed events
- the productivity and grazing characteristics of new sheep breeds in western NSW
- improved carcase characteristics and eating quality of adaptive beef cattle breeds
- the impact of intensive grazing management practices on the functioning of water limited ecosystems
- assessment of the genetic capacity of vegetation communities (particularly in the rangelands) to adapt to climate change
- the integration of C3 and C4 pasture species in the livestock feed base
- management of pests, diseases and weeds (see *Program A11*)

Program A2: Adaptation strategies for broadacre cropping

This program will include a range of projects aimed at increasing the flexibility and resilience of cropping and mixed farming systems through:

- crop pre-breeding to achieve greater resilience to extreme climatic conditions
- increased efficiency of water and fertiliser use
- better integration of livestock and cropping in mixed farming systems (livestock are likely to be less affected by climate variability than crops)
- better utilisation by livestock of crop residue and low quality roughage by supplementary feeding technology
- incorporation of perennial species of both crops and pastures into farming systems
- management of pests, diseases and weeds (see *Program A11*)

Program A3: Adaptation strategies for intensive cropping (horticulture and viticulture)

- This program will include projects aimed at developing strategies to address:
- the effects of elevated temperature and CO_2 on tree and vine phenology and fruit quality
- the impact of variable seasonal and annual water supply on tree and vine productivity and fruit composition
- the potential value of varieties and rootstocks from hotter and dryer environments
- management of pests, diseases and weeds (see adaptation program 11)

Similar projects will be required to identify adaptation strategies for annual horticultural crops.

Program A4: Adaptation strategies for irrigation industries

This program will build on analyses undertaken as part of *Impacts Program 1*, as well as other collaborative initiatives (e.g. the South Eastern Australia Climate Change Initiative (SEACI) and the

CSIRO Sustainable Yields project) which will assess the impact of climate change on water availability and allocation. It will include projects related to:

- precision management of soil moisture to reduce evapotranspiration losses (with added mitigation benefits of sequestering CO_2 and minimising emissions of nitrous oxide)
- testing of crop factors/coefficients for water use under increased or more variable temperature regimes
- development of efficient but less energy-intensive irrigation systems
- re-evaluation of the economic efficiency of fertiliser use
- development of "real options" methodology for economic evaluation of investment in water supply and on-farm infrastructure

Program A5 - Improved risk management tools for farming enterprises

This program will include the development of:

- a whole farm decision support tool/workshop, based on the current 'Ri$ky Business' workshop and the 'P2P' (Plan to Profit) farm business scenario analysis software. It will allow the evaluation of alternative adaptation scenarios aimed at maintaining profitability in a changing climate
- a web-based tool to assist decisions relating to the level and timing of fertiliser application in relation to current seasonal conditions and the seasonal outlook
- a web-based tool, based on the PaddockGRASP concept, to allow a risk-based approach to stocking rate decision making
- a web based tool to allow livestock producers to match market requirements to available pasture or feeding regimes to both maintain a sustainable pasture base and meet economic market outcomes
- tools to improve management of pests, diseases and weeds

Plantation Forestry

Program A6: Adaptation strategies for Plantation Forestry

This program will include:

- research into the interactive effects of increased atmospheric carbon dioxide in a water and nutrient-limited environment on the growth of major forest species
- research into the breeding of tree species for low rainfall and drought conditions
- modification of silvicultural practices, such as site preparation, establishment and thinning to optimise both timber volume and carbon pool management
- harvest strategies to optimise both timber and carbon pool management
- fire management under climate change
- managing forest health under climate change
- management of assets including road based infrastructure
- assessing the impacts of forest management and reafforestation on water yield to catchments and water quality

Aquaculture

Program A7: Adaptation strategies for aquaculture

This program will:

- develop new techniques to maintain productivity of oysters and other molluscs; and fin fish and crustaceans in the face of elevated and increasingly variable temperature and elevated CO_2
- identify and evaluate new species and cultivation technologies to adapt to changing environmental conditions (including new biosecurity risks)
- identify new lease areas for future oyster and mollusc farming and evaluate options for securing them

Mining

Program A8: Adaptation strategies for the mining sector

This program relies intrinsically on the outputs from program 1 of the *Impacts* theme and Cross Cutting Program 2: "*Communicating with stakeholders on climate change*" to inform the mining sector and regulatory authorities of the additional risks posed by climate change so they can adapt their risk management strategies (eg adjusting the prescriptions for retention ponds).

Natural and Wild Harvest Systems (native forests and wild harvest fisheries)

Program A9: Adaptation strategies for native forests

Several issues are similar to those for plantation forestry. Within the context of a risk-based, ecosystem-based, commercial native forest management system, this program will:

- determine the interactive effects of increased atmospheric carbon dioxide in a water and nutrient-limited environment on the growth of major forest species
- determine sustainable harvest strategies in terms of timber yields and carbon pool management while maintaining key environmental outcomes, such as biodiversity, catchment water yield and water quality
- fire management under climate change
- Managing forest health under climate change
- management of assets including road based infrastructure under more extreme climatic events
- identify key ecological indicators to be monitored to ensure sustainable management under projected climate change impacts and harvest scenarios

Program A10: Adaptation strategies for wild harvest fisheries (commercial and recreational)

Within the context of a risk-based, ecosystem-based fisheries management (EBFM) framework, this program will:

- define sustainable wild harvest strategies for key species while maintaining natural biodiversity values under the range of impacts of climate change identified in *Program I1.4* (eg decreased or more variable freshwater flows in rivers - and thence into estuaries, rising sea levels, increased temperature, increased ocean acidity and changed recruitment patterns)
- identify the long term impacts of land development on water quality, fish production and habitat
- predict trends in key ecological indicators that will be monitored under changed climate and harvest scenarios

Program A11: Adaptation strategies for biosecurity

This program goes across all production and wild harvest systems in agriculture, forestry and fisheries. It will:

- quantify the impact of climate change on the distribution (geographic range) of key aquatic and terrestrial pests, diseases and weeds
- undertake an initial assessment of the most effective strategies to address these threats
- model likely changes in pest distribution (geographic range) under climate change (*Impacts Project 1.5*)
- undertake experimental studies on the effect of changed and interacting climate variables on host-pest relationships and resultant modification of integrated pest management and pesticide resistance management strategies
- develop management or control strategies for high priority biosecurity threats

Program A12: Adaptation strategies for emergency management

This program goes across all production and wild harvest systems in agriculture, forestry, mining and fisheries. It will:

- Work with the State Emergency Management Committee Climate Change Working Group to develop response strategies to address the forecast greater incidence of extreme weather-related events due to climate change
- allocate resources to implement response strategies

Note: Preparing Communities for change

Analysis of the socio-economic impacts on industries, enterprises and regional economies of adaptation options, and of policy options to promote transition to alternative industries or forms of land use, for regions and industries where adaptive technologies alone are unlikely to ensure the continuation of economically or ecologically viable industries. Examples could include:

- some irrigation industries and schemes
- some perennial horticulture
- the marginal cropping zone
- rangeland pastoral industries
- some aquaculture and wild harvest fisheries industries
- some plantation forestry

These issues are picked up in the *Socio-economic Evaluation* cross cutting *Program C1.2* outlined towards the end of this document.

NSW DPI will adopt a knowledge brokering and mediating role in building community capacity for change through collaboration in development and dissemination of science-based information, appropriate adult learning E&T packages, change management, and support for structural adjustment policies and programs.

The major communication elements of the Adaptation and Transition Theme are picked up as part of a cross cutting *Information, Education and Training* program (*Program C2*).

A key policy issue relating to adaptation and transition will be ensuring the adequacy of structural adjustment programs for those industries likely to be most affected by climate change. This, along with other policy issues, is dealt with in cross cutting *program C3.*

Outcomes of Adaptation and Transition Theme:

Primary producers have viable and sustainable options to adapt their operations to cope with climate change impacts. Policy decisions to facilitate transition (structural adjustment) for those industries unlikely to be able to adapt to the expected rate of change are well informed.

Mitigation theme

Objectives: *Develop low cost methods to quantify the net greenhouse gas emissions from primary industries; quantify the carbon footprint of key primary industries; develop sustainable options for primary industries to reduce their net emissions, sequester carbon and produce bioenergy to replace fossil fuels; and inform the possible participation of the agriculture, forestry and mining sectors in a national emissions trading scheme.*

Mitigation technologies for Agriculture, Forestry and Fisheries

Program M1: Emissions measurement, modelling and accounting in agriculture and forestry systems

This program will:

- develop cost effective GHG measurement, accounting and modelling techniques to quantify
    a) the principal greenhouse gases emitted by agriculture and forestry systems (methane, nitrous oxide and carbon dioxide)
    b) the amount of carbon sequestered above and below ground by key agriculture and forestry systems
- apply accounting techniques to quantify the greenhouse balance of key agriculture and forestry systems in NSW to better inform the national carbon accounting system (NCAS) and the possible role of agriculture and forestry in a national emissions trading scheme (link to Mitigation Program 8)

- develop and apply methods to quantify, on an energy balance and life cycle analyses (LCA) basis, the whole of life greenhouse footprint of current and potential new agriculture and forestry systems (eg for bioenergy)
- Note: the NCAS does not adopt an LCA approach. Emissions from upstream activities (eg inputs such as fuel and fertiliser) and downstream activities (eg transport and processing) are attributed to other sectors of the economy in order to avoid double counting. LCA is important for comparing options – such as cropping for biofuel Vs food
- consider the broader environmental (water, soil, biodiversity) and socio-economic implications of proposed new agriculture and forestry production systems
- develop, validate and promote an enterprise (eg farm) level emissions calculator for agriculture and forestry

Program M2: Reduce methane emissions from livestock

Because methane (largely from ruminant livestock) accounts for over 65% of agricultural emissions, DPI will establish a national methane emissions reduction centre to:

- develop cost effective methods to quantify methane emissions from ruminant livestock at an individual farm level that are consistent with NCAS
- quantify methane emissions from ruminant livestock in both pasture and grain fed systems and incorporate results into greenhouse balance calculations for those systems
- identify options to reduce methane emissions from ruminant livestock by:
    - understanding the genetic control of low methane-emitting ruminant phenotypes and its value as a breeding objective
    - manipulating rumen ecology
    - improving feed conversion efficiency
- accelerate implementation of methane capture from intensive animal industry wastes
- help promote low greenhouse balance production systems for ruminant livestock both nationally and to other countries with high ruminant populations

Program M3: Reduce nitrous oxide emissions from agriculture

Nitrous oxide is the major greenhouse gas emitted from agricultural cropping systems. This program will evaluate options to reduce nitrous oxide emissions such as:

- more efficient use of nitrogen fertiliser/legumes
- adjusting application rates, timing and placement (precision agriculture) to match uptake
- slow release fertilisers or composts, nitrification inhibitors (particularly the role of biochar)
- better management of rotations

Program M4: Increase carbon storage in agricultural systems

This program will evaluate options for increasing carbon sequestered above and below ground in agricultural systems through:

- improved cropland management (eg improved crop rotations reduced or zero tillage, soil amendments such as biochar, mulches or biosolids, perennial pasture in rotations, etc)
- improved grazing land management (eg better matching grazing pressure to pasture growth, deep rooted perennial grasses, herbs and shrubs)
- agronomic practices (eg improved fertiliser mgt, better soil moisture mgt, opportunistic cropping)
- better management of native vegetation on agricultural land (eg shelter belts, wood lots, riparian revegetation, degraded lands)
- quantification of multiple benefits from native vegetation management (carbon, biodiversity, water and salt management)
- short rotation woody crops for essential oils (eg mallee), charcoal, etc
- organic amendments, such as biochar, biosolids and compost to sequester carbon in soil, reduce emissions of non CO_2 greenhouse gases and improve soil physical, chemical and biological characteristics. Particular emphasis will be focussed on biochar - the most promising current prospect

This program will include:

- the maintenance of existing and, where necessary, establishment of new long term research and demonstration sites to provide credible data on the greenhouse footprint of agricultural systems, evaluate carbon sequestration options and validate greenhouse accounting models

Program M5: Mitigation technologies for Forestry

This program will

- evaluate harvest and management strategies to minimise emissions of greenhouse gases and maximise carbon sequestration from various plantation and native forest operations
- evaluate options for the expansion of forests in high and medium rainfall areas of the state
- quantify the net greenhouse balance of converting agricultural land to plantation forestry for relevant agriculture and forest systems
- quantify the amount of carbon stored in wood products from an LCA perspective for softwood and hardwood plantation and native forest systems for the range of forest products produced
- explore options for the inclusion of timber products in the national emissions trading scheme
- compare timber to alternative building products from an LCA perspective to inform building design guidelines
- evaluate the role of soil amendments (such as biosolids and biochar) in reducing net greenhouse gas emissions, nutrient and moisture management and carbon sequestration in plantation forestry

This program will include:

- maintenance of existing and, where necessary, establishment of new long term forestry research and demonstration sites to evaluate a range of low rainfall species, establishment and management techniques

Program M6: Reduce NSW DPI's carbon footprint

This program will:

- extend NSW DPI's existing energy efficiency program to cover all sources and sinks of greenhouse gases arising from NSW DPI's operations
- include air and car transport and better use of ICT to reduce travel
- develop and implement improved building and maintenance guidelines that take account of lifecycle greenhouse footprint of building materials
- demonstrate best practice farm and land use management actions
- create an intranet staff forum on energy saving opportunities to encourage staff engagement.

Program M7: Bioenergy research program

This program will:

- assess current and potential biomass resources in NSW to evaluate the potential for a viable and sustainable bioenergy industry in NSW
- develop farming systems that include woody perennials, such as short rotation woody species and agroforestry
- develop management systems to prevent biomass from becoming weeds
- research sustainable harvesting systems for selected biomass (including weeds)
- evaluate algal biomass production options
- develop and evaluate technologies to convert biomass to bioenergy (including ligno-cellulose to ethanol, pyrolysis, burning of biomass for energy, etc)
- assess the net greenhouse balance of bioenergy production systems using the methodology outlined in *Program M1*

Program M8: Clean Coal technologies

There are two components to this program.

M8.1: Geosequestration

This project will:

- identify and characterise sites for storing compressed carbon dioxide in deep geological strata and/or aquifers in NSW. This is part of an integrated program to develop and demonstrate post combustion CO_2 capture (from coal dependent industries such as power generation) and the safe transport and storage of that compressed CO_2. DPI's role will focus on the storage component of the project - where we have expertise).
- DPI will lead an national working group on CO_2 transport and storage

M8.2: Fugitive methane emissions from coal mining

This activity will, in collaboration with the NSW Minerals Council and regulatory authorities:

- participate in discussions with the commonwealth who have responsibility to document baselines and subsequent improvement to allow miners' participation in a national emissions trading scheme
- inform the development of appropriate NSW policies to reduce fugitive methane emissions from coal mining (administered by the Department of Planning)

Program M9: Multifaceted research into the policy implications of an emissions trading scheme on primary industries

This program will:

- review different policy approaches to control of non-point source pollution
- assess the economic implications of an ETS on primary industries including:
    - likely impact of an ETS (irrespective of the inclusion of primary industries) on the price of inputs used in primary industries (fuel, electricity, fertiliser, chemicals) and resultant prices for primary products and food
    - the marginal costs of emission abatement and sensitivity of land uses to emission prices based on the current carbon footprint of key agricultural and forestry sectors and the various mitigation options that are feasible in those sectors
    - likely impact on farm profitability for key agricultural systems
- assess plausible features of an ETS scheme from the perspective of primary industries such as:
    - initial or delayed entry
    - baseline period for recognition of emissions
    - method of allocating emission rights (grand-fathering versus auction)
    - phasing in of reductions in emission rights
    - point of obligation requirements
    - partial or full industry coverage
    - options to minimise transaction costs
- evaluate the role of the mitigation options outlined in Mitigation Programs above in a national emissions trading scheme (ETS)
- engage with key stakeholders on the merits of being included in an ETS and to develop strategies for effective participation
- assess how other environmental priorities could be integrated with the incentives provided by an ETS to achieve multiple environmental benefits (biodiversity, salinity, water quality).

Socio-economic issues are picked up in the *Socio-economic assessment* cross cutting *Program C1.2*.

The major communication elements of the Adaptation and Transition Theme are picked up as part of a cross cutting *Information, Education and Training* program (*Program C2*).

Policy development is a key aspect of climate change mitigation. This, along with other policy issues, is dealt with in cross cutting *program C3.*

Outcomes of Mitigation Theme:
Cost effective methodologies to quantify the net greenhouse gas emissions from primary industries developed, validated and adopted; the greenhouse footprint of key primary industries quantified; sustainable options to reduce net greenhouse gas emissions, sequester Carbon and produce bioenergy developed and adopted by primary producers; and options for agriculture and forestry to participate in a national emissions trading scheme evaluated resulting in appropriate policy prescriptions being included in national legislation.

Cross Cutting Programs

Three keys issues have arisen across all themes in this report. They are:

- Socio-economic assessment;
- Information, education and training; and
- Policy development.

While these issues have been raised under each theme, the proposed programs to address them are listed here as cross cutting programs. This will simplify the process of determining resource requirements for their implementation.

However, it is important that these programs not be established in isolation either of each other, or of other programs to address climate change. Cross disciplinary and cross divisional teams will be required to adequately address the challenge of climate change.

Program C1: Socio-economic assessment of climate change

Objective: *Assess the economic impact of climate change on primary industry sectors to inform the development of effective policy and guide adaptation and mitigation responses by primary industries.*

The relationship between the cross cutting theme and other themes in the climate change strategy is shown in Figure 1. Work in the cross-cutting theme is based around the economic assessment of the biophysical effects of climate change and the effects of policy responses to climate change on primary industries. A key role of the economics program is to inform choices about the allocation of research and development resources to adaptation and mitigation options and to aid the selection of efficient policies to reduce emissions.

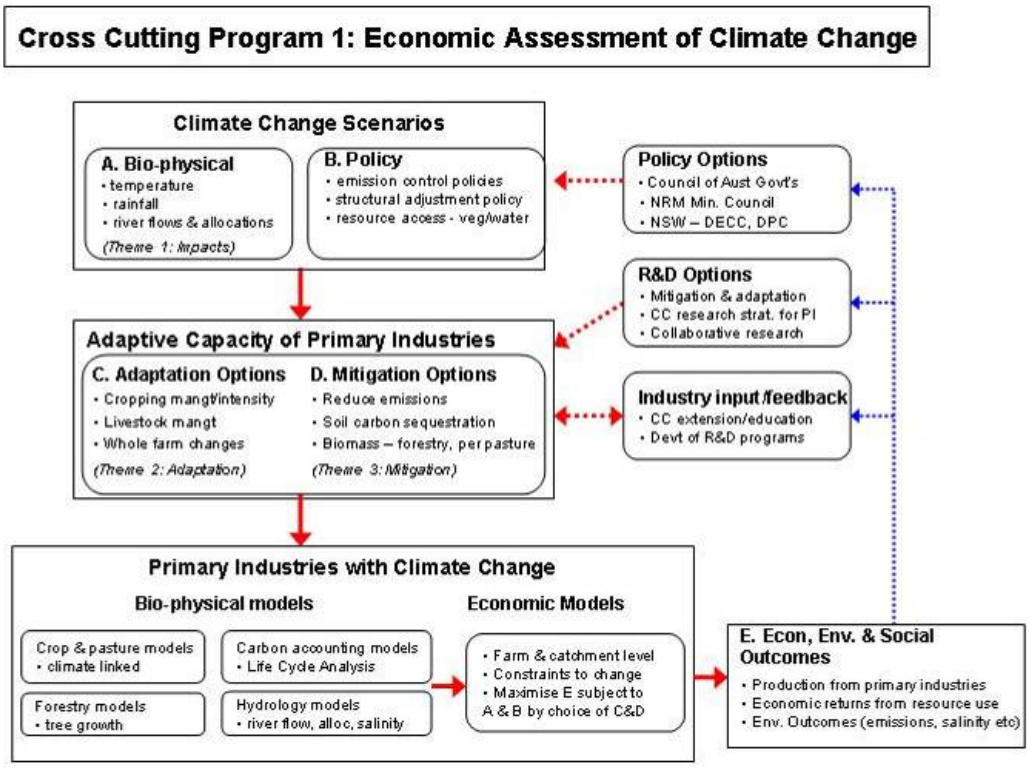


Figure 1: Economics Program

Simultaneous assessment of both biophysical and policy induced effects of climate change has the obvious attraction of completeness. An important second reason however, is that there may be some degree of tension between primary industries adapting to the biophysical impacts of climate change on the one hand, whilst also constraining their level of emissions on the other.

The schematic starts from the identification of climate change scenarios which are jointly determined by biophysical effects (A) and policy settings (B). The economic implications of any scenario depend on the adaptive capacity of primary industries represented by the scope of adaptation (C) and mitigation options (D). Potential changes to primary industries under climate change can be assessed by combining key biological data, production constraints and prices within an optimisation framework. Results of the economic analysis provide input into the setting of policies, the selection of R&D options and consultations with industry. The underlying objective represented in the schematic is to maximise environmental and economic outcomes (E), through the selection of adaptation (C) and mitigation options (D), subject to biophysical effects (A) and policy settings (B).

The two major project areas under the cross-cutting theme are discussed below.

Economic Project C1.1 –Quantify the economic impact of changes in climate on primary industries and the potential for adaptation

This project will:

- quantify the economic impacts of projected changes in climate on key primary industry sectors covering both dryland and irrigated systems
- evaluate the economic benefits of adaptation options and consider the importance of any constraints to their adoption
- evaluate policy options to promote transition to alternative industries or forms of land use, in industries where adaptation options are limited.
- provide input into the prioritisation of R,D&E in respect to adaptation
- inform policy makers on structural adjustment issues for those industries worst affected by climate change

Socio-economic Project C1.2 – Assess the economic effects of policies and technologies aimed at reducing emissions from primary industries

This project will:

- assess the economic effects and potential changes in land use under different policies to control emissions from primary industries including:
    - quantity based approaches - emission targets and trading
    - price based approaches – an emissions tax
- assess the economic effects on primary industries of design features of an emissions trading scheme including the allocation of rights, recognition of baseline emissions and the point of obligation for greenhouse accounting (see further detail in Mitigation Program 9)
- determine the economic feasibility of current and longer term mitigation options available to primary industries under different emission policy settings
- provide input into the prioritisation of R,D&E in respect to mitigation

Given the potential scope of work under project areas 1.1 and 1.2, there needs to be some prioritisation of economic resources. The setting of an emissions limit introduces a fundamental change to the operating environment of primary industries and highlights the need for efficient mitigation options. The effects of policies aimed at reducing emissions are also likely to be more identifiable (more certain), more immediate and more significant than any of the biophysical impacts of climate change. Consequently, the main priority for economic research is in mitigation, in evaluating the economic merits of both policies and technologies.

Outcomes of Economic assessment:
Efficient and effective policies and technologies developed to assist primary industries contribute to emissions reduction targets and best bet options identified for primary producers to adapt to projected changes in climate change.

Program C2: Information, education and training (IET)

NSW DPI will adopt a knowledge brokering and mediating role in building organisational, client, community and industry capacity for change through collaboration in development and dissemination of science-based information, appropriate adult learning E&T packages, change management, and support for structural adjustment policies and programs. The proposed IET Plan outlines the rationale, target audience, key messages, processes & products, resources and implementation plan required to successfully deliver the Department's Integrated Climate Change Strategy across all themes and priority programs.

In brief the program will:

In the short Term

- Reassess the climate risk dimensions of all existing extension and education and training programs, such as PROfarm
- develop regional industry case study scenarios to help farmers perceive the consequences of climate change
- Continue "train the trainers" through the Bureau of Meteorology short course on "Climatology"
- Continue "Farmers' Guide to Managing Climate Risk"
- Produce / review a series of Prime Notes about different aspect of climate change adaptation and mitigation
- Establish a "*Climate Change and Primary Industries*" newsletter to focus attention on key R,D&E and policy initiatives (both within DPI and external). The newsletter will be both electronic and in hard copy with links to other publications such as *Ag Today*, *Bush Telegraph* and *Minfo*
- Inform primary producers of options to reduce their greenhouse gas emissions, sequester carbon and replace fossil fuels with bioenergy
- Communicate the implications of agriculture and forestry participating in a national emissions trading scheme

In the medium term the program will:

- Develop new extension programs to fill identified gaps or extend new knowledge
- develop a basic whole farm enterprise climate change risk management training product
- Develop and promote "ready reckoners" for self directed "carbon dieting", coping and adaptation strategies
- Continue collaboration with Catchment Management Authorities
- Assess and, if necessary, adapt Tocal internal and external certificate, diploma, short courses, accreditation and skill recognition programs for their climate risk and mitigation content
- Develop case for BOM commitment to maintaining/redesigning "Climate Risk Management in Agriculture" (Primary Industries) awareness raising project under Section 2.4 of the NSW Greenhouse Plan
- Maintain the "*Climate Change and Primary Industries*" newsletter
- Continue to inform primary producers on options to mitigate greenhouse gases (including their possible role in emissions trading)

Program C3: Policies to address climate change

This program brings together the policy issues highlighted under each theme and includes:

- securing adequate resources to implement this strategy
- coordinating national and state action to address climate change through
    - the COAG Working Group on Climate Change and Water and its 5 sub-groups (water, adaptation, emissions, energy efficiency and renewables)
    - PIMC/PISC
    - The Garnaut review
    - NSW Climate Change CEOs Cluster Group and its 3 coordinating groups (adaptation, emissions, economics)
- informing the establishment of emissions reduction targets for primary industries

- evaluating policy options to achieve emission reduction targets for primary industries
- providing an informed contribution to the debate on establishing a national emissions trading scheme and the possible role of agriculture and forestry
- negotiating access to downscaled GCM data for impact assessment
- reviewing the adequacy of current structural adjustment policy in the light of climate change projections
- developing regulatory responses to increased biosecurity threats
- ensuring adequate capacity to respond to the increased risk of emergency management issues
- negotiating appropriate water access and sharing rules
- reviewing sustainable harvest prescriptions and management strategies for wild harvest fisheries and native forests
- reviewing regulatory controls over mining operations – given the expected increase in severe climate events

NSW DPI Climate Change Strategy Working Group Members

	1	2	3	4	5	6
Theme	**Impacts**	**Adaptation**	**Mitigation**	**Bioenergy**	**Clean coal**	**Emissions Trading**
Chair	**James Scandol**	**Ron Hacker**	**Helen Scott-Orr**	**Bob Martin**	**Brad Mullard**	**Jason Crean**
Members	Helen Fairweather	Geoff Allen	BP Singh	Paul Martin	N.A	Nick Cameron
	Brad Mullard	Don MCaffery	Craig Barton	Lucas Van Zwieten		Robert Larkings
	Rob Williams	Hilary Smith	Eileen Tucker	Brendan George		Murray Spicer
	Satendra Kumah	Bob Creese	Simon Oliver	Annette Cowie		Michael Cashen
	Regina Fogarty	Philip Gibbs	Steve Barry	Tony Vancov		Fabiano Ximenes
	Clinton Ratich	Andrew Kennedy	Yin Chan			Rick Fowler
	Jason Crean	Gary Want	Roger Hegarty			Annette Cowie
	Bill Williamson	Greg Marwick	Peter Slavich			
	Peter Regan	Joanne Finlay	Gary Alan			
		Rod Kavanagh	Alison Bowman			

Climate Change Priority Actions for NSW DPI

Activity		Impacts	Adaptation & Transition	Mitigation*
R&D	biophysical	**Forecast impacts** (models + experiments)	**Develop adaptation options for PIs**	**Quantify emissions from PIs**
		agriculture	production systems (eg breeding, risk mgt tools, flex systems)	develop low cost accounting methods
		forestry	(breeding, harvest mgt strategies, fire risk strategies, etc)	GHG footprint of PI systems quantified - LCA
		fisheries	wild harvest systems (fire mgt, sust. harvest strat, etc)	**Develop mitigation options**
		mining	mining - (water supplies, retention ponds, etc)	Clean Coal
		water	improve water use efficiency (all sectors and systems)	reduce emissions (eg CH_4, N_2O)
		biosecurity risks	develop options to address increased biosecurity risks	sequester carbon (forestry + timber products, soil)
		emergency management	quantify emergency mgt response requirements	replace fossil fuels (biomass for bioenergy)
		Monitor impacts (& inform models)	**Monitor adoption of adaptation responses**	**Monitor emissions profile** (eg DPI's footprint)
	socio-economic	**Evaluate consequences & prioritise actions**	**Evaluate adaptation capacity & prioritise options**	**Evaluate targets, policies & prioritise options**
		industry scale (eg wheat, beef, oyster)	industry scale	mitigation targets
		enterprise scale (farm, forest, etc)	enterprise scale	mitigation options (eg ETS)
Information Education Training		**Engage & inform key stakeholders**		
		Extension, education and training program for key stakeholders (including DPI staff)		
		Communication strategy		
Policy		**Coordinate national action (COAG, PISC)**		
		Secure resources to implement strategy		
			Structural adjustment framework revised	**Emission reduction targets for PIs**
			Biosecurity regulations amended as required	**Policy options to achieve targets**
			Emergency mgt responses capability enhanced	Emissions Trading Scheme
			Water management policy	taxes (on inputs - fuel/fertiliser; or outputs - meat, fish)
			Sectoral issues addressed eg	BMPs (eg conservation farming)
			revised sustainable fish harvest prescriptions (comm'l & rec'n)	incentives (eg for native veg. mgt, or pyrolysis)
			revised sustainable harvest prescriptions for native forests	**Sectoral issues** eg
			regulatory controls over mining (eg retention pond design)	use of forest harvest residues for bioenergy
				native vegetation management in agr
				legal responsibility for leakage from geosequestration

te: there are strong linkages across all themes and across all activities

Note: boundaries between themes (Impacts, Adaptation, Mitigation) are arbitrary (eg increasing soil carbon will sequester carbon [mitigation] but also increase soil moisture holding capacity [adaptation]

Addressing Climate Change: Priority Actions for NSW DPI

1. Introduction

NSW DPI has been undertaking a range of policy, research and extension actions to address climate change for several years. However, these initiatives were often developed in isolation of other sections of the department and of other broader initiatives.

In late October 2007, NSW DPI ran a two day facilitated workshop, introduced by the Director-General, to bring together key staff from a broad cross section of the department to develop priority actions to deal with the challenges and opportunities posed by climate change for primary industries (see INT07/56205). Four position papers were presented to the workshop (one for each primary industry sector) - see http://www.dpi.nsw.gov.au/research/topics/climate-change/impacts-on-industry along with scene setting presentations by the Bureau of Meteorology (BOM) and on the national Climate Change Research Strategy for Primary Industries (CCRSPI) process. Senior policy and research staff from the NSW Department of Environment and Climate Change (DECC) also participated.

The workshop identified three key areas for DPI action:

1. Assessing the impacts of climate change on primary producers;
2. Developing adaptation strategies to help primary producers cope with those impacts; and
3. Developing options to mitigate greenhouse gas emissions.

Workshop participants were divided into working groups to identify priority actions DPI should undertake within each of the themes. However, given the range of mitigation options available to primary industries, three additional working groups were established to deal with specific elements of mitigation in more detail. They were in the areas of bioenergy, emissions trading and clean coal. The six teams and their leaders were:

Table 1.1: Climate Change Working Groups and Leaders

Theme	Leader
1. Impact Assessment	James Scandol/Helen Fairweather
2. Adaptation & Transition	Ron Hacker
3. Mitigation	Helen Scott-Orr
4. Bioenergy	Bob Martin
5. Clean Coal	Brad Mullard
6. Emissions Trading	Jason Crean

Each working group was asked to prepare a report addressing the following topics:

1. Objective
2. Issue
3. Background
4. Action required to address the issue
5. Work already underway
6. Gaps in current work
7. NSW DPI's capabilities in addressing these gaps
8. Priority actions for DPI
9. Outcomes to be delivered
10. Links to other themes
11. Potential partners
12. Communication/engagement requirements.
13. Key policy issues to be addressed

This report presents the deliberations of those six working groups. It serves as a background information paper to the DPI Board of Management setting out the logic behind the recommended "priority actions" outlined in section 8 of each theme.

In preparing the report four broad areas of activity emerged under each theme:

1. Developing new biophysical knowledge;
2. Quantifying the socio-economic implications of climate change and actions to address it;
3. Developing information, education and training programs for a range of stakeholders; and
4. Policy development.

The recommended Priority Actions are listed under each theme using an alpha-numeric system ("I" is the prefix for "*Impacts*"; "A" for "*Adaptation and Transition*"; "M" for "*Mitigation*"; and "C" for "*Cross Cutting*"). Following the prefix, actions are simply listed in numeric order.

This background document is complemented by a Climate Change Action plan which summarises the priority actions and draws linkages to broader national and state climate change initiatives. An early draft of the Climate Change Action Plan was presented to the DPI Board on the 21st of February 2008, while a draft of this "Priority Actions" document was presented to the DPI Board on the 20th of March.

Implementing the priority actions is expected to have significant resource implications and will require commitment from the DPI executive and the minister to achieve success. Resource requirements to implement these actions have been compiled by the project team and will be presented to the Board in a separate submission. That submission will also suggest some structural and process issues in relation to implementing the priority actions and ensuring integration with broader national initiatives, such as the COAG Climate Change and Water Working Group and the Climate Change Research Strategy for Primary Industries (CCRSPI) endorsed by PIMC at its April 2008 meeting.

2. Background

Background information on the nature and causes of climate change, historical climate data, climate projections and the resultant impacts on NSW primary industries are comprehensively reviewed in the background papers prepared for the workshop (referenced above) and in a background paper prepared for the Ministerial Advisory Council on Primary Industries Science (MACPIS - Fairweather and Cowie, 2007) and is not repeated here. The MACPIS paper is available on the DPI external web site at http://www.dpi.nsw.gov.au/research/topics/climate-change/discussion-paper

3. Assessing the Impacts of Climate Change

3.1 Objective

Provide knowledge to inform decision making regarding the impacts of climate change on primary industries in NSW.

3.2 Issue

Climate change will cause a series of complex, interacting and cascading impacts upon primary industries production in NSW. These impacts, and the responses to these impacts, will occur over a multitude of temporal, spatial and institutional scales. There are varying degrees of uncertainty associated with the range of predicted impacts.

The complexity and magnitude of these impacts requires systems to inform and prioritise departmental and stakeholder responses (such as mitigation and adaptation) to the impacts of climate change on primary industries in NSW. These systems need to provide strategic information to departmental policy makers and primary industry stakeholders (over decadal timescales), as well as tactical information at shorter timescales (months and years) to departmental staff (such as extension officers) and managers of primary production and emergency response units.

Two program areas have been identified in the Impacts Theme. The first program area is a Forecasting Program, where deductive and inductive inference will be used to predict the likelihood and consequences of climate change impacts on primary industries in NSW. The second program area is a Monitoring Program, which includes the development of systems to monitor, evaluate and report upon the impacts of climate change. This program will include projects with a spatial focus (eg. land use mapping) and temporal focus (e.g. climate impact indices). Such a program must include data and information systems to manage what will be significant volumes of information.

Note that the *Impacts* theme will focus on monitoring and forecasting the impacts of climate change. This theme will not recommend institutional or individual responses based upon that knowledge. Those responses are addressed in the *Adaptation* and *Mitigation* theme. These themes will need to consider the costs and benefit of various strategies which will inevitably include socio-economic considerations (such as the capacity of various primary industries to adapt or mitigate).

3.3 Background

Because understanding of climate change requires projection into the future, there is uncertainty inherent in the predictions. The degree of uncertainty differs between the variables. There is very little uncertainty in projections of increased atmospheric concentration of greenhouse gases if the world continues down the 'business as usual' path. The uncertainty associated with the impact this will have on the radiative response – and therefore the global temperature impacts – is somewhat greater. There is considerably more uncertainty associated with predicted changes in rainfall and the hydrological cycle as a result of increased concentration of greenhouse gases. Uncertainty escalates as the predictions for changes to global climate are translated to a regional and local level.

The Forecasting Program will co-ordinate and undertake the research required to translate the global climate change projections to predicted impacts at a local and industry scale. Methods include statistical and dynamic modelling as well as experimental studies to measure responses from primary production units and the impact on ecological systems of altered climate variables.

All natural systems have evolved to their current state as a result of the climate in which they developed. Similarly, production systems (such as agriculture, forestry and fishing) have developed to suit the climate experienced over the last 100 or so years. The capacity of different systems to adapt to changes in climate, outside those that have been experienced previously, is largely unknown, which adds further uncertainty to the prediction of climate change impacts.

Given this uncertainty about forecast changes, there is a need to "ground truth" or "validate" our understating of the impacts of climate change with up-to-date observations via a Monitoring Program. The projections from the Forecasting Program will thus be combined with the evidence-based strengths of the Monitoring Program to provide a scientific foundation to deliver comprehensive knowledge about the impacts of climate change on primary industries and related ecological systems in NSW.

The projected changes in climate will have major impacts on both natural and human-influenced ecosystems. While it is impossible to be definitive about the impacts of climate change, controlled environment studies and modelling provide an indication of **probable** impacts. Biodiversity is threatened, especially where landscape fragmentation limits the opportunities for species to migrate as climate changes. Primary industries are also particularly vulnerable. In Australia, variation in crop yield and livestock production from year to year is largely a result of variation in rainfall. Australian agriculture, therefore, is very vulnerable to the increased variability and shifts in precipitation patterns that are predicted under climate change. Livestock are likely to suffer increasing heat stress. Crop yields are threatened, especially by impacts on rainfall and length of the growing season.

Australian animal and plant production systems are also vulnerable to an array of endemic invasive species that include pests, diseases and weeds. Under future climate change scenarios these will continue to spread further south and increase in importance in major southern production areas. Aspects of climate change, including increases in temperature, atmospheric carbon dioxide concentrations and nitrogen depositions may favour existing or exotic species that are physiologically adapted to exploit such conditions. With the projected climate change combined with increased global trade, Australian borders will be exposed to an increased threat of exotic pests and diseases.

The potential impacts of the projected climate changes on Australian forests are not clearly understood. Where trees are not water-limited, climate warming may expand the growing season of exotic softwood and native hardwood plantations in southern Australia due to the CO_2 fertilisation effect, although the amount of increase will be limited by feedbacks such as nutrient cycling. However, increased fire incidence and pest damage may negate some productivity gains. The impact of climate change on forest biodiversity, particularly in native forests is also not well understood, though NSW DPI does have a good base on which to build in this area.

Apiculture is an industry that is particularly vulnerable to climate change. Recent research by NSW DPI has emphasised the role of prevailing climate as an influence on flowering patterns and nectar production of eucalypts. Eucalypts are the most important source of nectar for honeybees in NSW, not to mention the vast array of nectar-dependent fauna in Australia.

The projected rise in sea level, increased frequency of storms and salt water incursion into estuaries will impact on commercial and recreational fisheries as a result of impacts on habitats. A further concern for fisheries is the projected increase in ocean acidity, resulting from increased ambient concentrations of carbon dioxide. This will affect the formation of calcium carbonate in shells and corals.

NSW DPI has responsibility for emergency management responses involving agriculture and animals across a range of climate driven events (eg. floods, storms, bushfires and plagues). The impact of climate change on the frequency and intensity of these events will have consequences for how the Department manages this responsibility within the resources available. A Climate Change Working Group has recently been established by the State Emergency Management Committee and is one avenue for developing the strategies for managing the implications on emergency management for NSW DPI.

3.4 Action Required

Efficient and accountable responses to the impacts of climate change will require a two pronged approach to enable adaptive (short term) and strategic (long term) responses to climate change. In the context of the Impacts Theme, the adaptive response relies on up-to-date, interpretable and accessible information on the current state of natural and human-influenced ecosystems. A forecasting capability (such as dynamic and statistical modelling) is required to inform the longer term strategic response.

As impacts of climate change are far reaching and complex, strategies are required to rank the likelihood and consequence of impacts so that adaptive and transitional responses to those impacts can be developed and implemented in an accountable, transparent and evidence-based manner. There are close relationships between the *Impacts* theme – which is projecting possible impacts, and the *Adaptation and Transition* theme which develops responses to those projections. A joint communication strategy is therefore required between these themes.

At a broad level the *Impacts* theme identifies **two programs** for an effective response to this challenge (see Figure 1):

Forecasting - This requires a range of scientific and analytical studies (including experiments, models and analyses) to forecast the likelihood and consequence of impacts upon primary industries and other areas for which DPI has statutory responsibility (eg emergency management, aquatic ecosystems) as a result of changes to the climate. This program will inform the most cost-effective strategies to adapt to and/or mitigate against the impacts of climate change.

Monitoring - This requires the collection, evaluation, integration, interpretation and reporting of data, information and knowledge on the impacts of climate change on primary industries and DPI's other statutory responsibilities.

The building blocks of these two programs are:

Forecasting: Predicting the impacts of climate change will be achieved through a suite of projects that are conducted in collaboration with a range of other agencies (eg CSIRO Bureau of Meteorology – BOM, and Department of Environment and Climate Change – DECC) industries (e.g. rural Research and Development Corporations RDCs) and regional partners (eg. Catchment Management Authorities CMAs). A number of these impact studies are in varying stages of progress and there is a requirement for a coordination group to link these studies and provide a consistent reporting framework.

An important element of the forecasting program is impact prioritisation. There will inevitably be very many impacts of varying consequence and likelihood. Analyses are required to categorise these impacts so that the more important issues are given higher priority for: additional research and development of various options for adaptation, communicating these inputs with various stakeholders, or high level policy consideration (e.g. industry restructure).

Various methods are available to undertake prioritisation and all will require the best possible information regarding impacts. Possible models include risk assessment (where the likelihood and consequence of impacts are either quantified or qualified); multi-criteria decision analysis; Bayesian belief networks; and cost-benefit or other relevant economic analyses.

A major challenge with this work is that current climate forecasting models are a very course scale. It is therefore difficult to get climate projects that are meaningful for specific regions and industries. This needs to be a focus of future work.

Much of the understanding about the interactions between climate scenarios and biophysical responses will be sourced from other national and international organisations (Inter Governmental Panel on Climate Change (IPCC), Bureau of Meteorology (BoM) and other research providers such as CSIRO and

universities). It is neither appropriate, nor possible for NSW DPI to develop expertise in global circulation models. Our role will be to take the output from these models and apply it to relevant regions and industries at an appropriate scale and to facilitate an understanding of impacts by stakeholders groups.

Monitoring: Systems are required to collect, manage, interpret and communicate the data, information and knowledge on how the climate is changing and what impacts those changes are having on NSW Primary Industries. This will involve a series of tasks including:

- data collection programs (including remote sensing and field work and spatial data on the changing uses of terrestrial and aquatic systems (including multiple-use allocation strategies such as state forests and marine parks);
- data management (technology and architecture requirements as well as metadata/dictionary management);
- facilitating the further development of current monitoring programs (eg. Monitoring and Environmental Reporting – MER) to meet the needs of monitoring the impacts of climate change, including socio-economic indicators;
- communicating key messages to stakeholders; and
- informing policy development (eg exceptional circumstances).

Although much of this program will need to be developed and maintained by NSW DPI, the specifications (rules) should be based upon international, national and state-wide standards. Where such standards are unavailable, existing standards should be adapted or (at last resort) developed.

An important aspect of cost-effective and scalable monitoring is the development of effective information systems. This route enables DPI to share outcomes with the broadest possible range of stakeholders at the lowest possible costs. These technologies are also expected to continue to improve over the coming decades.

There are parallels in the fisheries and native forests monitoring activities, especially the ecosystem based scenario-modelling. The breakdown of fisheries into wild harvest, aquaculture and aquatic pests all have forest parallels (native forests, commercial forests and pests and diseases and their consequent impact on habitats).

3.5 Impact Assessment Work Already Underway

Key work already underway by both NSW DPI and others to assess the impacts of climate change on primary industries includes:

Activity	Institution	Contacts
Climate Change projection modelling	IPCC, BoM, CSIRO, Universities and other state agencies (esp DECC)	Clinton Rakich, Betrand Timball and David Jones (BoM), Steve Crimp, Mark Howden (CSIRO) and Andy Pitman, (UNSW) Peter Smith (DECC)
Biological/ecological responses to climate change (both modelled and empirical)	CSIRO, NSW DPI, APRSU, other state DPIs, Universities, CRCs	Helen Fairweather, Phillip Gibbs, Doug Alcock, Ron Hacker, Matt Ives, Richard Eckard, Peter Hayman (SARDI), Mark Howden, Steve Crimp, Daniel Rodriguez, Hu Quon Bi.
Development of distributed information and data systems.	NSW DPI (ICT)	DPI ICT Adam King (coord)
Risk assessment, prioritisation models	CSIRO, NSW DPI, CRCNPB, ACERA	James Scandol Helen Fairweather
Management of research outputs; metadata management	NSW DPI (S&R + ICT)	DPI ICT and the "*Clarity*" database Adam King
Spatial and temporal monitoring (eg. NSW MER, DIMWIG)	NSW DPI (aquatic monitoring, forest ecology, behavioural flexibility of a range of forest species and studies that document species distributions and the direct influence of climate on distribution), DECC (terrestrial and satellite imagery [obtaining annual Spot 5 imagery]), ABS, BoM, Forestry, CMAs, Geosciences Aust.	Bob Creese, DPI Advisory Officers, Adam King, Wayne Mackey, David Jones (BoM), James Scandol, Brad Law Rod Kavanagh
Emergency management	NSW DPI, other state agencies with EM role	Graeme Eggleston (NSW DPI), Suzanne Robinson (NSW DPI),

Activity	Institution	Contacts
		Simon Oliver (NSW DPI & State Emergency Management Committee Climate Change Working Group rep)
Communication	NSW DPI	Gary Allan
Policy Development	PISC NSW DPI	Rick Fowler, Austin Whitehead, Scott Davenport

3.6 Gaps in Current Impact Assessment Work

- Downscaling projections from Global circulation models to region and industry specific information;
- Analysis of data and information needs;
- Establish the coping range across all primary industries sectors;
- Developing new and/or implementing existing methodologies to undertake impact assessments;
- Developing appropriate methodologies for forecasting the impacts of climate change at industry and regional scale and assessing the risks and consequences;
- Development of a common language or syntax (e.g. data dictionary) for:
- integrating the climate scenarios of climate research for primary industries;
- publishing the outcomes of research on projects of relevance to climate change;
- Communicating projected impacts in a language appropriate for key stakeholders (primary producers, DPI staff, policy makers);
- Developing policy to address the challenges and take advantage of the opportunities presented by climate change (eg, exceptional circumstances, industry adjustment, bioenergy).

3.7 NSW DPI's Capabilities in Addressing these Gaps

Strengths

- Existing monitoring programs in forestry, fisheries and freshwater aquatic systems;
- Officers with a breadth and depth of knowledge of primary industries in NSW and willingness to learn from other national and international experience;
- Extensive research base on the impacts of climate change on the resource base of primary industries (such as the coping range of plants and animals);
- Strong links with key national RD&E processes (eg CCRSPI)
- Existing ICT infrastructure for delivery of data and information;
- Existing preparedness in Emergency Management;
- Permanent staff offer ongoing momentum to the implementation of long-term public policy (decadal time scales);
- Strong track record with external funding bodies and potential collaborators;
- There is no other organisation in NSW that operates in direct partnership with the sectors that are most vulnerable to climate change.
- Strong existing network of extension/communication staff;
- Education/training staff and infrastructure (eg Yanco, Tocal, etc)

Weaknesses

Deleted from this version

Resources

- Extensive, appropriately skilled human resource base within DPI; (research, extension, education, communication policy)
- Existing ICT infrastructure;
- Linkages to Australian research funding bodies;
- Linkages to other Australian and international research collaborators.
- NSW Greenhouse Plan funded projects (coming to an end and needs refreshing)
- Infrastructure (research stations distributed over key agro-ecological zones)
- Distributed network of extension staff

3.8 Priority Actions for DPI

Two program areas have been identified:

Program I1: Forecasting future climate change impacts on primary industries.
Achieved through a suite of projects that are conducted in collaboration with a range of industries (eg RDCs) and regional partners (eg CMAs) and linked to national initiatives.

An outcome from this program will be the identification of appropriate responses based on risk assessments at various time points in the future based on various climate change scenarios.

Project I1.1 - Develop expertise in the application of downscaled global circulation model outputs to simulation models and other analyses of primary industries in NSW.
This project will develop the necessary expertise to use the results from existing climate models to issues associated with primary industries in NSW. The downscaled results will be presented in a form that is accessible to researchers and policymakers and will include documentation of uncertainties and caveats.

Project I1.2 – Defining the coping range/resilience of key production systems for each primary industry sector.
This project will predict the susceptibility of key production systems to forecast changes in climate variables (eg carbon dioxide, temperature, rainfall, evaporation, stream flow). The activities in this project will include both experimental and modelling work and will have linkages to projects in the adaptation themes. These projects will be at a production system scale (e.g. crop or forest type, estuaries, etc).

Project I1.3 – Apply models and climate change data sets to forecast the likelihood of a range of possible impacts of climate change and their resultant consequence on primary industries production systems.
This project will link the land use monitoring data (from *Project I2.1*) and the results of research on the susceptibility (including the coping range) of primary production (from *Project I1.2*) to changes in climate variables. By linking the probabilistic climate scenarios to this spatially explicit information, regional risk assessments (at various time-points in the future) will be generated. More detailed models will be able to capture the varying ability of systems to adapt to gradual or sudden changes in climate variables.

Project I1.4 – Forecast the impacts of climate change on aquatic ecosystems (commercial and recreational).
This includes consideration of decreased or more variable flows in rivers (and thence estuaries), increased sea level, increased temperature, increased ocean acidity and changed recruitment patterns. The outcomes from this project will feed directly into *Program A10*: *adaptation strategies for wild harvest fisheries*.

Project I1.5 - Estimate the biosecurity risks associated with climate change.
Risk-based methods will be applied to address biosecurity issues including consideration of the likely behaviour of both endemic and exotic pests and diseases. This will be similar to *Project I1.3* but focus on biosecurity issues only for agriculture, forestry and fisheries.

Project I1.6 Forecast the expected changes in Emergency Management support that are likely to result from climate change.
There will likely be shifts in extreme weather events (eg fire, flood, drought, extreme heat) that will affect EM in NSW. DPI will work closely with the State Emergency Management Committee Climate Change Working Group to examine these issues.

Assessing socio-economic impacts of climate change
Socio-economic assessment of climate change will draw on the expertise and a range of models held by DPI research and policy economists to collate current data sources and interpret these data for strategic policy development and prioritisation of subsequent action. Issues to consider include:

- Assessment of projected biophysical impacts on enterprise and industry financial performance;
- Implications for structural adjustment.

Socio-economic assessment of climate change impacts will be fully integrated with socio-economic assessment of adaptation strategies and mitigation options, including participation by agriculture and forestry in the proposed national emissions trading scheme (ETS). Because socio-economic assessment is a key

requirement of all themes and will, in many cases, be undertaken using similar techniques, it has been developed into a *cross cutting* program. Cross cutting programs are outlined in detail in Section 9.

Program I2: Monitoring the Impacts of Climate Change on NSW Primary Industries
Systems are required to collect, manage, interpret and communicate the data, information and knowledge associated with the impacts of climate change. An outcome of this program will be that decision making in regard to the impact of climate change will be based on the best available knowledge.

Project I2.1 Spatial monitoring of land use and coastal geomorphology.
This project will develop an understanding the current status of the primary industries resource base for informing the spatial extent and magnitude of climate change impacts. Inputs include remotely-sensed data (aerial photography and satellite imagery) as well as spatially explicit sampling of terrestrial and aquatic ecosystems. The project will include the identification of indicators that can be used to validate predictive models. Although this project will have a spatial/mapping focus, it will be closely linked to the time-series project (*I2.2* below).

Project I2.2 Time series of production indicators and climate indices.
This project will collate and report time-series data for validating predictive models and provide a direct understanding of climate changes that are occurring. This will inform the predictive models in Impacts Program 1 as well as the adaptive responses being developed by the *Adaptation and Transition* Theme. Other statutory responsibilities of DPI for forest and aquatic resources (including the likely integration of climate change issues with the state-wide MER program) will be addressed within this project. This project must be capable of distinguishing the synergistic effects of non-climate stressors (pollution, inappropriate land use, exotic pests, modification / loss of aquatic habitat) from climate change impacts.

Specific Exclusions (issues that are out of scope of this theme)
- DPI will not engage in development of global circulation models (this is a CSIRO and BOM responsibility);
- Response to impacts (strategies or options) – this is addressed in the *Mitigation and Transition* theme;
- Development of new sophisticated and specialised process models (existing models will be adopted or adapted).

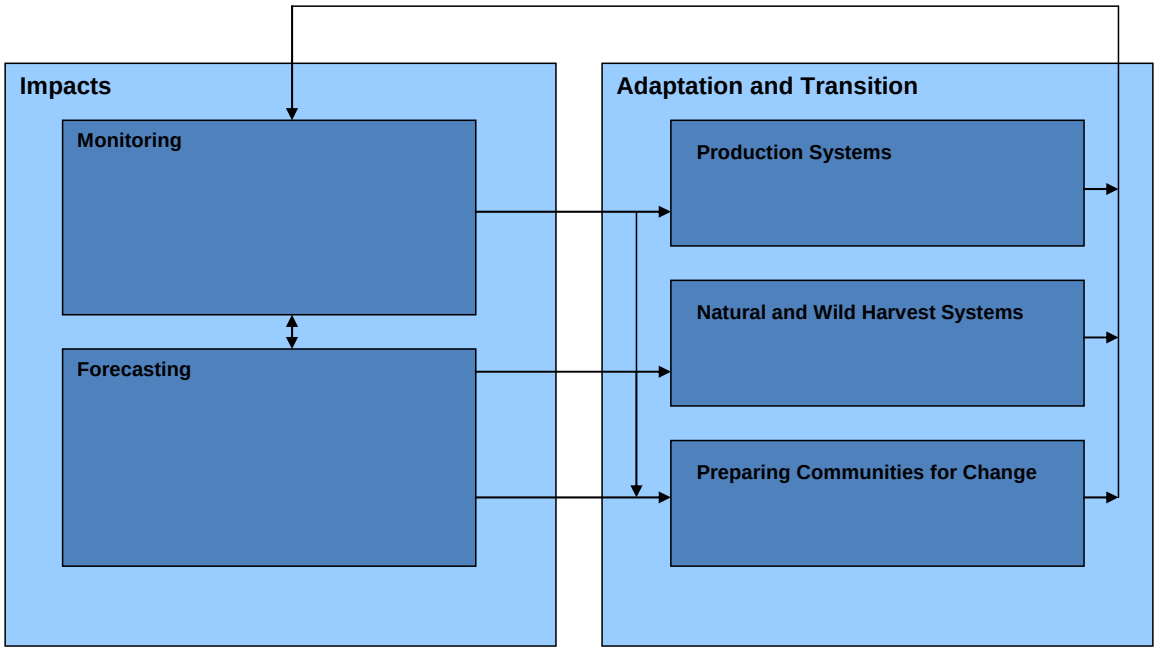
3.9 Outcomes

Program I1
- The forecast of climate change impacts will provide guidance on the identification of appropriate responses across a range of industries (linked to the adaptation theme) [5 year time frame];
- Prioritisation of climate change impacts on a geographical, temporal and industry basis [5 year time frame];
- stakeholders able to make informed decisions about the impacts of climate change.

Program I2
- A systems approach to the collection, management, interpretation and communication of data, information and knowledge associated with the impacts of climate change [3 year time frame];
- Decisions that need to be made with respect to the impact of climate change will be based on the best available knowledge [4 year time frame];
- Climate Change adaptation, transition and mitigation studies will be guided by the best available base-line data [4 year time frame].

3.10 Links to other themes

Figure 3.1: Relationships between Impact Assessment and Adaptation/Transition Theme



3.11 Potential Partners

Institution	Projects	Comments
BOM		Climate change scenarios from GCMs
CSIRO		Climate change scenarios from GCMs and impact studies and the sustainable yields project
AGO		South Eastern Australia Climate Initiative
DECC		Coordinate downscaled modelling for NSW
BRS/DAFF		Water availability project
CMAs		Regionally specific information
DWE		Impacts on hydrological cycle
PISC		Manages climate change research strategy for primary industries - CCRSPI
NRMSC		Links to modelling on NRM
DIMWG		Data and Information Management Working Group of the Natural Resource Sector CEO Cluster Group (DPI representative Renata Brooks)
AFMF		Australian Fisheries Management Forum (co-ordinates national fisheries policy)
CRC for Plant Biosecurity		Biosecurity impacts
Industry Associations		Industry specific issues
RDCs		Industry specific issues
National Centre for Climate Change Adaptation		National coordination and funding for impact and adaptation research
State Emergency Management Committee		State Emergency Management Committee Climate Change Working Group is determining the consequences of climate change on emergency management services
Other state DPIs		Coordination of modelling requests and assessments

3.12 Critical Communication/Engagement Requirements

The major communication elements of the *Impacts Theme* are picked up as part of a cross cutting *Information, Education and Training* program outlined in detail in Section 9.

3.13 Key Policy Issues to be Addressed

A range of policy issues are outlined throughout the climate change strategy. In terms of impact assessment, key policy issues include:

- coordinating national action on climate change (through COAG, PISC and the NSW Climate Change CEOs)
- securing the resources necessary to implement this strategy

These policy issues are picked up in a cross cutting policy program outlined in Section 9.

4. ADAPTATION AND TRANSITION THEME

4.1 Objective

To provide options for primary producers to adapt their operations to the anticipated future climate in which they will operate and inform the process of transition for industries unlikely to cope with the magnitude of expected changes.

4.2 Issue

All primary industries that depend upon harvesting the net primary or secondary production from terrestrial or aquatic ecosystems will be affected in some way by the climate changes forecast for coming decades. While the predicted magnitude of these changes varies with future emissions scenarios even those associated with a modest 'best bet' scenario are likely to affect, in a wide variety of ways, the biophysical processes on which primary and secondary biological production depends, especially since changes in average conditions will be associated with a greater frequency of extreme events.

A feature of the analysis of likely impacts is that effects will not only vary between sectors but also spatially within individual sectors. While the wool industry overall, for example, is likely to be relatively robust in the face of climate change, the sector located in the semi-arid rangelands is expected to be more vulnerable to these impacts. At the macro-scale, commercial and recreational fisheries will continue but 'species-by-area' harvest strategies may need to change to maintain economic and ecological viability at the local level. The species suitable for aquaculture operations are likely to change with some species (e.g. trout) becoming unviable in some areas due to rising temperatures while warm temperate species are likely to be more viable. In general, native forest systems are likely to adapt if management practices promote ecosystem resilience but effects on individual species may impact production, biodiversity and ecosystem health in specific areas. Effects on pests and diseases, an issue affecting all production sectors, can also be expected to have specific local manifestations. Temporal variability in the rate at which even susceptible regions are impacted could be expected to accompany this spatial variability.

In addition to spatial and temporal heterogeneity, climate change impacts are also likely to vary across 'biological' scales, from species to ecosystems.

To some extent, the ongoing R, D & E activities of NSW DPI will help position primary industries, and specific sub-sectors or regions, to adapt to the changes produced by a non-stationary climate.

In agriculture, breeding of drought- or disease-resistant varieties, management for improved water use efficiency in both dryland and irrigated production systems, and development of seasonal risk management tools are all examples of current activities that will assist with adaptation to the expected future changes. However, many of these activities may need to be ramped up or refocussed to address climate challenges.

In the forestry sector adaptation strategies will vary between the plantation and native forestry sub-sectors. For plantations, strategies will include modification of plant breeding objectives, nursery management practices, silvicultural practices and estate modelling. In native forests adaptive harvest prescriptions, management practices and a range of regulatory and non-regulatory approaches will be required. Across all sectors, management of fire and control of biosecurity risks will be paramount.

Current adaptation to climate change for aquatic ecosystems and wild harvest fisheries is by incorporation of appropriate risk management frameworks into the Department's governance of commercial and recreational

fisheries. In the aquaculture area investigation of temperature tolerant strains of fish and invertebrates and research into the alternate formulation of aquaculture feeds to reduce reliance on fishmeal provide some adaptation to climate change scenarios.

In mining, the most significant impacts will be those relating to changes in government and policy relating to controlling emissions. This is dealt with in Sections 5 and 8. Direct impacts on mining operations as a result of climate change include issues such as availability of water and dealing with more extreme climate events (such as increased in the size of retention ponds to cope with storm events).

Given the varying degree of impact across spatial, temporal and biological scales, a critical issue in formulating appropriate responses is to identify those industry sectors and regions that are unlikely to be able to adapt to the expected rate of change. In these areas an orderly and informed process of transition will be required to achieve structural adjustment in industries that are no longer sustainable. Specific activities that may become untenable under climate change must also be identified and alternative procedures developed. Conversely, for the remaining areas in which adaptation and long term sustainability are feasible, the need for adaptation strategies beyond those resulting from ongoing, productivity-oriented R&D must be defined and the justification for additional investment determined.

4.3 Background

The potential impacts of climate change on the primary industry sectors in NSW have been described in detail in the background papers presented to the October workshop.
http://www.dpi.nsw.gov.au/research/topics/climate-change/impacts-on-industry

Briefly, in the agricultural industries, significant impacts can be expected to result from reduced rainfall, particularly in winter and spring, on winter crop yields and on pasture productivity, composition and resilience to grazing (particularly in the semi-arid zone). Significant effects related to temperature and other meteorological extremes can be expected in the horticultural and viticultural industries while impacts of reduced runoff on the availability of irrigation water will have major repercussions across a wide range of industries. Irruptions of new or more aggressive weeds, pests and diseases will likewise affect many agricultural sectors.

In mining, the primary direct impacts will be access to quality water and managing more extreme climate events at mining sites. Maintaining primary industries in the face of these impacts will require ongoing adaptation, perhaps beyond the extent that would be achieved by the normal processes of productivity improvement, and in some cases structural adjustment in industries whose economic viability or ecological sustainability are threatened by climate change and its interactions with production processes.

Impacts on forest industries can be expected from the predicted increase in the frequency and intensity of bushfires, increases in storms, changed incidence and severity of pests and diseases, and tolerance of different species to higher temperatures and reduced water availability. In general, water dependent or fire intolerant ecosystems, including plantations, will be most affected.

For fisheries, aquatic environments in river floodplains and estuarine intertidal areas may not be able to adapt to the effects of increasing water temperatures, changes in freshwater runoff, rising ocean acidity and sea-level rise, with consequent impacts on production of wild harvest fisheries and conservation of natural biodiversity /ecological health. In the marine environment, phytoplankton assemblages, the basis of marine food webs, may change as a result of decreased pH caused by increased CO_2 absorption, again with significant implications for production. Freshwater aquaculture and recreational fisheries for trout and salmon may not be sustainable because they rely on cold waters.

4.4 Action Required

Identification of industry sectors or regions at greatest risk from climate change, and key adaptation strategies, will be achieved by the activities outlined in Section 4.8 (Priority Program Areas) below. However, in order to achieve the decadal outcomes of this theme, defined below, a number of key capacities are required both within DPI and the NSW Government at large. These include:

- A modelling capacity capable of informing an adaptive, risk-based approach to ongoing management of vulnerable species or ecosystems, or policy development in relation or particular industry sectors (link to *Impacts Program 1*).
- A capacity to monitor key ecological indicators for both aquatic and terrestrial environments, and economic or productivity indicators for sectors or regions at risk (link to *Impacts Program 2*);
- Maintenance of a R,D&E capacity within NSW DPI that will ensure that adaptive technology is developed and delivered to primary industries;

- Development of incentive programs that will ensure that the costs of adaptation and transition initiatives are appropriately shared among industry and public beneficiaries;
- A responsive regulatory and policy environment capable of translating scientific data into effective and equitable adaptive responses.

Required Outcomes of National Actions
Within 5 years, in conjunction with stakeholders:

- Develop a thorough understanding of the implications of plausible climate change scenarios for individual production, natural and wild harvest system (through *Impacts Program 1*);
- Identify priority adaptation strategies for those systems and activities that are considered potentially sustainable;
- Be able to provide sound policy advice to support appropriate adjustment /transition for those systems and activities that are unlikely to remain sustainable.

Within 10 years, in conjunction with stakeholders:

- Adaptation strategies being extended to all primary industry sectors or regions with potential for long term sustainability;
- Policies informed by sound science implemented by the Commonwealth and State government to assist transition of industries or parts of industries at risk under a changed climate.

4.5 Action Already Underway

Much current and past research within NSW DPI has relevance to the issue of adaptation to climate change. Little if any has addressed the issue of transition at either a technical (identification of potentially unsustainable industries, sectors or practices) or policy level (note Primary Industries Standing Committee (PISC) and Ministerial Council (PIMC) are currently reviewing Exceptional Circumstances (EC) as part of this policy issue).

Within the agriculture sector R&D particularly relevant to adaptation includes that focussed on seasonal risk assessment, development of risk management tools, and water use efficiency in both irrigated and dryland production systems, the latter in particular related to conservation farming technology. Plant breeding programs have provided a wide variety of genotypes for crops and pastures whose adaptation will remain valuable under future climates even if the spatial distribution of their preferred niche alters. However, given the current rationalisation of national plant breeding activities, some specific focus on pre breeding activities may be required. Past animal breeding research has identified adaptive breed types and breeding systems to better cope with variable and harsher climate. Breeding programs for ruminant livestock will need to simultaneously improve the capacity of livestock to adapt to changes in climate while reducing methane emissions (see *Mitigation Program 3*).

In the fisheries sector existing research on ecological modelling of coastal systems combined with the ecosystem based management of wild harvest fisheries will allow adaptive management of fisheries harvest, to protect natural biodiversity and maintain a sustainable harvest under species recruitment shifts from future climates. In the aquaculture area, investigation of high-temperature tolerant strains of fish and invertebrates and research into the alternate formulation of aquaculture feeds to reduce reliance on fishmeal provide some adaptation to climate change scenarios.

Relevant research within the Forest Resources Research biodiversity group includes long-term (20 year) forest ecology experiments that will provide base-line data for assessing the impact of climate change on forest biodiversity and for modelling the effect on biodiversity of increased frequency of droughts and wildfire. In addition, studies of the ecology and behavioural flexibility of a range of forest species and of species distribution in relation to climate, will help in interpreting species capacity to adapt to climate change, and likely regional impacts. Operationally, significant research has also been undertaken into the genetic improvement of tree species used for plantations and into the potential of these across a range of sites, including dryland environments.

These areas of R,D&E will need to be maintained and enhanced to provide adaptive solutions to primary producers.

4.6 Gaps in Current Adaptation Work

Productions Systems

Agriculture

Adaptation to climate change in agricultural production systems will require the development of new technologies and practices that:

- Increase the coping range of both species (eg via breeding programs) and systems (eg by moving towards mixed enterprises to provide flexibility);
- Increase tactical flexibility in decision making, allowing key decisions to be delayed until the probability of a desirable outcome is high (e.g. decisions to commit to a cropping program or to apply additional fertiliser);
- Increase the coping range of systems to climate change by incorporating enterprises or practices less susceptible to seasonal variability (e.g. more emphasis on livestock – considering breed and type of plant and animal - in mixed farming systems, incorporation of perennials – noting that full life cycle analysis is required to determine the net greenhouse impact of such a change;
- Improve water use efficiency in both irrigation and dry land systems;
- Provide timely information for decision making at farm level;
- Provide protection against new biosecurity threats arising for changed distribution or incidence of weeds, pests and diseases.

For those regions or industries that will be severely affected by climate change there is a critical need to understand the spatial distribution of impacts, in terms of both biolophysical and socio-economic parameters, and the policy initiatives that may be needed to affect the required changes in land use with minimal social disruption.

At a more immediate level there is a need to ensure that all NSW DPI's current education and training activities encompass climate change awareness and encourage clients towards adaptive thinking.

Forestry

Adaptation to climate change in forestry production systems will vary between plantation and native forest systems although there will be common elements. Priorities include:

- Modification of silvicultural practices including site preparation, establishment and harvesting;
- Estate modelling that incorporates anticipated impacts of climate change and responds to factors likely to vary with climate change;
- A decision making environment that facilitates the application of adaptive and active management to optimize production outcomes;
- An improved understanding of the regionally specific consequences of climate change to drive responsive silvicultural practices;
- A new approach to fire management;
- More effective management of assets including road based infrastructure;
- An improved understanding of the risks from biosecurity, including the spread of pests; and
- Consideration of the hydrological impacts of reforestation and forest management.

Aquaculture

- Adaptation to climate change in aquaculture production systems will require:
- The development of new technologies and practices for culture of existing species under the new climate regimes;
- Increased efficiency of water resource use for inland aquaculture;
- Provision of timely information on climate for decision making at farm level for marine and freshwater aquaculture;
- A more flexible regulatory and decision making environment that facilitates the capacity to apply adaptive and active management to optimise production outcomes (e.g. allows culture of species previously not endemic to NSW);
- An improved understanding of the regionally specific consequences of climate change to drive responsive aquaculture practices; and
- An improved understanding of the risks to biosecurity, including the spread of pest and diseases.

Some aquaculture industries will be more severely affected by climate change than others. For those likely to be most affected, e.g. trout, there is a need to understand the spatial distribution of impacts, in terms of

both biological and socio-economic parameters, and the technical initiatives that may be required to offset the changes or, in the worst case, provide adjustment assistance to help ensure minimal social disruption.

As for agriculture production systems, there is a need to ensure all NSW DPI's current education and training activities encompass climate change awareness and encourage clients towards adaptive thinking.

Mining

The key focus for the mining sector is to provide projections on the impact of more extreme weather events (eg rainfall) and contribute information to any review of regulations governing key design parameters – such as retention pond design by relevant regulatory authorities. Information on predicted water supplies are also required to allow mining companies to plan for future needs.

Natural and wild harvest systems

The information needs for natural and wild harvest fisheries systems, as identified at the October 2007 National climate change and fisheries workshop are:

- understanding the impacts of climate change on the resources (as per *Impacts Program 1.4*).;
- provision of predictive tools and /or models within an ecosystem based fisheries management (EBFM) framework; and
- developing flexible fisheries management, governance and policy frameworks.

Understanding, based on robust monitoring systems, of stock sustainability for aquatic fish and invertebrate species that are harvested directly from natural systems (wild harvest) is required. This needs to be complemented by monitoring and evaluation of the impact of climate change on ecological health of non-harvested species (natural biodiversity) including those species caught as by-catch in fishing activities and then discarded. Maintenance of aquatic habitats for both the wild harvest and natural biodiversity species and animal communities is essential for sustainable harvest and data on the effect of sea level rise on the spatial distribution of the different aquatic habitats is needed.

These data are required as input to risk-based models capable of evaluating the impact of alternative harvest strategies on fisheries resources. The term "harvest strategy" in this context includes the variety of fish and invertebrate species which can be taken, the fishing gear/methods able to be used by licensed fishers, the geographic area where fishing by an approved method can occur and the statutory management controls and compliance rules applying to the commercial and recreational fishing industries.

The information needs for native forests are, to some extent, similar to those identified for production forestry. The primary concerns are about understanding the adaptive capacity of ecosystems and the resilience of these to climate extremes. The likely impacts of climate change on Australia's native forests are not well understood and there appears to be limited systematic research. Where research is being undertaken the challenge remains to translate results into effective operational practice.

Information about the systematic relationship between ecosystem properties and functions that are vulnerable to climate change is required to ensure sustainable harvest thresholds are achieved for wild harvest forest and fisheries industries.

In both sectors, there is a requirement to develop flexible management practices, policy frameworks and governance which recognise the need for an adaptive regulatory environment, particularly for individual species, and for evaluation of alternatives by scenario or option modelling.

Preparing communities for change

Communities based on primary industries are conscious of their dependency on weather and climate but there are varying levels of internalisation of the associated risks, due both to perverse government policy and a misreading of inherent landscape carrying capacity. The coincidence of the current drought with the step wise reduction in medium term rainfall patterns, combined with the maturing science on induced climate change, has now brought climate variability to the fore in regional and rural communities.

The capacity of primary producers to respond and prepare for the changes they will experience will be a function of dealing with their fears and ignorance (specific to climate change but also in their wider economic, social and environmental context). Rural and regional communities can take control through:

- access to good information (and by participating in the collection, analysis and application of that information);

- training in the use of simple decision support tools that help them understand the risks and options (short, medium and long term) associated with climate change;
- making decisions about coping, transition or exit in a suitable economic social and environmental framework (eg property management planning);
- opportunities to be involved in the solutions - trading, offsets, “green power” generation, bio fuels, carbon dieting etc;
- government policy, operational, education and training responses that not only lead by example but provide the pathway and safety net to take the primary industries community into a more adaptive and dynamic future.

Key information needs thus centre on the requirement to provide timely and scientifically-based information on climate variability and climate change, its likely impacts on rural businesses and the associated opportunities so that individuals and businesses can make informed and appropriate responses. These decisions need to be made within a policy context which is also based on sound analyses of climate change impacts at the regional level, and of the available policy options.

4.7 DPI Capabilities

Strengths

- Long history and extensive expertise in production R,D&E which can be applied to develop and deliver adaptive technologies;
- Expertise in economics that can support advice both industry and to government;
- Extension and education network capable of delivering relevant information to rural communities to support adaptation or transition.
- Baseline harvest statistics on fish and invertebrates;
- Established capacity to collect, assess and apply climate change relevant data for key aquatic species;
- Some monitoring of natural aquatic biodiversity;
- Good survey data for threatened species in native forests;
- Long-term forest ecology experiments able to provide baseline data for monitoring climate change impacts;
- Long term forest growth and operational inventory data;
- Long term water quality monitoring data in strategic locations;
- Opportunities for inter-divisional collaboration to develop a better picture of the issues with respect to some non-timber wild harvest industries (e.g. apiary);

Weaknesses

- Deleted from this version

Resources

- DPI currently lacks the human and financial resources to undertake the R, D&E required to address climate change without significant additions or redirection.
- Resources will be required particularly to support the development and/or application of process-based models that will allow the evaluation of alternative management systems and to undertake the monitoring that will underpin adaptive management strategies in both the fisheries and forestry sectors.

4.8 Priority Actions for DPI

The priority actions for adaptation and transition are described below in terms of programs within the general areas of production systems (including agriculture, forestry and aquaculture), natural and wild harvest systems, and community change and transition. Each program represents a broad area of research, extension or policy development and will include a number of specific projects.

Production Systems

Agriculture
These programs include R&D issues that have particular relevance to climate change adaptation and are less likely to be addressed by more traditional, production-oriented research. Much of the latter will have correlated or intended benefits in terms of adaptation to the future climate. Some areas of RD&E have thus been specifically excluded. For example, the highly corporatised pig and poultry industries have been excluded since adaptive R&D in these industries should not require major public investment. DPI also has significant investment in plant and animal breeding (although this is facing major rationalisation), plant and animal health and in managing invasive plants and animals. However, these resources will need to be refocussed in order to address the extra challenges of climate change.

Program A1 - Adaptation strategies for the livestock industries
This program will build on the analysis of climate change impacts on the grazing industries, and regions within industries, undertaken by *Impacts Program 1*. These analyses will use downscaled climate data and models such as GRASP, the SGS Pasture Model and DAIRYMOD to estimate the interactions of likely future temperature, rainfall, elevated CO_2 and grazing on the productivity of the livestock industries on a regional basis. Particular attention will be paid to the effect of decadal as well as inter-annual climate changes on pasture and livestock productivity.

The program will include a range of projects aimed at building greater flexibility and resilience into livestock management systems, and understanding the natural capacity of pasture resources to adapt to the expected rate of change. It will include projects related to:

- pasture pre-breeding to achieve greater resilience to extreme climatic conditions
- multi-species pasture or pasture-crop systems for greater continuity of production and increased flexibility
- fodder conservation, storage and feed out strategies that maximise opportunities of high feed availability events and reduce impact of low feed events
- the productivity and grazing characteristics of new sheep breeds in western NSW
- improved carcase characteristics and eating quality of adaptive beef cattle breeds
- the impact of intensive grazing management practices on the functioning of water limited ecosystems
- assessment of the genetic capacity of vegetation communities (particularly in the rangelands) to adapt to climate change
- the integration of C3 and C4 pasture species in the livestock feed base
- management of pests, diseases and weeds (see *Program A11*)

This program will be field-based predominantly but the results will be tested for operation under future climates by use of the same models used initially for impact assessment.

Program A2 - Adaptation strategies for broadacre cropping
This program will build on the analysis of regional climate change impacts on the productivity of broadacre cropping industries undertaken by Program 1 of the Impacts theme. This analysis will use downscaled climate data and models such as APSIM to estimate the interactions of likely future temperature, rainfall, elevated CO_2 and nutrient levels on crop production.

The program will include a range of projects aimed at increasing the flexibility and resilience of cropping and mixed farming systems through:

- crop pre-breeding to achieve greater resilience to extreme climatic conditions
- increased efficiency of water and fertiliser use
- better integration of livestock and cropping in mixed farming systems (livestock are likely to be less affected by climate variability than crops)
- better utilisation by livestock of crop residue and low quality roughage by supplementary feeding technology
- incorporation of perennial species of both crops and pastures into farming systems
- management of pests, diseases and weeds (see *Program A11*)

Increased efficiency of water use will be influenced particularly by the promotion of conservation farming techniques while increased efficiency of fertiliser use will be achieved by more precisely adjusting the level and timing of fertiliser application to current and expected seasonal conditions and by a greater reliance and legumes in systems than on artificial nitrogen fertilisers.

Again, this program will be predominantly field based but the results will be tested for operation under future climates by use of the same models used initially for impact assessment.

Program A3 - Adaptation strategies for intensive cropping (horticulture and viticulture)
This program will build on the analysis of regional climate change impacts on the horticultural and viticultural industries undertaken by *Program I1*. It will include projects aimed at developing strategies to address:

- the effects of elevated temperature and CO_2 on tree and vine phenology and fruit quality
- the impact of variable seasonal and annual water supply on tree and vine productivity and fruit composition
- the potential value of varieties and rootstocks from hotter and dryer environments
- management of pests, diseases and weeds (see Program A11)

Similar projects will be required to identify adaptation strategies for annual horticultural crops.

Program A4 - Adaptation strategies for irrigation industries
This program will build on analyses undertaken as part of *Impacts Program 1*, as well as other collaborative initiatives (e.g. the South Eastern Australia Climate Change Initiative (SEACI) and the CSIRO Sustainable Yields project) which will assess the impact of climate change on water availability and allocation. It will include projects related to:

- precision management of soil moisture to reduce evapotranspiration losses (with added mitigation benefits of sequestering CO_2 and minimising emissions of nitrous oxide)
- testing of crop factors/coefficients for water use under increased or more variable temperature regimes
- development of efficient but less energy-intensive irrigation systems
- re-evaluation of the economic efficiency of fertiliser use
- development of “real options” methodology for economic evaluation of investment in water supply and on-farm infrastructure

Program A5 - Improved risk management tools for farming enterprises
This program will include a number of sub-projects aimed at assisting producers in those areas in which management of increased risk associated with changing climate will be an essential component of adaptation. These projects will include development of:

- a whole farm decision support tool/workshop, based on the current ‘Ri$ky Business’ workshop and the ‘P2P’ (Plan to Profit) farm business scenario analysis software. It will allow the evaluation of alternative adaptation scenarios aimed at maintaining profitability in a changing climate
- a web-based tool to assist decisions relating to the level and timing of fertiliser application in relation to current seasonal conditions and the seasonal outlook
- a web-based tool, based on the PaddockGRASP concept, to allow a risk-based approach to stocking rate decision making
- a web based tool to allow livestock producers to match market requirements to available pasture or feeding regimes to both maintain a sustainable pasture base and meet economic market outcomes
- tools to improve management of pests, diseases and weeds

Plantation Forestry

Program A6 - Adaptation strategies for Plantation Forestry
This program will include:

- research into the interactive effects of increased atmospheric carbon dioxide in a water and nutrient-limited environment on the growth of major forest species
- research into the breeding of tree species for low rainfall and drought conditions
- modification of silvicultural practices, such as site preparation, establishment and thinning to optimise both timber volume and carbon pool management
- harvest strategies to optimise both timber and carbon pool management
- fire management under climate change (in conjunction with the bushfire CRC)
- managing forest health under climate change
- management of assets including road based infrastructure
- assessing the impacts of forest management and reafforestation on water yield to catchments and water quality

Aquaculture

Program A7 - Adaptation strategies for aquaculture
This program will build on the analysis of regional climate change impacts undertaken by Program 1 of the Impacts theme. For the aquaculture industries this program will include a number of projects that:

- develop new techniques to maintain productivity of oysters and other molluscs; and fin fish and crustaceans in the face of elevated and increasingly variable temperature and elevated CO_2
- identify and evaluate new species and cultivation technologies to adapt to changing environmental conditions (including new biosecurity risks)
- identify new lease areas for future oyster and mollusc farming and evaluate options for securing them

These projects will provide guidance to NSW aquaculture farmers and future investors in understanding, adapting to and exploiting climate change and the opportunities that might arise.

Mining

Program A8 - Adaptation strategies for the mining sector
This program relies intrinsically on the outputs from Program 1 of the *Impacts* theme and Cross Cutting Program 2: "*Communicating with stakeholders on climate change*" to inform the mining sector and regulatory authorities of the additional risks posed by climate change so they can adapt their risk management strategies (eg adjusting the prescriptions for retention ponds).

Natural and Wild Harvest Systems

Program A9 - Adaptation strategies for native forests

Several issues are similar to those for plantation forestry. Within the context of a risk-based, ecosystem-based, commercial native forest management system, this program will:

- determine the interactive effects of increased atmospheric carbon dioxide in a water and nutrient-limited environment on the growth of major forest species
- determine sustainable harvest strategies in terms of timber yields and carbon pool management while maintaining key environmental outcomes, such as biodiversity, catchment water yield and water quality
- fire management under climate change
- Managing forest health under climate change
- management of assets including road based infrastructure under more extreme climatic events
- identify key ecological indicators to be monitored to ensure sustainable management under projected climate change impacts and harvest scenarios

Program A10 - Adaptation strategies for wild harvest fisheries (commercial and recreational)
Within the context of a risk-based, ecosystem-based fisheries management (EBFM) framework, this program will:

- define sustainable wild harvest strategies for key species while maintaining natural biodiversity values under the range of impacts of climate change identified in *Impacts Program 1.4* (eg decreased or more variable freshwater flows in rivers - and thence into estuaries, rising sea levels, increased temperature, increased ocean acidity and changed recruitment patterns)
- identify the long term impacts of land development on water quality, fish production and habitat
- predict trends in key ecological indicators that will be monitored under changed climate and harvest scenarios

Program A11 - Adaptation strategies for biosecurity
This program goes across all production and wild harvest systems in agriculture, forestry and fisheries. It will:

- quantify the impact of climate change on the distribution (geographic range) of key aquatic and terrestrial pests, diseases and weeds
- undertake an initial assessment of the most effective strategies to address these threats
- model likely changes in pest distribution (geographic range) under climate change (*Impacts Project 1.5*)
- undertake experimental studies on the effect of changed and interacting climate variables on host-pest relationships and resultant modification of integrated pest management and pesticide resistance management strategies

- develop management or control strategies for high priority biosecurity threats

Program A12 - Adaptation strategies for emergency management
This program goes across all production and wild harvest systems in agriculture, forestry, mining and fisheries. It will:

- Work with the State Emergency Management Committee Climate Change Working Group to develop response strategies to address the forecast greater incidence of extreme weather-related events due to climate change
- allocate resources to implement response strategies

Preparing communities for change

Socio-economic assessment of adaptation and transition options
Socio-economic assessment will:

- identify best bet options for primary industries to adapt to climate change
- guide the prioritisation of R,D&E
- analyse the socio-economic impacts on industries, enterprises and regional economies of adaptation options, and of policy options to promote transition to alternative industries or forms of land use, for regions and industries in which adaptive technologies alone are unlikely to ensure the continuation of economically or ecologically viable industries. Examples could include:
  - some irrigation industries and schemes
  - some perennial horticulture
  - the marginal cropping zone
  - rangeland pastoral industries
  - some aquaculture and wild harvest fisheries industries
  - some plantation forestry

Socio-economic assessment of adaptation and transition strategies will be fully integrated with socio-economic assessment of climate change impacts and mitigation strategies. Because socio-economic assessment is a key requirement of all themes and will, in many cases, be undertaken using similar techniques, it has been developed into a *cross cutting* program. See *Program C1.* in Cross cutting programs in Section 9.

Building capacity for climate change adaptation and transition in rural communities
NSW DPI will adopt a knowledge brokering and mediating role in building community capacity for change through collaboration in development and dissemination of science-based information, appropriate adult learning E&T packages, change management, and support for structural adjustment policies and programs.

The major communication elements of the *Adaptation and Transition* Theme are picked up as part of a cross cutting *Information, Education and Training* program (*Program C2*) presented in Section 9.

4.9 Links to Other Themes

The priority programs outlined above will have significant linkages with programs developed under other themes:

- Most will be dependent on the sectoral and regional impact analyses conducted under *Program I1* of the *Impacts* theme and close collaboration with these projects will be required to ensure that the models and climate scenarios used reflect the critical features of each production system.
- Monitoring of climate change impacts on natural systems and species will require close linkages with *Program I2* of the *Impacts* theme.
- Forest adaptation has strong linkages with the *Mitigation* theme as mitigation and adaptation practices will be complementary and natural forest systems are tied closely to productive forest systems in an operational context.

4.10 Potential Partners

NSW Department of Environment and Climate Change (DECC)

- Provision of downscaled, regional climate data (for one only future climate scenario) that can provide input to process models for impact assessment;
- Collaboration in implementation of the NSW Biodiversity and Climate Change Adaptation Framework (which identifies the ways in which NSW public sector agencies will address climate change and its effect on biodiversity);

- Linkage with the NSW Government's Natural Resources program for Monitoring, Evaluation and Reporting (MER - led by DECC under State Plan priority E4);
- Collaboration with the Rangeland Conservation Initiative within DECC to assist development of land use and land stewardship policies, and to promote the uptake of research findings by CMAs and government.

Queensland Climate Change Centre of Excellence

- Modelling of climate change impacts on rangeland productivity;
- Support for application of the GRASP model and development of web-based pasture growth forecasting tool.

CSIRO

- Support for model applications eg GrassGRO, APSIM, etc.

Funding agencies

- National Centre for Climate Change Adaptation – will be the major means for the commonwealth government to fund R,D&E on climate change adaptation;
- Department of Climate Change (Federal);
- DECC (NSW);
- For the aquatic projects funding via FRDC, NHT 3, NLWRA, Recreational Fishing Trusts, etc;
- Land & Water Australia Managing Climate Variability Program;
- All rural RDCs through the CCRSPI process.

Cooperative Research Centres

- Bushfire CRC - particularly Project Vesta dealing with the behaviour of high-intensity bushfires in eucalypt forests;
- Future Farm Industries CRC – especially program 2 (new farming systems, focussing on development of perennial-based farming systems) and program 3 (new woody crop industries, focussing on development of woody species for timber, charcoal , biomass energy and carbon sequestration);
- CRC for Irrigation Futures – aimed at defining and implementing the principles of sustainable irrigation practice in all environments and establishing processes that resolve the water use compromises necessary for people's needs, the environment, production and amenity;
- Invasive Animals CRC;
- CRC for National Plant Biosecurity;
- Seafood CRC;
- Cotton CRC;
- CRC Forests.

4.11 Communications

Effective implementation of the priority programs outlined above will require clear and targeted communication both internally within DPI and the NSW Government, and externally, aimed at generating support for the initiative and disseminating the results.

Within DPI a structure is required to manage the initiative upwards to the Executive, Minister and Treasury, and to ensure the necessary collaboration with other agencies. A structure is also required to manage the initiative and its results downwards to front line staff.

Externally, it is vital that support from CMAs, industry stakeholders in all PI sectors, and the community at large (particularly recreational fishers) be obtained at an early stage to allow input to the final proposal and to provide endorsement for funding organisations. The same structure that solicits and facilitates this support should also be responsible for co-ordinating the dissemination of results to levels in stakeholder organisations that will not be effectively contacted by front line staff of DPI.

A single structure should be capable of achieving all of these objectives. It should have an ongoing responsibility for climate change action across all Divisions of NSW DPI. As such, information education and training has been picked up *Program C2* in the cross cutting programs in Section 9 of this report.

4.12 Key Policy Issues

Policy issues will need to be further defined in consultation with S,P&C Division, particularly by linkages with the Water & Resources Policy Branch. Some issues which are likely to require policy development include:

- Revision of current Exceptional Circumstances support policies in light of the expected increase in frequency of extreme events;
- Options to balance EC support policies with incentive programs that encourage improved natural resource management and increase landscape resilience to climate variability (e.g. incentive for achievement of ground cover targets);
- Establishment of cost sharing programs that will ensure that the costs of adaptation and transition initiatives are appropriately divided among private and public beneficiaries;
- Establishment of a responsive regulatory and policy environment capable of translating scientific data into effective and equitable adaptive responses in consultation with stakeholders.

The major policy issues in the Adaptation and Transition Theme are picked up as part of a cross cutting policy program (*Program C3*) presented in Section 9.

5. Climate Change Mitigation

5.1 Objective

Develop low cost methods to quantify the net greenhouse gas emissions from primary industries; quantify the carbon footprint of key primary industries; develop sustainable options for primary industries to reduce their net emissions, sequester carbon and produce bioenergy to replace fossil fuels; and inform the possible participation of the agriculture, forestry and mining sectors in a national emissions trading scheme.

5.2 Issue

Prior to the industrial revolution, the level of CO_2 in the atmosphere was 280 parts per million (ppm). By 2005, the burning of fossil fuels and other human activities had increased atmospheric gases to 430ppm. Methane and nitrous oxides had also increased significantly. This concentration of greenhouse gases is increasing by approximately 2ppm CO_2e per year.

The Intergovernmental Panel on Climate Change (IPCC) estimates that, in order to prevent the worst-case change scenarios from occurring, atmospheric carbon dioxide levels must be stabilised at below 550 ppm. This will require developed countries to reduce their emissions by at least 60% below 1990 levels by 2050 (IPCC 2007). This target has been endorsed by both the Australian and NSW Government and has been enshrined in the NSW State Plan along with an interim target of emissions returning to 2000 levels by 2025.

5.3 Background

Sources of greenhouse gases for Australia are shown in Table 1.

Table 5.1 Australia's greenhouse gas emissions by sector (changes since 1990) (Source: AGO, 2007a).

	Emissions Mt CO_2-e		Per cent change in emissions
	1990	2005	1990–2005
Australia's net emissions	**547.1**	**559.1**	**2.2**
Energy	**287**	**391**	**36.3**
Stationary energy	196	279.4	42.6
Transport	61.9	80.4	29.9
Fugitive emissions	29.1	31.2	7.3
Industrial processes	**25.3**	**29.5**	**16.5**
Agriculture	**87.7**	**87.9**	**0.2**
Land use, land use change and forestry	**128.9**	**33.7**	**-73.9**
Waste	**18.3**	**17**	**-6.9**

Agriculture contributed 16% of 2005 emissions, largely methane from enteric fermentation of cattle and sheep. Land clearing emitted 53.3 Mt CO_2-e, while the sink value of reforestation was 19.6 Mt CO_2-e, giving

net emissions from the land use, land use change and forestry sector of 33.7 Mt CO_2-e, or 6% of 2005 emissions. The major greenhouse gas emitted is carbon dioxide, representing 74% of the total national emissions, followed by methane (20%) and nitrous oxide (4%). Eighty-six per cent of Australia's carbon dioxide emissions originate from fossil fuel combustion, extraction and distribution activities, while 85% and 60% of Australia's nitrous oxide and methane emissions, respectively, originate from agriculture (AGO 2007a).

The emissions profile for NSW is similar to the national profile.

Table 5.2 NSW's greenhouse gas emissions by sector (Mt) (AGO 2007d).

	1990	2005	Trend (%)
TOTAL	**159.8**	**158.2**	**-1.0**
ENERGY SECTOR	**94.4**	**111.8**	**18.4**
Stationary energy	60.5	76.0	25.6
Energy industries	47.8	61.8	29.3
Electricity generation	44.0	57.8	31.4
Other energy industries	2.3	2.4	4.3
Manufacturing and construction	9.0	9.6	6.7
Other sectors	3.5	4.4	25.7
Transport	18.4	21.6	17.4
Fugitive fuels	15.5	14.2	-8.4
INDUSTRIAL PROCESSES	**13.8**	**13.1**	**-5.1**
AGRICULTURE	**23.1**	**18.6**	**-19.5**
Livestock	18.6	14.5	-22.0
Other agriculture	4.5	4.0	-11.1
LAND USE, LAND USE CHANGE AND FORESTRY	**22.6**	**8.8**	**-61.1**
Afforestation and reforestation	0.0	-1.6	
Land use change (deforestation)	22.6	10.4	-54.0
WASTE	**5.8**	**6.0**	**3.4**

The stationary energy sector makes the highest contribution, due to the heavy reliance on coal for electricity generation. Agriculture, land use and forestry made significant reductions over the period, just enough to offset the growth in emissions from the energy sectors. Agriculture contributed 12% of total NSW emissions in 2005. Livestock emissions were 14.5 Mt CO_2-e, representing 78% of the Agriculture sector's emissions and 9% of total NSW emissions. The other agriculture sub-sectors contributed 4.0 Mt CO_2-e in 2004, including 3.7 Mt from agricultural soils and 0.2 Mt from rice cultivation.

Net NSW emissions in 2004 were 1% lower than 1990 emissions, despite a 24% increase in emissions from fuel combustion. Emissions from the agriculture sector were 22% lower in 2005 than in 1990, largely as a result of the 2001–2006 drought which led to reduced sheep populations. Emissions from deforestation declined by 54% between 1990 and 2005, largely due to the introduction of controls over clearing of native vegetation on agricultural land.

5.4 Action required

All primary industry sectors have a role to play in mitigating climate change to a greater or lesser degree. Different measures must be subject to full life cycle analysis to ensure action to reduce one type of emission or sequester carbon (eg increased perennial pasture) is not simply offset by another (methane emissions from livestock grazing that pasture). A summary of known / estimated emissions from different primary industries' sources and potential reductions or sequestration opportunities is given in the Table 5.3 below. Question marks indicate lack of knowledge on currently available mitigation technologies, and hence the need for R&D to fill that knowledge gap.

Table 5.3 NSW sources of GHG and possible reductions.

Emission Source/C Sequestration opportunity	Current (2005) emissions (Mt CO2-e per year)	% NSW emissions	Potential reduction/ sequestration (Mt CO2-e per year)
Fugitive Coal Mine Methane	14.2	9%	2.84 by 2018, 7.1 by 2050
Livestock	14.5	9%	? 1-5 by 2018
Rice Growing			
Cropping soils	4.0	2.5%	? 2 by 2018
Forest soils and burning	?	?	?
Acid sulphate soils	?	?	0.27?
Biomass pyrolysis and biochar			14 ? subject to plants being built
Agricultural & forest soils			7? by 2018
Extra forestry and native veg			Potentially a big number?
Algal biomass			? subject to better technology
Waste biomass for bioenergy & biofuels			? subject to better technology

5.4.1 Reduce Greenhouse Gas (GHG) Emissions

i Emissions from Livestock

Source: enteric methane emissions from livestock. (13.6 Mt, 73% of NSW agricultural emissions).

Abatement: Reduce emissions intensity per hectare grazed or per kg of product:

- Breed livestock to reduce emissions intensity per animal and improve their net feed efficiency – proven technology, long term but cumulative genetic improvement possible.
- Improve feeding: more concentrates/less forage, improved pasture, hormones to improve growth, strategic supplementation, feedlot finishing (note: - LCA needed to ensure net benefits).
- Suppress methanogens by: antibiotics (banned in EU), halogenated compounds, novel plant compounds (tannins, saponins and essential oils), probiotics/yeasts, alternate hydrogen acceptors, vaccines, oil/oilseed supplements such as coconut oil. Speculative technologies, unproven results - need a lot of R&D yet.
- Improve herd productivity: parasite control, cull barren females.
- Manage grazing to optimise productivity from low input perennial pastures.
- Reduce livestock numbers or the proportion of high emission animals. NSW sheep numbers have fallen significantly from “normal” due to the prolonged drought. This will pose a major challenge for agriculture’s emission profile as livestock numbers rebuild.

Source: Methane and nitrous oxide emissions from manure from intensively managed livestock. (0.9 Mt CO_2e, 5% of NSW agricultural emissions).
Abatement: cover solid manures, cool manure ponds, separate solids and liquids, anaerobic digestion and capture methane as biogas for energy, compost solids, alter feeding practices to reduce manure.

ii Emissions from Cropping

Source: Nitrous oxides released from soils after application of nitrogen fertilisers, legumes and manure; (3.7Mt CO_2e, 20% of NSW agricultural emissions).
Abatement: more efficient use of nitrogen fertiliser/legumes; adjust application rates, timing and placement (precision agriculture) to match uptake; avoid water logged conditions; slow release fertilisers or composts; nitrification inhibitors; manage rotations.

Source: Methane released from rice paddies; (0.2Mt CO_2e, 1% of NSW agricultural emissions in non-drought years).
Abatement: use raised beds where possible, incorporate organic material in dry rather than flooded periods, compost residues before incorporating them, drain paddies a couple of times during growing season.

Source: Methane, some nitrous oxides and ozone precursors released from burning crop residues (0.12Mt CO_2e, 0.6% of NSW agricultural emissions).

Abatement: use management/harvesting technologies that avoid the need to burn e.g. no till and stubble retention, compost, use excess residues (eg from sugar and rice) for bioenergy.

Source: Soil carbon released as CO2 when previous pasture land is ploughed due to ground cover removal, accelerated microbial respiration and oxidation of soil organic carbon. Australia's cropping soils have lost an estimated 1050 Mt carbon (30% to 50% of pre-cropping levels) following the introduction of intensive cropping.
Abatement: zero or minimum tillage cropping, direct drilling of crops into pastures for rotations. A long term experiment at Wagga Wagga has shown that over a 20 year trial, continuous wheat growing using conventional cultivation and stubble burning depleted soil carbon by an average of 400kg C/ha/year. In comparison, a wheat : sub-clover rotation with zero tillage and stubble retention increased soil carbon by 185kg C/ha/year (Chan 2008).

Source: Emissions from crop chemical input manufacture and application (synthetic fertilisers, herbicides, pesticides and fossil fuels – included in industrial emissions in the national carbon accounts).
Abatement: Minimum or zero tillage, integrated pest, disease and weed management systems, organic production systems, use of legumes to reduce inputs.

Source: emissions from fossil fuels in farm machinery and infrastructure. (not reported in the agricultural sector but a direct result of agricultural activity).
Abatement: reduced tillage and increased soil carbon to reduce fuel use due to less farm operations and better soil structure, alternative power (biofuels, wind, methane, solar).

iii Emissions from forestry
Source: Burning of harvest residues, prescribed burning and wildfire in managed forests.
Abatement: Improve forest thinning & management practices to reduce fire risks. Remove slash / thinnings for bioenergy or biofuels to reduce fossil fuel use.

iv Other Emission Reductions
Source: Methane, some nitrous oxides and ozone released from savannah / woody weeds burning (0.02Mt CO_2e, 0.1% NSW emissions) and native vegetation burning for bushfire hazard reduction.
Abatement: litter management, early season burning, burn less often, harvest biomass or thinnings for bioenergy.

Source: Carbon emissions due to drainage of peaty wetlands underlain by acid sulphate soils (ASS) may be as high as 119 t/ha of CO_2e per year in tropical climates.
Abatement: Prevent further drainage of ASS, manage the impacts of drained acid sulfate soils on water quality (retaining more water in the landscape) to result in peat soil formation. NSW has 260,000 ha of high risk ASS including 150,000 ha under agriculture, which could capture 0.27 MT CO_2e/y.

5.4.2 Increase Carbon Sequestration in Soils

v All Soils
Opportunity: Biochar is produced by pyrolysis of biomass of all varieties to yield renewable energy and a chemically stable form of carbon. Biochar application to soil will lead to long term increase in soil C stocks as char has a very long half life – hundreds of years. It may also cause other positive effects (e.g. improved crop yield, reduced leaching losses, reduced emissions of nitrous oxides and remediation of degraded soils). Possible negatives which need investigation include addition of chemicals to soil (depending on source material) and enhanced turnover of native soil carbon.

Uptake of biochar technology is limited by lack of commercial scale pyrolysis units in NSW. A distributed network of moderate size pyrolysis plants in NSW could make biochar from local biomass and waste sources. Location near biomass waste streams would reduce transport and distribution costs and emissions. 200 plants using 10 MT of biomass and generating 4 MT of biochar per year plus green electricity could sequester about 8 MT CO_2e per year as char, produce 2790GWh renewable electricity, displacing 3 Mt CO_2e from coal-fired power generation and reduce nitrous oxide emissions by up to 3 Mt CO_2e, giving total emissions reduction of up to 14 MT CO_2e per year.

vi Agricultural soils
Opportunity: Improve cropland management to increase yield and carbon input by best practices eg: improved crop varieties; extended crop rotation (especially perennial crops with deep roots to increase below ground carbon inputs); avoided/reduced use of bare/fallow land; retained crop residues; avoided burning of residues, reduced or no tillage; direct drilling; stubble ;retention; controlled traffic; increased

irrigation to increase yield and therefore carbon; added high carbon soil amendments such as biochar, compost, biosolids and mulches; conversion from cropping to pasture or increased perennial pasture component of rotations.
Abatement: Soil carbon in cropping soils in NSW may be increased by about 10 t/ha over a 20 year period or by up to 39 MT C - equivalent to an average annual storage rate of 7 MT CO_2e i.e. about 4.5% of current total annual NSW emissions. Some of these gains, however, may be lost later due to higher global temperatures.

Opportunity: Improve grazing land management to increase soil carbon input including: optimise intensity of livestock (better matching stock numbers to pasture growth), introduce more deep rooted and perennial grasses, increase strategic native vegetation areas (e.g. Landcare plantings) and apply tactical grazing in low or variable rainfall areas to maintain groundcover.

vii Forest soils
Opportunity: Conversion of cropland to forest is likely to increase soil carbon by 18%–20% in the long term. Conversion from fertile pasture to forest is likely to initially decrease soil C stock, as a result of a decline in pasture root litter inputs in the early phase of plantation establishment and exposure to the atmosphere due to deep ripping. As the plantation grows, soil carbon is replenished from litter fall and root turnover. In broadleaf forest species, soil C is generally restored to the original stock within 30 years. However, reforestation with pine species may lead to around a 15% net decline in soil carbon stock.

5.4.3 Increase Carbon in Above Ground Biomass

viii Forests
Opportunity: Growing forests sequester carbon until they reach maturity, when carbon stock remains essentially constant, unless the forest is disturbed (e.g. by harvest or fire). The sequestration rate of planted forests depends on climate, soil factors and forest management (i.e. planting configuration, species, stocking rate, establishment methods, thinning, fertiliser and weed control).
Abatement: Annual sequestration over the growth phase ranges from 8–25 t CO_2e.ha^{-1}. A commercial hardwood plantation on the NSW North Coast may sequester 600–1000 t CO_2e.ha^{-1} by the time it reaches rotation age. The average carbon stock over several rotations, (long term net mitigation benefit of the plantation), is about 300–500 t CO_2e.ha^{-1}. In lower rainfall regions, the productivity and final stock may be less than 1/3 of this. Variability in climates and soils, and incidence of pests, disease and fire causes uncertain estimates of forest sequestration potential.

Opportunity: Wood products play an important role in Australia's carbon balance with accumulated carbon stocks (in service and in landfills) of about 230 MT C (1.5 times Australia's annual greenhouse gas emissions). Timber products significantly extend the carbon sequestration benefits of forests. NSW is the main producer of both sawn softwood (790 000 m^3) and sawn hardwood (316 000 m^3) in Australia. 75% of sawn timber is used for residential purposes, (80% of sawn pine for house framing and 50% of sawn hardwood for sub-flooring and fencing). Up to 70% of the carbon in harvested logs is effectively permanently stored, directly in wood products (including storage in landfill after disposal of redundant products) or through use for bioenergy (displacing fossil fuel emissions).
Abatement: A plantation with carbon stock at harvest of 375 t CO_2-e.ha^{-1} would contain 300 t CO_2-e.ha^{-1} above-ground, including 250 t CO_2-e.ha^{-1} in the stem. Of the stem amount, 175 t CO_2-e.ha^{-1} would be permanently stored at each harvest. After three rotations, the value of carbon stored in wood products or through avoided fossil fuel use would be 525 t CO_2-e.ha^{1}, compared with the carbon storage in the forest of 375 CO_2-e.ha^{-1}.

ix Agriculture
Opportunity: increase agricultural biomass within existing systems (eg from improved agronomic practices, fertilisers, better soil moisture management, opportunistic cropping, etc); increase perenniality including grasses, herbs, shrubs and horticultural plantings,

Opportunity: Native vegetation on private agricultural land e.g. planting shelter belts, wood lots or enhancing riparian revegetation, land use changes such as allowing pasture or cropland to return to natural vegetation and revegetating degraded lands, are very important carbon sinks, with land clearing restrictions and consequent growth / regrowth of native vegetation since 1990 responsible for most of the emissions reduction in Australia. The decade of Landcare started in 1990 (Kyoto compliant). Quantifying and promoting carbon sequestration through reduced clearing and Landcare plantings will support participation in emissions trading. A mechanism to pool, carbon sequestered by many small individual plantings is necessary to reduce transaction costs. *Abatement:* to be assessed.

Opportunity: purpose grown crops for biomass or biofuels (see separate section), short rotation woody crops for essential oils (eg mallee), charcoal, etc. Many of these are suitable for lower rainfall areas.
Abatement: potential to be assessed

Opportunity: Weeds are highly efficient at carbon sequestration. They grow without external inputs, often prolifically in dense stands. Sustainable and practical means of harvesting them could be developed, particularly for woody weeds in different environments, for bioenergy and / or biochar production. Management systems which prevent bioenergy crops becoming weeds are also needed – such as the protocols developed by the CRC Future Farm Industries.
Abatement: potential to be assessed

x Aquaculture
Opportunity: Algae are very efficient photosynthesisers and a number of pilot and proprietary technologies are being developed and commercialised around the world to exploit this opportunity for greater carbon capture. Options to utilise algae include use in bioenergy to replace fossil fuels (see Section 6) or as a source of carbon for biochar to sequester carbon in agriculture and forest soils.
Abatement: potential to be assessed

xi Waste Biomass Utilisation
Opportunity: Biomass sources that are currently considered waste products include biomass from agriculture and forestry (such as packing materials, paper, food wastes, etc) as well as sewage biosolids, urban green waste and so on. Depending on the type of waste biomass, there is considerable scope to divert this material from landfill or burning either directly or after treatment to agriculture and forestry as soil amendments (eg biosolids, composts, etc) where they add to soil organic matter and provide extra nutrients, or to utilise them for bioenergy (see Section 6) and / or biochar.
Abatement: NSW recycled 1.41MT organic waste in 2004/05, much as compost or mulches with relatively short half lives. Converting it to bioenergy and stable biochar could have far greater C sequestration benefits – life cycle and economic analysis is needed to optimise results.

5.4.4 Substitution of Bioenergy for Fossil Fuels

See section 6 for a detailed analysis of bioenergy options. In summary, the opportunities are:

Opportunity: Methane from intensive livestock - feedlot cattle, dairies, pigs – can be captured after anaerobic manure digestion and used for bioenergy. Abatement: needs to be quantified.

Opportunity: Ethanol or biodiesel from agricultural crops – proven technology but NSW does not have high and reliable rainfall which would guarantee crop feedstock supply to many biofuel plants without wild price swings and severe competition with human and livestock food chain prices.
Abatement: Manildra ethanol plant at Nowra can produce enough ethanol from domestically grown gluten by-product to satisfy NSW 2% mandate for petrol. Biodiesel plants can use all waste cooking oil as well as tallow from abattoirs. Expansion of production limited by lack of reliable feedstock streams.

Opportunity: 2nd generation biofuels from biomass show great promise. Commercial scale plants for lignocellulosic ethanol are just coming on stream in USA. Lots of new technologies need further evaluation.

5.4.5 Clean Coal

NSW cabinet has approved pa $20m project to investigate the potential to capture CO_2 from coal fired power stations and sequester it in stable geological strata. The CO_2 CRC and Coal 21 fund are also major contributors to this program.
Clean Coal is dealt with in detail in section 7.

5.4.6 Greenhouse Accounting, Lifecycle Analysis and Sustainability Modelling

Australian is currently modifying its system of reporting greenhouse gas emissions across all sectors. (National Greenhouse and Energy Reporting System - NGER) and simultaneously developing a national emissions trading Scheme (ETS). These systems depend on reliable estimates of emissions from all activities in each sector. In some cases, these data do not exist and accounting methods often rely on inaccurate estimates, sometimes applied from overseas data. Because of Australia's unique climate, soils and production systems, the use of overseas data is generally inappropriate, particularly in agriculture. There is a critical need to provide accurate emissions estimates and further develop emission accounting systems and models for application at regional and individual farm or forest levels.

The AGO's greenhouse accounting model, FullCAM is used to quantify Australia's emissions profile. The version distributed as NCAT, the National Carbon Accounting Toolbox, can be used to assess the potential for sequestration in the agriculture, forestry and land use change sectors, at specific sites.

Forests NSW has developed accurate models of sequestration for its major plantation species, which are used in carbon accounting under the NSW Greenhouse Gas Abatement Scheme. A Carbon Sequestration Predictor has also been developed for lower rainfall regions of NSW (< 800 mm) where few data are available. To date there has been little activity to develop such a methodology for agriculture. Calculators for some activities are provided on the university of Melbourne's web site.

Many options for mitigating greenhouse gas emissions have complex interactions and unintended consequences for total emissions. For example, an increase in fertiliser application to increase above ground biomass may increase soil carbon, but could increase emissions of N_2O and NH_4 from the soil. One molecule of methane has 25 times the global warming effect of one molecule of CO_2, while one molecule of nitrous oxide has 298 times the effect. If livestock numbers are increased as a result of the increased biomass, the net result could be a net negative greenhouse gas outcome. To address these issues, a lifecycle approach to accounting is required.

Options proposed to mitigate emissions can also have unintended adverse environmental or socioeconomic impacts. For example, use of agricultural crops for biofuel has led to inappropriate clearing of native vegetation (eg tropical rainforests for palm oil plantations in Asia) and has also led to food shortages in third world countries. To prevent such perverse outcomes, a broader sustainability assessment methodology needs to be developed and applied to mitigation proposals.

5.5 Mitigation Work Already Underway

Current NSW DPI projects on mitigation include:

Measurements on fluxes of N_2O and CH_4 from forest soils during pasture–plantation transitions: Drs Singh and Cowie, with Ensis, CSIRO L&W and Queensland DNR&M, funded by the AGO, for hardwood and softwood plantations of different ages in climatically different regions of Australia (NSW, Qld, WA). The overall aim is to improve the predictive ability of the FullCAM model for estimating emissions during the pasture to plantation transition.

Quantifying greenhouse and crop productivity benefits of biochar application to soil: Drs van Zwieten, Cowie, Chan, Singh and Kimber with Best Energies: investigating (a) slow pyrolysis for production of biochar, (b) the use of char as soil amendments to sequester carbon and reduce nitrous oxide emissions, (c) desktop analysis of whole of life GHG balance of various biochars applied to different cropping systems.

Monitoring changes in soil C stocks under cropping, pasture and forestry systems, and as affected by land management practices: Drs Chan, Cowie, Singh, and Young are quantifying the effects of land use and land management practices on soil carbon, including impacts of revegetation, biochar application, altered crop rotations and grazing.

Ligno-cellulosic fermentation of NSW feedstocks for ethanol: Drs Vancov and Martin in collaboration with UNE (PIIC Climate Technology Action Grant project), are assessing lignocellulosic feedstocks for conversion to ethanol and other value added products. Focus is on developing pre-treatment technology to utilise these feedstocks and assessment of life cycle greenhouse benefits of ethanol production systems.

Potential for low-rainfall tree species integration into farming systems: Drs Cowie, Barton and Morgan are evaluating the role of low rainfall forestry in delivering environmental benefits (e.g. salinity mitigation, biodiversity enhancement) and C sequestration. Establishment of a network of 48 x 2Ha species demonstration trials and current testing of new species and genotypes through a Climate Action Grant. Continued support needed to manage these long term trials, trial additional species and extend research into forest management and new products for low rainfall environments (eg mallee oil, biomass for bioenergy). Linkages with CSIRO Forestry and CRC Future Farm Industries.

Eucalyptus genetic improvement program: Forests NSW project (Mike Henson) breeding to increase C sequestration in biomass of conventional forest species, eg through faster growth and higher tree density (Climate Action Grant funded).

Viability of biomass products for bioenergy and biofuels, as well as composite wood products, to enhance greenhouse mitigation benefits and financially viable low rainfall forestry industry (Drs Cowie and George) Past assessments of fast pyrolysis (with Dynamotive Canada and Country Energy), trialling camphor laurel and forest residues in sugar mills, interest in bioenergy by Forests NSW.

Best incentives for land managers' practice change to deliver GH benefits. Strong policy incentives need to be devised to promote widespread practice changes towards effective mitigation measures, for which the life cycle GH benefits have been demonstrated, and sustainability (from all perspectives) assessed. GHG policy for this sector has potential for spill-over impacts within and beyond the sector. This requires collaboration between agricultural and forest science, economics and policy perspectives to devise appropriate, workable and effective greenhouse policy. Planned collaboration with UNE through PIIC needs funding.

Promotion and assessment of conservation farming NSW DPI's farming systems researchers, linked with Agriculture and Fisheries Division, have had sustained impact in this area including consideration of carbon sequestration and all other aspects of sustainability. They aim to develop production systems with enhanced carbon sequestration in biomass and soil, as well as lower life cycle emissions, that are sustainable with regard to all environmental attributes, and have the capacity to adapt to climate change.

5.6 Gaps in Current Mitigation Work

Strengthen current life cycle analysis capability Full GHG life cycle analysis of current and alternative primary industries practices and CC mitigation strategies are critical, to identify and develop best management practices to mitigate GHG emissions and enhance carbon sequestration in NSW. It is recommended that DPI utilise its existing LCA expertise and detailed knowledge of NSW agricultural and forestry systems, with additional staff resources, to build capacity to undertake NSW-specific LCA studies.

Sustainability modelling of various biomass production and harvesting options and agricultural and forestry land use systems to answer numerous questions e.g. Under what conditions are trees the best option for mitigating greenhouse emissions (would some other crop for biofuel be better under some/all situations)? How best to integrate trees into farming systems (management, economics, interactions eg water use, stock, shade)? Growth rates, silviculture, species selection, final carbon stocks, risks (current and future)? What are limitations to establishment of new plantations or farm plantings (eg what is limiting plantation expansion in traditional forestry area (>800mm rainfall - high land prices)? What is limiting inclusion of trees in agricultural landscape (fear of locking up land, loss of water for dams streams)?

Compare land use potential of forestry (plantations as well as native), grazing and cropping systems in mitigating soil GHG emissions in different climatic zones in NSW.

Biomass availability in NSW must be mapped in detail as a matter of priority. This should include urban, rural and commercial biomass waste streams e.g. green and putrescible wastes, animal manures, paper pulp etc, as well as forestry and agricultural waste streams. Current biomass from agricultural residues in NSW is 7.6 MT, increasing to 9.2 MT with forestry plantation and urban green wastes. The development of biochar, bioenergy and/or biofuels as mitigation options must be linked with waste biomass availability, existing recycling programs to composts and mulches, and new forest and agricultural management opportunities. Strategic location of processing facilities will reduce costs and GHG emissions due to raw material or final product transport.

Biochar research, demonstration and monitoring. Test biochar as a tool to mitigate non-CO_2 GHG emissions and increase soil C sequestration. Char carbon stability and GHG mitigation ability of different biochars in different farming soils and climatic conditions needs to be thoroughly assessed, as do indirect benefits of biochar application e.g. through fertiliser displacement by increased CEC and nutrient conservation.

Information on **non-CO_2 greenhouse emissions from new and native forests**, relative to adjacent pasture or cropping lands, and their drivers, is required for accurate emissions reporting and modelling at regional / national scales. Rigorous comparison of current practices against potentially best practices is required through carefully designed field and lab based research, so that emissions intensity is benchmarked and mitigation benefits are quantified.

Existing long-term agronomy trials studying the **influence of management on soil C in agricultural systems** need be maintained and C sequestration quantified through continuous measurements and

modelling approaches. Other potential soil C building practices (e.g. improved cropping and grazing land management) also need to be researched thoroughly (paired-site approach, together with modelling, could be used to quantify the soil C sequestration benefits of improved practices).

Strengthen ruminant methane reduction work and profile, building on good work done on genetics of net feed efficiency and measurement in beef cattle. Develop methodologies and apply to sheep.

Promote information on best mitigation options and management practices through innovative extension programs, and continued improvement of best options and practices through appropriate research and development and innovation.

5.7 DPI's Capabilities in Addressing These Gaps

Strengths

- Office of Rural Greenhouse Gas Studies (ORGGS) collaboration with UNE through PIIC
- Extensive R,D&E expertise in agriculture, forestry and fisheries
- Network of research facilities for key production systems in agriculture, forestry and fisheries including strengths in all aspects of plant production and soils
- History of research and expertise in carbon based research with agriculture (eg through farming systems group and Centre for Recycled Organics in Agriculture (CROA) and forestry (through Forest Resources Research team) including participation in the CRC for Greenhouse Accounting
- Analytical laboratories
- Expertise in economics that can evaluate mitigation options and advise industry and government
- Extension and education network capable of delivering relevant information to rural communities to support mitigation
- Long term research trials on agricultural and forestry systems that can quantify carbon sequestered under various systems

Weaknesses

- Deleted from this version

Resources

- established tree growth plots and species trials in 500-700 mm rainfall zone
- Significant experience and credibility with life cycle analysis
- good carbon accounting methods for traditional forestry systems and some for dryland areas
- Long term agricultural study sites on DPI research stations and other farms throughout the state
- Ruminant methane emission measurement equipment and facilities through the Beef cattle CRC

NSW DPI will need:

- Specialised gas monitoring equipment/devices, for field measurements
- appropriately trained research and technical staff to undertake emission monitoring in field and lab
- better organised collaboration / communication among researchers
- Strong links into policy formulation on ETS

5.8 Priority Actions for DPI

Mitigation technologies for Agriculture, Forestry and Fisheries

Program M1: Emissions measurement, modelling and accounting in agriculture and forestry systems

This program will:

- develop cost effective GHG measurement, accounting and modelling techniques to quantify
  c) the principal greenhouse gases emitted by agriculture and forestry systems (methane, nitrous oxide and carbon dioxide)
  d) the amount of carbon sequestered above and below ground by key agriculture and forestry systems
- apply accounting techniques to quantify the greenhouse balance of key agriculture and forestry systems in NSW to better inform the national carbon accounting system (NCAS) and the possible role of agriculture and forestry in a national emissions trading scheme (see Section 8)
- develop and apply methods to quantify, on an energy balance and life cycle analyses (LCA) basis, the whole of life greenhouse footprint of current and potential new agriculture and forestry systems (eg for bioenergy)
  Note: the NCAS does not adopt an LCA approach. Emissions from upstream activities (eg inputs such as fuel and fertiliser) and downstream activities (eg transport and processing) are attributed to other

sectors of the economy in order to avoid double counting. LCA is important for comparing options – such as cropping for biofuel Vs food
- consider the broader environmental (water, soil, biodiversity) and socio-economic implications of proposed new agriculture and forestry production systems
- develop, validate and promote an enterprise (eg farm) level emissions calculator for agriculture and forestry

Program M2: Reduce methane emissions from livestock
Because methane (largely from ruminant livestock) accounts for over 65% of agricultural emissions, DPI will establish a national methane emissions reduction centre to:
- develop cost effective methods to quantify methane emissions from ruminant livestock at an individual farm level that are consistent with NCAS
- quantify methane emissions from ruminant livestock in both pasture and grain fed systems and incorporate results into greenhouse balance calculations for those systems
- identify options to reduce methane emissions from ruminant livestock by:
  - understanding the genetic control of low methane-emitting ruminant phenotypes and its value as a breeding objective
  - manipulating rumen ecology
  - improving feed conversion efficiency
- accelerate implementation of methane capture from intensive animal industry wastes
- help promote low greenhouse balance production systems for ruminant livestock both nationally and to other countries with high ruminant populations

Program M3: Reduce nitrous oxide emissions from agriculture
Nitrous oxide is the major greenhouse gas emitted from agricultural cropping systems. This program will evaluate options to reduce nitrous oxide emissions such as:
- more efficient use of nitrogen fertiliser/legumes
- adjusting application rates, timing and placement (precision agriculture) to match uptake
- slow release fertilisers or composts, nitrification inhibitors (particularly the role of biochar)
- better management of rotations

Program M4: Increase carbon storage in agricultural systems
This program will evaluate options for increasing carbon sequestered above and below ground in agricultural systems through:
- improved cropland management (eg improved crop rotations reduced or zero tillage, soil amendments such as biochar, mulches or biosolids, perennial pasture in rotations, etc)
- improved grazing land management (eg better matching grazing pressure to pasture growth, deep rooted perennial grasses, herbs and shrubs)
- agronomic practices (eg improved fertiliser mgt, better soil moisture mgt, opportunistic cropping)
- better management of native vegetation on agricultural land (eg shelter belts, wood lots, riparian revegetation, degraded lands)
- quantification of multiple benefits from native vegetation management (carbon, biodiversity, water and salt management)
- short rotation woody crops for essential oils (eg mallee), charcoal, etc
- organic amendments, such as biochar, biosolids and compost to sequester carbon in soil, reduce emissions of non CO_2 greenhouse gases and improve soil physical, chemical and biological characteristics. Particular emphasis will be focussed on biochar - the most promising current prospect

This program will include:
- the maintenance of existing and, where necessary, establishment of new long term research and demonstration sites to provide credible data on the greenhouse footprint of agricultural systems, evaluate carbon sequestration options and validate greenhouse accounting models

Program M5: Mitigation technologies for Forestry
This program will:
- evaluate the harvest and management strategies to minimise emissions of greenhouse gases and maximise carbon sequestration from various plantation and native forest operations
- evaluate options for the expansion of forests in high and medium rainfall areas of the state
- quantify the net greenhouse balance of converting agricultural land to plantation forestry for relevant agriculture and forest systems

- quantify the amount of carbon stored in wood products from an LCA perspective for softwood and hardwood plantation and native forest systems for the range of forest products produced
- explore options for the inclusion of timber products in the national emissions trading scheme (see section 8)
- compare timber to alternative building products from an LCA perspective to inform building design guidelines
- evaluate the role of soil amendments (such as biosolids, composts and biochar) in reducing net greenhouse gas emissions, nutrient and moisture management and carbon sequestration in plantation forestry. Particular emphasis will be focussed on biochar - the most promising current prospect

This program will include:
- maintenance of existing and, where necessary, establishment of new long term forestry research and demonstration sites to evaluate a range of low rainfall species, establishment and silviculture techniques

Program M6: Reduce NSW DPI's carbon footprint
This program will:
- extend NSW DPI's existing energy efficiency program to cover all sources and sinks of greenhouse gases arising from NSW DPI's operations
- include air and car transport and better use of ICT to reduce travel
- develop and implement improved building and maintenance guidelines that take account of lifecycle greenhouse footprint of building materials
- demonstrate best practice farm and land use management actions as part of Mitigation Program 6
- create an intranet staff forum on energy saving opportunities to encourage staff engagement.

Note: Socio-economic assessment of mitigation options
There are a number of important socio-economic issues to be considered when mitigating greenhouse gas emissions. These include:
- the implications of imposing a range of mitigation targets on primary industries
- a range of policy options to reduce emissions from primary industries (eg taxes, subsidies, best practice guidelines)
- the implications of the agriculture and forestry sectors participating in the proposed national emissions trading scheme (detailed in Section 8)
- the economic feasibility of a range of mitigation options available to primary industries

These socio-economic issues are addressed in Cross Cutting Program C1.2 in Section 9.

5.9 Outcomes

Outcomes in 5 years
- Low cost accounting methods developed for agriculture and forestry.
- GHG emissions quantified for key agriculture and forest production systems.
- Methodology developed to compare primary industry activities on a LCA basis which also includes broader environmental and socio-economic implications.
- Enterprise level emissions calculator developed for agriculture and forestry.
- Ruminant methane emissions reduction strategies developed and validated.
- Strategies to reduce nitrous oxide emissions from agriculture and forestry identified and validated.
- Options to sequester carbon in agriculture and forest soils (including biochar) quantified.
- Primary producers and other stakeholders understand potential to mitigate greenhouse gas emissions.
- Increased community, industry and stakeholders knowledge of mitigation technologies that not only reduce GHG emissions but enhance and sustain primary production for future generations.
- Regional industries better informed with regards to environmental, social and economic implications of important mitigation strategies.
- NSW DPI recognised as leader in best practice for government agencies to reduce their carbon footprint.

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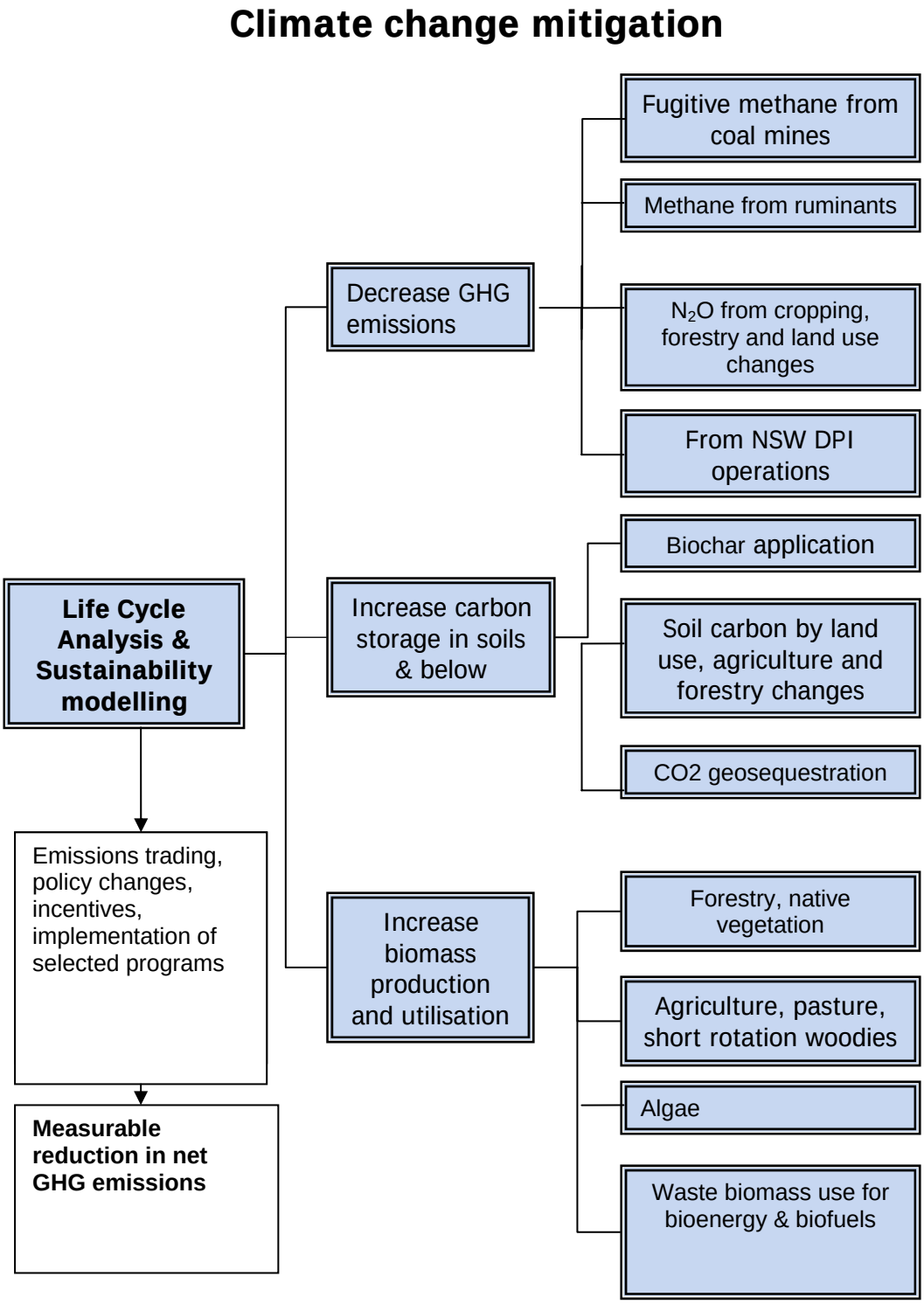
5.10 Links to Other Themes



5.11 Potential Partners

Other PISC agencies; CRCs for Future Farm Industries, Beef and Sheep; Universities in Australia and New Zealand, Landcare; New Zealand Ministry of Agriculture and Forestry, CMAs, RDCs, private forestry and other industry – and as detailed above for specific projects.

5.12 Critical Communication / Engagement Requirements

Communicating with various stakeholders is also a key aspect of developing mitigation strategies for primary industries and needs to address:

- emissions from key systems
- opportunities to reduce emissions

Communication and engagement issues are addressed in Cross Cutting Program C2 in Section 9.

5.13 Key Policy Issues to be Addressed

There is a range of key policy issues related to mitigation including:

- Coordinating input into national and state policy development (through the COAG Working Group on Climate and Water, PIMC/PISC and the NSW Climate Change CEOs).
- Informing the establishment of emissions reduction targets for primary industries.
- Evaluating policy options to achieve emission reduction targets for primary industries.
- Providing an informed contribution to the debate on establishing a national emissions trading scheme and the possible participation of agriculture and forestry in the ETS (see Section 8 for more detail).

These policy issues are taken up in Cross Cutting Program C3 in Section 9.

6. Bioenergy

6.1 Objective

To examine the biophysical and socio-economic potential for bioenergy from agriculture, forestry and aquaculture to replace fossil fuels.

6.2 Issue

Australia has one of the highest rates of greenhouse gas emission per person in the world, and is the ninth-largest emitter in absolute terms, producing about 1.8% of total world greenhouse gas emissions. Australia's total emissions in 2005 were 559Mt, of which 158Mt (28%) were produced by NSW. The energy sector makes the largest contribution to NSW greenhouse emissions, accounting for 71% of emissions in 2005 (111Mt). Electricity generation, which was mostly coal-fired, accounted for 52% (57.8Mt) of the emissions from the energy sector.

The Australian Government has set a Mandatory Renewable Energy Target (MRET) of 20 percent share for renewable energy in Australia's electricity supply by 2020. This implies an increase in the MRET from 9,500 gigawatt-hours to 45,000 gigawatt-hours in 2020. The expanded measure is to be phased out between 2020 and 2030 as the national emissions trading scheme matures and price signals become sufficient to drive deployment of renewable generation technologies. In December 2007, the Commonwealth and States agreed to work cooperatively, commencing early in 2008, to bring the existing MRET and the various state-based targets into a single, expanded national MRET scheme by early 2009.

Coal accounts for over half of Australia's energy production while renewable energy accounts for around 5% of total stationary energy production. Biomass is the major source of renewable stationary energy, most of which is utilised in sugar mills and saw mills to provide heat energy. Electricity generation from biomass could contribute to the MRET, but significant market and technological development is required to meet this opportunity.

With regard to energy generation from biomass, the key issues to be addressed are:

- Can Australia's MRET be met or exceeded by 2020?
- What is the potential contribution to this target by production of energy from biomass? and
- Can the bioenergy contribution be sustained beyond 2020 in a mature emissions trading market?

6.3 Background

Bioenergy is the term used to describe energy and energy related products derived from biomass. Biomass resources include wood from plantation forests, residues from agricultural and forest production, and organic waste streams from industry, livestock, food production, general human activities, and purpose-grown crops. Examples of waste streams are "slash" from timber harvest operations, sawdust and wood waste from timber processing, cotton ginning trash, nut shells, manure and human sewage.

Bioenergy can be regarded as a form of solar energy, as photosynthesis combines atmospheric carbon dioxide with water in the presence of sunlight to form the biomass, while also producing oxygen. The energy bound into the biomass can be recovered through a variety of energy conversion processes and technologies. During the energy recovery process, the carbon dioxide bound in the biomass is released to the atmosphere. Bioenergy is regarded as renewable when the biomass resource consumed in the energy conversion process is replenished by the growth of an equivalent amount of biomass. Under the Kyoto Protocol bioenergy is regarded as carbon dioxide neutral (Bioenergy Australia 2007).

Biomass for combustion applications can be supplied from harvest and processing residues from forest and agricultural industries, as well as from purpose-grown crops. A similar range of potential biomass feedstocks could be utilised to produce liquid biofuels, or pyrolised to produce energy and 'bio-char'. Biochar also offers the potential for the farm sector to contribute to long term sequestration of carbon.

The most common biofuels are ethanol (produced by fermentation from sugar and starch crops) and biodiesel (produced from waste cooking oil, tallow and oilseed crops). The various pathways for converting biomass to energy, chemical feedstocks and liquid biofuels are shown in Figure 6.1. Production of ethanol from ligno-cellulosic feedstocks has not been economically viable to date, but recent developments have greatly improved prospects for this technology. The increased cost of fossil fuels for transport, as well as environmental concerns (including health and climate change) and concerns for the security of energy supply have increased interest in biofuels.

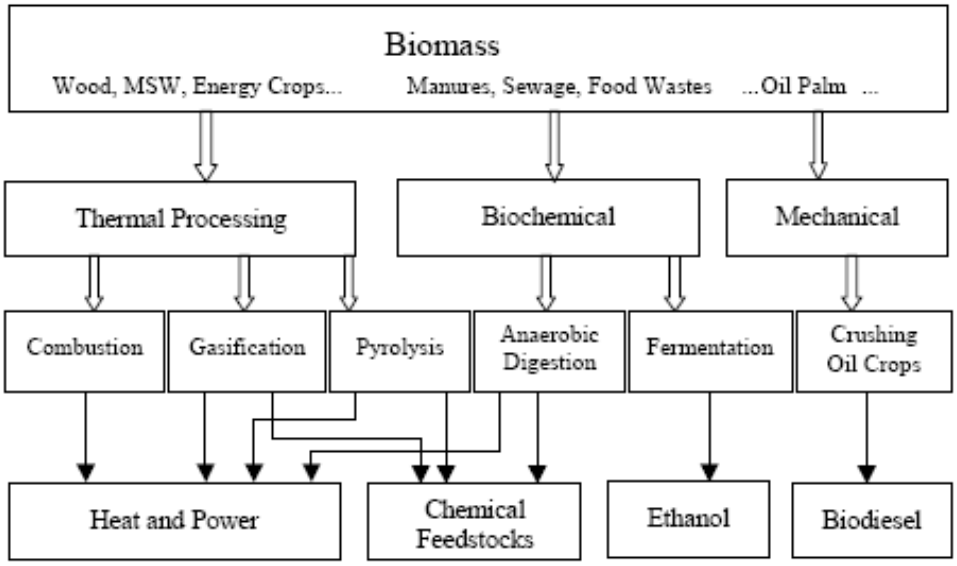


Figure 6.1: Energy processing paths for converting biomass to energy, chemical feedstocks and liquid biofuels (Stuckley et al 2004).

The production of biofuels from food crops, or purpose-grown bioenergy crops, carries with it the potential for competition with food and fibre production. Second generation ligno-cellulosic production should minimise this adverse spillover. However, the technology is still in the research phase and is not currently an economically viable alternative to fossil fuels.

The NSW Government has established a task force to investigate the opportunities and issues associated with mandating a 10% ethanol blend: a 2% volumetric mandate came into force in September 2007, with the

task force to further consider the implications of increasing the mandate to 10% by 2011. Some basic considerations for agriculture in meeting the demand generated by this mandate include:

- capacity to produce feedstock;
- sustainability and resilience of production systems;
- energy balance of production systems;
- impact of new markets on existing industries (eg grain use by intensive industries);
- development of technology for 'second generation' biofuel systems that will deliver greater energy efficiency and greenhouse gas mitigation, and will not compete directly with food and fibre supplies; and
- economic competitiveness of current and future ethanol sources compared to fossil fuels.

Significant research and policy work is required to ensure that bioenergy systems deliver substantial greenhouse gas mitigation benefits, and that they are economically competitive. Confirmation of beneficial greenhouse outcomes will increase consumer acceptance, thereby increasing market potential. However in the end energy markets are price sensitive, so no benefits will accrue if the fuel is not price competitive with alternatives.

The benefit of a bioenergy system is sometimes expressed in terms of energy output relative to energy input, or greenhouse gas emissions per unit energy output; however, the most appropriate measure of greenhouse mitigation benefit is the net emissions reduction of the bioenergy system with respect to the fossil fuel system that is displaced (Schlamadinger et al 1997).

The benefit depends on the feedstock (eg use of wood residues or wastes from processing delivers more positive greenhouse and energy balance outcomes than use of purpose-grown crops), and the energy conversion process (eg production of heat is more efficient than generation of electricity).

Estimates of mitigation benefits of bioenergy production vary widely. Much of the variation is due to inconsistent application of life cycle assessment (LCA) methodology and the analysis is strongly influenced by determination of the system boundaries. To allow for comparison of the respective fossil and biofuel systems, it is important that 'upstream' emissions are included.

Upstream (or pre-combustion) emissions are produced during:

- extraction of fuel (eg removal from oil fields)
- production of fuel (eg cultivation and harvest of biomass)
- transport of crude oil/biomass to respective conversion facility (eg by ship, rail, road or pipeline)
- processing and conversion of oil/biomass to a finished fuel (eg with energy from coal, gas or co-generation)
- distribution of fuel to retail stations or bulk wholesale uses.

Generally, the production of biofuels from annual crops (eg maize, wheat, sugarcane), with associated high intensity of production, will have a marginal environmental benefit compared with biofuel production from woody and grass (ligno-cellulosic) production systems, which have higher efficiency and energy yields. Reported net energy balance for maize to ethanol usually shows that around 10%–25% more energy is produced than is invested (Hill et al 2006); for biodiesel from oilseeds this figure is 70%–90% (Farrell et al 2006), while for ligno-cellulosics a range from 200% to over 600% has been suggested (Morton 2001). An additional advantage of bioenergy systems based on woody crops is that they are less susceptible to yield fluctuations due to climate variability.

6.4 National Action Required

Significant research is still required to develop an understanding of the optimal biomass production systems (eg which product from which crops), as well as how the systems compare in terms of net greenhouse gas mitigation.

The LCA approach, considering a range of environmental attributes in addition to greenhouse gas mitigation, is a valuable tool to quantify impacts of alternative bioenergy systems. The LCA process helps to systematically identify areas in which research is required to meet the objectives of sustainable production systems. It can be used to inform policy development, and to assure consumers that the biofuel they use is benefiting the environment in relation to air quality, energy balance, greenhouse gas emissions and production system sustainability.

There are few detailed LCA reports available for Australian bioenergy systems and there is a clear need for Australian research to assess the performance of bioenergy systems under local conditions and agronomic/forestry systems.

Significant work is required to develop the data required for these LCA studies. Furthermore, economic and social impacts also need to be considered in the development of sustainable land use systems that optimise greenhouse outcomes.

Specific technical studies are required to evaluate the prospects and barriers for specific biomass feedstocks and energy conversion technologies. This research will involve detailed laboratory work, with progress to pilot scale testing (with industry partners).

Biomass availability studies are required to determine the potential for bioenergy to contribute to mitigation of NSW GHG emissions. Both current and future availability should be estimated, the latter requiring modelled assessments of alternative scenarios that should recognise projected impacts of climate change.

Farming system studies are required to develop sustainable land use systems that optimise outcomes for carbon sequestration, mitigation of GHG emissions, other environmental attributes, and production objectives. These studies will utilise models that incorporate both biophysical and economic interactions, and evaluate risk.

Besides technical experts, the project team should include policy advisors to ensure that policy development for greenhouse mitigation, particularly in relation to emissions trading and bioenergy, is informed by understanding of the potentials and tradeoffs associated with alternative bioenergy systems.

6.5 Bioenergy Work Currently Underway

The department is actively involved in bioenergy activities, through participation in Bioenergy Australia (the peak government-industry forum) and representing Australia at the International Energy Agency bioenergy forums on ‘Short rotation crops for bioenergy systems’ and ‘Greenhouse gas balances of biomass and bioenergy systems’.

Through the CRC for Future Farm Industries, NSW DPI is working with Victoria, Western Australia and South Australia to investigate the suitability and productive capacity of native woody species for bioenergy production that may be integrated into farming systems in the 300–700 mm rainfall zone.

In collaboration with BEST Energies, NSW DPI has conducted agronomic trials to assess the impacts of biochars derived from a range of feedstocks, to determine the influence on plant growth and soil properties. Current studies are investigating the role of biochar in reducing nitrous oxide emissions from soil. A current project utilising a novel approach based on stable isotopes is investigating the turnover rate of char-carbon.

NSW DPI has formed an alliance with the University of New England, to create the Primary Industries Innovation Centre (PIIC). Within PIIC, the Office of Rural Greenhouse Gas Studies (ORGGS) has been established with a focus on greenhouse gas mitigation studies. Biofuels and biomass energy have been identified as a key future program of ORGGS and alliances with industry and researchers are being pursued.

The department is collaborating with UNE on a project, funded under the NSW Government’s Climate Action Grants program, to examine candidate feedstocks for ligno-cellulosic ethanol production, and thereby identify ‘best bet’ feedstocks with regard to availability, environmental impact, and possible pre-fermentation and fermentation techniques to optimise their use.

In collaboration with Crucible Carbon and the University of Newcastle, NSW DPI is developing the concept of the ‘NSW Carbon Pump’, aimed at accelerating and scaling up projects for large-scale bioenergy production from novel sources (e.g. algae), and concurrent production of biochar for carbon sequestration in agricultural and mine rehabilitation uses.

6.6 Gaps in Current Bioenergy Work

NSW DPI’s current effort in the field of bioenergy research is in its infancy. Although research has commenced in some areas, significant gaps exist in the following areas:

- There is a need for life-cycle analysis of potential bioenergy systems that are relevant to Australian conditions and agronomic/silvicultural systems (addressed in Program M1);
- Technical data are required for specific biomass feedstocks and potential energy conversion technologies;

- Biomass analysis and modelling are required to determine current and future availability considering projected impacts of climate change;
- Farming system studies are required to develop sustainable land use systems that optimise outcomes for carbon sequestration, mitigation of emissions, other environmental and social attributes, and production objectives;
- Modelling is required to incorporate biophysical and economic interactions, and evaluation of risk;
- Economic and social constraints to the development of sustainable land use systems that optimise greenhouse outcomes need to be identified and addressed;
- There is a need to provide policy advice on potential options and tradeoffs associated with alternative bioenergy systems and emissions trading; and
- Ultimately, there will need to be an information/extension program for primary producers (farmers, foresters, fishers, policy makers, consumers).

A viable bioenergy sector in New South Wales will need to satisfy the Government taskforce criteria and gaps exist in all of the following areas:

- capacity to produce feedstock;
- sustainability and resilience of production systems;
- energy balance of production systems, LCA;
- impact of new markets on existing industries (eg grain use by intensive industries); and
- development of technology for 'second generation' biofuel systems that will deliver greater energy efficiency and greenhouse gas mitigation, and will not compete directly with food and fibre supplies.

The key questions for bioenergy research can be grouped under five headings:

1. **What are the options for biomass production?** These could include wood from plantation forests, residues from agricultural and forest production, and organic waste streams from industry, livestock, food production, general human activities, purpose-grown crops. The impacts of climate change on biomass production also need to be considered.
2. **What are the environmental impacts of biomass production for bioenergy?** This would involve Life Cycle Analysis (LCA), energy balance, impacts on land, water and air quality, sequestration options including biochar.
3. **Where should bioenergy production plants be located?** This would involve determination of the availability/accessibility of biomass feedstocks, impact on the local environment and infrastructure needs of the plant for local (transport, electricity and water). Modelling would be important for simulation and optimisation of the logistics of bioenergy chains.
4. **What are the optimal pathways for biomass use and energy conversion?** Biomass conversion routes? Energy conversion technologies (combustion, gasification, fermentation, pyrolysis etc), metabolic engineering of microbial pathways, product recovery, process development and implementation strategies.
5. **What are the social and economic considerations that need to be taken into account?** This will include benefit, cost and risk analysis of bioenergy production, understanding public perception, ethical aspects of biomass utilisation, .and policy research and advice.

6.7 NSW DPI's Capabilities in Addressing these Gaps

The Department has a significant capacity to address bioenergy issues through redirection of existing staff and infrastructure resources.

Strengths ▪ Professional staff with relevant knowledge and expertise ▪ Network of field research stations with basic infrastructure ▪ Internationally recognised scientific expertise on bioenergy ▪ Network of extension and regulatory staff ▪ Existing collaborative partnerships (eg BEST, Crucible)
Weaknesses ▪ Deleted from this version
Resources ▪ Laboratory facilities at Wollongbar for lingo-cellulose and at Wollongbar and West Pennant Hills to analyse biochar ▪ Access to pilot plant for lingo-cellulose analysis at Harwood ▪ Strong collaborative arrangements with the private energy sector ▪ Engagement with planning authorities, regional development and catchment agencies

6.8 Priority Actions for DPI

Note: as these programs relate to the issue of "mitigation", they continue the alpha-numeric numbering for other mitigation actions from Section 5.

Program M7: Bioenergy research
This program will:

- assess current and potential biomass resources in NSW to evaluate the potential for a viable and sustainable bioenergy industry in NSW
- develop farming systems that include woody perennials, such as short rotation woody species and agroforestry
- develop management systems to prevent biomass from becoming weeds
- research sustainable harvesting systems for selected biomass (including weeds)
- evaluate algal biomass production options
- develop and evaluate technologies to convert biomass to bioenergy (including ligno-cellulose to ethanol, pyrolysis, burning of biomass for energy, etc)
- assess the net greenhouse balance of bioenergy production systems using the methodology outlined in *Program M1*

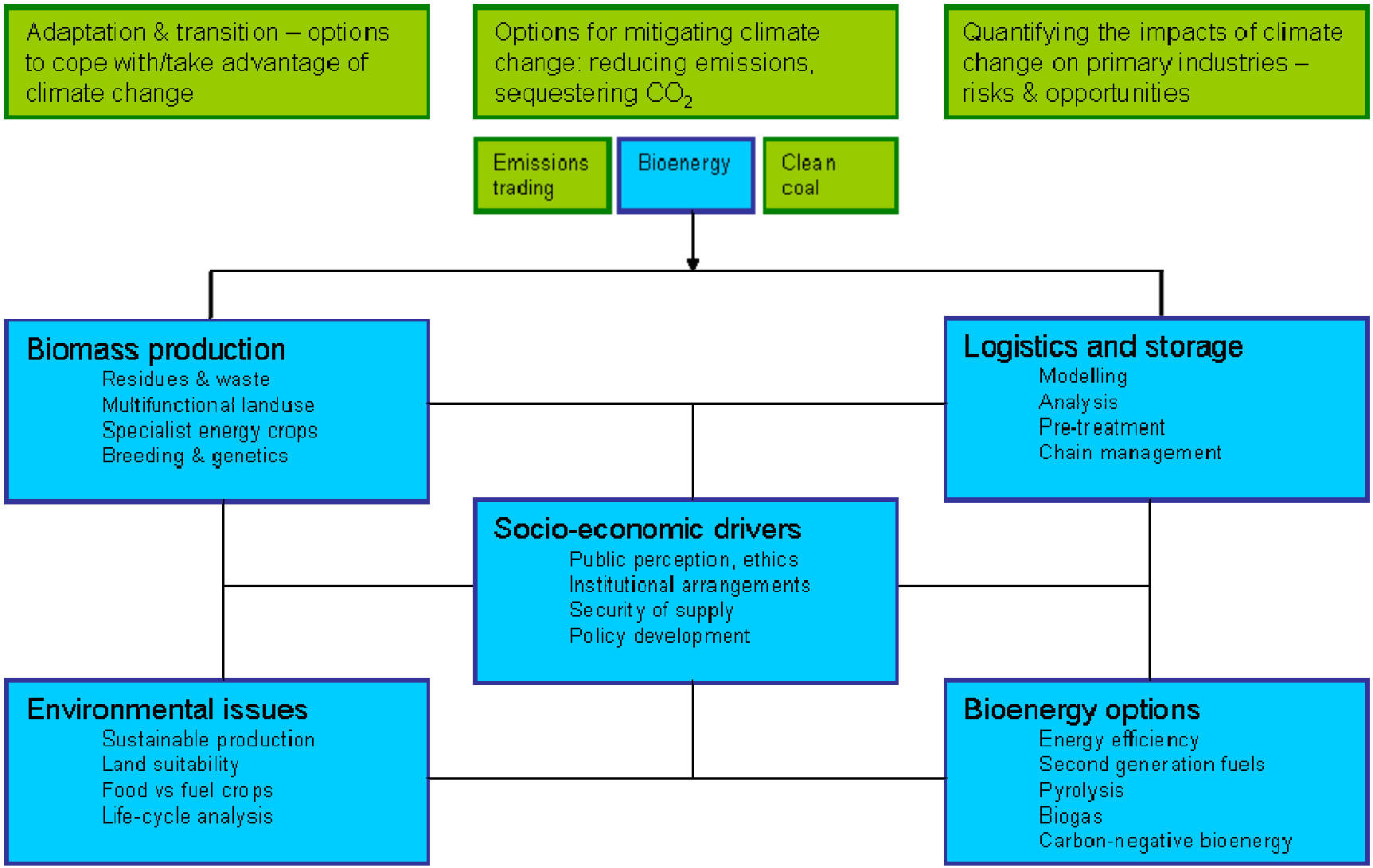
6.9 Outcomes

The overall outcome is that bioenergy production in New South Wales will contribute to meeting Australia's 20% MRET by 2020 and that can this contribution will be sustained beyond 2020 in a mature emissions trading market.

Outcome	Targets	Timeframe
Biomass production options identified and validated	• Expand feedstock base for bioenergy production particularly natives such as mallee eucalypts, woody weeds, and assess novel sources such as giant reed (Arundo donax), jatropha, pongamia, aquatic plants and algae • Investigation into the technical and economic viability of products such as biomass for bioenergy production (for liquid fuels and stationary energy), as well as composite wood products • Breeding for bioenergy traits (e.g. robustness, yield, sustainability and processability [enhanced sugars with minimum lignin and toxic inhibitors], microalgal lipid yield)	Up to 5 years 5-10 years – up to 15 years if genetically engineered
Environmental impacts	• Life-cycle analysis of potential bioenergy systems that are relevant to Australian conditions and agronomic systems • Farming system studies to develop sustainable land use systems that optimise outcomes for carbon sequestration, mitigation of emissions, other environmental attributes, and production objectives . • understand the effects of long-term biomass harvesting on soil fertility and determine how to maintain ecosystem function, productivity and resilience in a changing climate.	5-15 years
Logistics and storage	• Technical data for specific biomass feedstocks and potential energy conversion technologies; • Biomass availability analysis and modelling to determine current and future availability considering projected impacts of climate change	

Outcome	Targets	Timeframe
Bioconversion and biofuel production options.	• Research into co-firing a range of biomass materials in coal-fired power plants • Investigation of the potential of photobioreactor systems, growing algae to produce biodiesel and using existing waste streams such as: nutrient rich effluents, CO2 captured from power stations. • Survey algal species for biomass production potential, amenability to culture and harvest and biochemical composition. • Optimise/develop pretreatment technologies to generate maximal sugar hydrolysates with minimal release and or generation of inhibitory compounds • Survey Australia's natural enzyme diversity for novel and superlative activity against lignocellulosic feedstock • Engineer and/or isolate new microbial strains with novel capabilities such as: co-fermentation of C_5 and C_6 sugars, stress and inhibitor tolerance, high sugar and temperature tolerance to deliver greater fuel/chemical productivity • Assessment of biochemical options, including integrated biorefinery concept, whereby high-value chemicals are produced from biomass in addition to energy products • Integrated bioenergy systems tailored to regions with fully consolidated processing to simplify the end-to-end production of biofuels/chemicals/energy	5-10 years 5-10 years 5-10 years Up to 10 years Up to 15 years
Socio-economic assessment of the bioenergy chain.	• Modelling to incorporate biophysical and economic interactions, and evaluation of risk • Economic and social constraints to the development of sustainable land use systems that optimise greenhouse outcomes identified and addressed • Socioeconomic assessment of the impacts of a bioenergy industry on other NSW primary industries, and the macro-economic implications for the national economy	5 years
Policy development	• Policy advice on potential options and tradeoffs associated with alternative bioenergy systems and emissions trading • Policy responses to promote the establishment of a sustainable bioenergy sector. Options could include: provision of direct or indirect incentives; subsidies; penalties; taxes and market-based mechanisms	
Communication and engagement	• A communication and engagement program to promote the development of a bioenergy sector involving all levels of government, industry, energy sector, transport, producers, consumers and the wider community	

New South Wales Department of Primary Industries Climate Change Strategy
Bioenergy theme



6.10 Potential Partners

- Australian Pork Limited
- BEST Energies
- BioEnergy Australia Limited
- Bureau Rural Sciences
- Charles Sturt University
- CRC for Future Farming Industries and partners
- Cotton Research & Development Corporation
- Crucible Carbon
- CSIRO
- Department of Climate Change (DCC)
- Department of Agriculture, Fisheries & Forestry
- Delta Electricity
- Department of Environment & Climate Change
- Ethanol Technologies Limited (Ethtec)
- Grains Research & Development Corporation
- International Energy Agency
- Macquarie Generation
- Meat & Livestock Australia
- NSW Department of Environment & Climate Change
- Oil Mallee Company Ltd
- Penn State University
- Rural Industries Research & Development Corporation
- University of New England (through PIIC and ORGGS)
- University of Newcastle
- University of NSW
- WhatIf Technologies, Ontario, Canada
- Department of Water and Energy
- Department of State and Regional Development
- Department of Premier and Cabinet

6.11 Communication and engagement

A communication and engagement program to promote the development of a bioenergy sector will need to involve all levels of government, industry, energy sector, transport, producers, consumers and the wider community. The critical issue for NSW DPI is that development of the biofuels sector may require engagement with a broader set of clients and stakeholders than was previously the case. Communication and engagement between State government agencies is likely to be critical for development of a bioenergy sector in NSW. These would include:

- Department of Environment & Climate Change;
- Department of State and Regional Development.

Communication and engagement issues are addressed in Cross Cutting Program C2 in Section 9.

6.12 Key policy issues

Key policy hurdles for bioenergy are the politics of energy policy, gaining support for and recognition of environmental benefits, and overcoming perceptions and attitudes towards resource use (Morton 2001). Policy development for bioenergy production in New South Wales will need to take account of existing relevant legislation regarding land management, native vegetation and plant biosecurity such as:

- Native vegetation Act 2003 (NSW);
- Quarantine Act 1908 (Australian); etc.

The Commonwealth and NSW Governments are committed to the development of a competitive and commercially viable biofuels industry in Australia as a means of encouraging regional development and diversifying Australia's transport fuel mix (DAFF 2007). The Government has created a policy framework to encourage the development of Australian sources of biofuels, and ensure their long term competitiveness. However, the Commonwealth and State Governments differ in their positions on support of mandatory ethanol. Consumer choice has been a factor leading to differing positions.

The New South Wales Government can consider a range of policy responses to promote the establishment of a sustainable bioenergy sector (NSW DPI 2007). These could include: provision of direct or indirect incentives; subsidies; penalties; taxes and market-based mechanisms. Funding for research and education programs is also a policy issue. In NSW, the Greenhouse Plan encapsulates the current suite of policy responses. Of particular relevance to NSW DPI is emissions trading, which provides incentives for mitigation measures, and opportunities for research, extension and education.

Policy issues are addressed in Cross Cutting Program C3 in Section 9.

7. Clean Coal

7.1 Objective

Reduce fugitive methane emissions from coal mining operations and identify options for the sustainable storage of compressed carbon dioxide from coal fired power stations in deep geological strata.

7.2 Issue

Australia has one of the highest rates of greenhouse gas emissions per person in the world, and is the ninth-largest emitter in absolute terms, producing about 1.8% of total world greenhouse gas emissions (UNFCCC 2006b; UNFCCC 2006c). Australia's largest source of greenhouse gas emissions is the energy sector, predominantly fossil fuel combustion for electricity and heat production, and energy use in the manufacturing and construction industries. The energy sector, contributed just over 70% of total NSW emissions in 2005 and total energy consumption in NSW increased by 18.4% between 1990 and 2005 to 112MT CO_2e p.a. Electricity generation accounted for just over half of energy use in NSW in 2005 and its consumption rose by 31.4% between 1990 and 2005.

Given the NSW State Plan target of a 60% reduction in emissions by 2050 and a return to 2000 emission levels by 2025 it is clear that there needs to be significant reduction in emissions from coal fired power stations. This can be achieved by finding alternative low emission generation capacity (wind, solar, geothermal, gas, hydro, nuclear, etc), and/or capturing and sequestering the majority of CO_2 from existing (and possibly new) coal fired power stations.

Capturing and storing CO_2 has the potential to be a cost-competitive and safe way to achieve large-scale reductions in emissions. ***Carbon capture and storage*** (CCS) technology offers an opportunity to significantly reduce CO_2 emissions while avoiding the enormous cost of scrapping the state's fossil fuel dominated energy infrastructure. In order to continue using the State's large coal resources for power generation while constraining emissions of CO_2, NSW will need to rely on technology that can capture CO_2 generated from coal-fired power plants and sequester it in deep stable geologic structures.

However, the integration and scaling up of existing technologies to capture, transport, and store CO_2 emitted from a full-scale power plant have not yet been fully demonstrated. While it is technically feasible to integrate a complete CCS system with a commercial-scale power plant it is necessary to build up experience by advancing early deployment.

The Federal Government's Low Emission Technology Demonstration Fund (LETDF) is funding a number of projects across Australia with the aim of demonstrating large scale low emission technologies. Projects funded to date are:

- *Solar Systems:* Solar concentrator power station (Victoria).
- *CS Energy:* Retrofit oxy-fuel technology with carbon capture and storage (CCS) (Queensland).
- *International Power:* Retrofit brown coal drying (Victoria) and PCC pilot plant
- *Fairview Power:* Coal seam methane extraction, with CCS (Queensland).
- *Gorgon (Chevron):* LNG production, with large CCS (Western Australia).
- *HRL International*: integrated drying gasification combined-cycle (IDGCC) power generation plant (Victoria).

While a number of these projects propose geo-sequestration of CO_2, no existing project is planning to test an integrated demonstration of Carbon capture and storage at an existing conventional pulverised coal combustion power station. This is a critical gap in the current portfolio of demonstration projects and is an essential component if NSW is to achieve significant reduction of CO_2 emissions from existing power stations.

It should also be noted that no CO_2 storage project that is currently operating (Sleipner - Norway; Weyburn - Canada; In Salah - Algeria) will provide the necessary modelling, monitoring, and verification experience to resolve outstanding technical issues at large scale in the NSW context.

The NSW and Australian governments, in conjunction with the coal and power industries are investing several $100m to develop a range of clean coal technologies, including geo-sequestration. The NSW Government has already agreed to provide $20m as part of this effort. The information below relates to the existing NSW Government approved program.

In addition to emissions from burning coal, ***fugitive methane emissions*** from coal seams in closed and open cut mines contributed 14.2MT CO_2e in 2005, or 9% of total NSW GHG emissions. A 50% reduction may be technically feasible by 2050, while a phased program could lead to 20% reduction within 10 years. However, legislative responsibility for fugitive methane emissions resides with relevant state and commonwealth regulatory authorities. NSW DPI's role will therefore be to inform regulatory authorities to help them set appropriate regulatory controls.

7.3 Background

Within the framework of the NSW Clean Coal Working Group, the Department of Primary Industries and the NSW electricity generators have completed a series of studies to assess the potential for geo-sequestration of carbon dioxide in deep saline aquifers and coal seams. A review of legal issues impacting geological storage was also undertaken.

The reports identified potential large scale aquifer storage sites in the Darling Basin and possible coal seams in the Gunnedah region. The depleted Moomba gas fields in South Australia have also been identified as a potential alternative storage should the above fields be limiting.

NSW DPI is undertaking similar geological modelling in the Sydney Basin to that undertaken for the Darling Basin. Whilst the Sydney Basin is unlikely to offer large scale, long term geo-sequestration opportunities, it is hoped that a site near a power station may be identified so that a demonstration project can be planned without the need for a major pipeline or rail transport of CO_2 to the injection site.

Planning is underway to develop a research scale post combustion capture absorption plant at Munmorah power station of up to 5,000 t CO_2/year capacity by 2008, with a long term goal of developing a demonstration scale facility of greater than 50,000t CO_2/year by 2013.

The pilot scale plant at Munmorah would lead to the development of a demonstration project which would involve the installation of a carbon capture plant at an existing NSW coal fired power station with capture capacity sufficient to support future "scale up" to commercial size - in the order of 50,000 to 100,000 tonnes CO_2 /year, establishment of a test CO_2 injection well and development of appropriate CO_2 transport infrastructure to permit storage at a similar scale to the capture plant.

The ultimate aim of this development is to provide a pathway for commercialisation of carbon capture and storage technology in NSW. To achieve this goal the project must ensure equipment suppliers, generators and regulatory bodies build sufficient confidence in the technology on completion of the demonstration to offer, purchase and approve it on a commercial basis. A successful demonstration will rely on collaboration between those who may ultimately be part of the technology commercialisation and could include generators, equipment suppliers, specialist drilling contractors, petroleum production companies and pipeline operators. Involvement of researchers and regulators such as planning bodies and DECC is also essential.

A High Level Master Plan is being developed to provide the working parties with a long-term approach to reduce carbon emissions from coal powered power stations by the development and deployment of carbon capture and storage technologies.

7.4 Action Required

The large scale capture and storage of CO_2 from power stations will require development of national carbon dioxide transport infrastructure to match the location of large CO_2 point sources, and of sinks with similar capacity.

A July 2007 study commissioned by the Victorian DPI on regulation of infrastructure suggested that private sector development of a transport infrastructure was likely to be effective, even if this was on a project-by-project basis. Victoria has large point sources in the Latrobe Valley, and a very large capacity 'sink' in the adjacent offshore area. The situation is different in New South Wales, and possibly Queensland. In these States, there are a number of relatively high emission point sources (power stations), with no locally identified storage formations of adequate capacity. It appears likely that long distance transport of carbon dioxide to recognised 'sinks', including the Gippsland and Cooper/Eromanga basins, will be required. No one operator is likely to be able to commit to the expense of such a pipeline. A service provider is also unlikely to commit to building a pipeline at this stage of the industry's development. The longer term infrastructure capacity requirement for eastern Australia needs to be considered, so that future efficiencies can be locked in by early design. It could be argued that 'over-sizing' a pipeline to accommodate multiple future loads is ultimately a more cost-effective path to establishing a large scale CCS industry, and is in the national interest. Also, capture projects can not be developed without first identifying a credible storage mechanism.

The Federal Government in conjunction with the States is developing a national framework for assessing environmental impact, licensing, verification and monitoring of injection/storage sites. NSW has been tasked with leading the effort on transport and storage.

7.5 Clean Coal Work Already Underway

In terms of ***geo-sequestration***:

A Pilot carbon capture project is being undertaken by Delta Electricity at Munmorah power station in conjunction with the CSIRO.

The project is proceeding with a significant amount of design complete, procurement of structural steel advanced and fabrication of the structure by Delta Maintenance underway. However, the delay in placement of orders for some long lead time items is likely to defer the construction completion date to June 2008.

The Department of Primary Industries is actively involved in assessing geological storage potential across NSW. Key activities include:

- Extensive analysis and physical testing of geological bore cores has been carried out and is continuing. Initial results indicate that potential sites within the Sydney Basin and the adjacent Gunnedah Basin contain geological units with acceptable porosity and permeability for storage of CO_2.

- In the Darling Basin, up to sixteen (16) potential storage sites have been highlighted by the Darling Basin Reservoir Prediction Study which was released in September 2007 and has been made available on the DPI external website.

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- Drilling of an exploratory borehole(s) by the Department in the Darling Basin will be integrated with the regional stratigraphic program mapped out for the Gunnedah/Sydney work.

- In the Sydney Basin, drilling in the vicinity of Munmorah power station is scheduled to commence by June 2008, pending rig availability. The unprecedented demand for drill rigs and the particular requirements for drilling cored boreholes to a depth of 2000m are necessitating a re-schedule, while other options for acquiring well data are being evaluated.

- A report commissioned to examine coal systems in the Sydney Basin is due for completion by March 2009, with the preliminary report by June 2008.

- Analysis of the burial history of the Sydney Basin is to be carried out by June 2008.

- Procurement has commenced for a Gravity Survey of the Sydney Basin, being carried out during April 2008.

- An examination of refraction seismic work performed as part of petroleum exploration off-shore from the Sydney Basin is to be carried out during Q2/Q3 2008, with the possibility of additional information from a “bounty well” in Q1 2009.

- Additional work is to be carried out in the Eromanga, Surat and Oaklands/Murray Basins and Clarence Moreton Basins.

In terms of ***fugitive methane emissions***:

- BHP has a power plant powered by fugitive methane emissions.

7.6 Gaps in Current Clean Coal Work

- The identification of and characterisation of storage sites in NSW for geo-sequestration remains the number one priority for NSW.
- The economic viability of transporting CO_2 long distance by pipeline to remote basins or interstate storage sites needs to be evaluated.
- Developing the legislative framework for carbon dioxide capture and geological storage in NSW needs to be accelerated - based on the current model being developed by the States and Commonwealth for the offshore regime.
- Current legislative regimes relating to CO_2 transportation need to be examined.

7.7 NSW DPI's Capabilities in Addressing these Gaps

Strengths • expertise to assess geological information in relation to CO_2 storage • co-ordination between different groups • opportunity to leverage information off other similar projects that are currently running in order to use their experience and knowledge of capture.
Weaknesses • deleted from this version
Resources • DPI holds vast amounts of information on the geology of NSW basins

7.8 Priority Actions for DPI

Note: as this program relates to the issue of "mitigation", it continues the alpha-numeric numbering for other mitigation actions from Section 5.

Program M8: Clean Coal technologies

There are two components to this program.

M8.1: Geosequestration
This project will:

- identify and characterise sites for storing compressed carbon dioxide in deep geological strata and/or aquifers in NSW. This is part of an integrated program to develop and demonstrate post combustion CO_2 capture (from coal dependent industries such as power generation) and the safe transport and storage of that compressed CO_2. DPI's role will focus on the storage component of the project - where we have expertise).

- DPI will lead a national working group on CO_2 transport and storage.

M8.2: Fugitive methane emissions from coal mining
This activity will, in collaboration with the NSW Minerals Council and regulatory authorities:

- participate in discussions with the commonwealth who have responsibility to document baselines and subsequent improvement to allow miners' participation in a national emissions trading scheme.
- inform the development of appropriate NSW policies to reduce fugitive methane emissions from coal mining (administered by the Department of Planning).

The project will NOT include:

- The Carbon Capture Pilot will not involve storage.
- Off-Shore storage options out of scope for the Demonstration.
- Capture options apart from Post Combustion Capture (PCC).
- Scale up of the Integrated Capture & Storage Demonstration to Commercialisation.

7.9 Outcomes

- **Carbon Capture Pilot**
  - Carbon Capture Pilot at Munmorah completed - mid 2009
  - Monitoring – mid 2009 – end 2010

- **Storage Project**
  - (Tier 1) State-wide sites assessment - 2007-2009
  - (Tier 2) two priority regions/basins identified - 2009-2011
  - (Tier 3) confirm selected Demonstration site - end 2010
  - Future long term storage and transport options identified - end 2013

- **Integrated Capture & Storage Demonstration** - end 2013
  - Community Engagement 2007 – ongoing
  - Technology and location selected for Integrated Capture & Storage Demonstration - late 2010
  - Demonstration transport option identified – end 2010
  - Lodgement of Environmental Assessment – end 2011
  - Govt Approval for injection for Demonstration – mid 2012
  - Govt Approval for Demonstration capture plant – mid 2012
  - Govt Approval of Demonstration storage site – mid 2012
  - Commence Demonstration Operation – end 2013

Funding:

Funding is being sought in a number of tranches. It is anticipated the large funding requirement for an integrated PCC & S demonstration will rely on feasibility data from pilot plant and storage assessment phases. In order to preserve the program these phases must commence in 2007. The pilot plant program has sufficient committed funding to commence however bridging funding is required urgently to commence the storage assessment program, prior to a formal funding submission for the demonstration component.

Costs:

- 2007 - Capture Pilot Plant ($6 million)
- 2007 - Storage Assessment, including legal and community frameworks ($15 million),
- 2009 - Storage Characterisation ($25 million)
- 2009 - Integrated Post Combustion Capture and Storage Demonstration ($110 million)
-

7.10 Links to Other Themes

Clean coal is a component of Mitigation.

7.11 Potential Partners

- Department of Primary Industries
- CO_2CRC
- CSIRO
- Australian Coal Association/Coal21
- Delta Electricity
- Eraring Energy
- Macquarie Generation

7.12 Communication and Engagement

The key stakeholders are:

- The state and commonwealth governments (politicians and public servants)
- The coal industry
- Energy generators
- Research partners
- The broader community

Considerable political and public interest will be generated by a demonstration project. The success of future deployment of capture technology, and storage sites may hinge on how the demonstration is perceived by the community. Early identification of environmental and safety performance measures, acceptable to, and easily understood by the community, along with early engagement will be critical to the success of the demonstration.

It is proposed to initiate and operate a community engagement program in parallel with the pilot plant and storage site characterisation described above.
Communication with these stakeholders is critical to the success of clean coal technology.

7.13 Key Policy Issues to be Addressed

The Department of Primary Industries will need to develop appropriate Legislation to provide secure title and legal framework for Geo-sequestration in NSW.

8. Emissions Trading

8.1 Objective

Evaluate the implications of introducing an emissions trading scheme (ETS) on primary industries to inform the policy debate.

8.2 Issue

An ETS is likely to be a core policy instrument used by governments to reduce greenhouse gas emissions. An ETS creates a market mechanism by which the release of emissions incurs a cost, and implementation of abatement measures generates a financial return. It allows those emitters who can abate or offset their emissions at low cost to trade their extra emission credits with others who can only do so at a high cost, thus achieving an emissions target in the most cost effective way.

Because an ETS puts a price on emissions it will be important for primary industries to have a range of different technologies and management practices that can either cost effectively abate its own emissions or are capable of sequestering emissions from other sectors. The mitigation theme report identifies a range of abatement and sequestration options for primary industries. These include better waste management systems in intensive agriculture, reducing methane emissions from livestock, the reduction of fugitive emissions from mines, more efficient utilisation of fertilisers in cropping systems, sequestration of carbon in forestry and in deep geological strata and increasing the capacity of soils to store carbon through the application of Biochar, land use change and conservation farming.

There are two main research issues. The first relates to whether an ETS is the most appropriate policy instrument for controlling emissions for industries like agriculture which typically is a diffuse rather than a point source of emissions. An important factor in determining likely industry effects is the marginal costs of emission abatement in key agriculture and forestry sectors. The impacts of an ETS on primary industries will also depend on resolution of a number of design elements including decisions about initial or delayed entry, baseline period used for emissions, method of allocating emission rights (grand-fathering versus auction), phasing in of reductions in emission rights, point of obligation requirements and partial or full industry coverage.

The second research area aims to find least cost ways of effectively monitoring emissions in primary industries. This is important to most policy approaches aimed at limiting emissions but is critical to an ETS if transaction costs are to be contained. It is also important if some primary industries stay outside a scheme

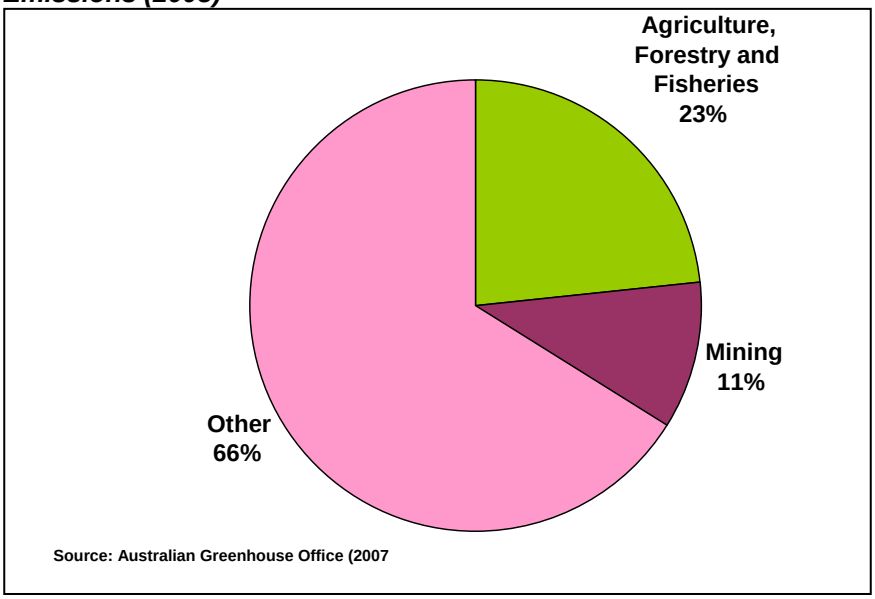
but wish to act as a source of eligible offsets to those sectors formally covered. This second issue was addressed in detail in the "*Mitigation*" theme (see program M1).

8.3 Background

Emissions profile

Agriculture, fisheries and forestry account for 23 per cent of total GHG emissions while mining accounts for 11 per cent. Hence, when the sectors are combined they contribute to over one third of Australia's GHG emissions. The agricultural sector alone accounts for around 16 per cent of total emissions on a national basis.

Figure 8.1: Contribution of Agriculture, Forestry, Fisheries and Mining to Australia's GHG Emissions (2005)



NSW produces 28 per cent of Australian emissions. The energy sector makes the largest contribution to NSW greenhouse emissions accounting for 71 per cent of emissions in 2004. Agriculture accounts for 12 per cent, waste disposal 4 per cent, and land use, land use change and forestry 6 per cent of greenhouse emissions (AGO 2006). In terms of agriculture, livestock contributes 78 per cent of agricultural emissions while agricultural soils (emissions associated with fertilisers, crop residues and animal wastes and nitrogen fixing crops and pastures) contribute 22 per cent.

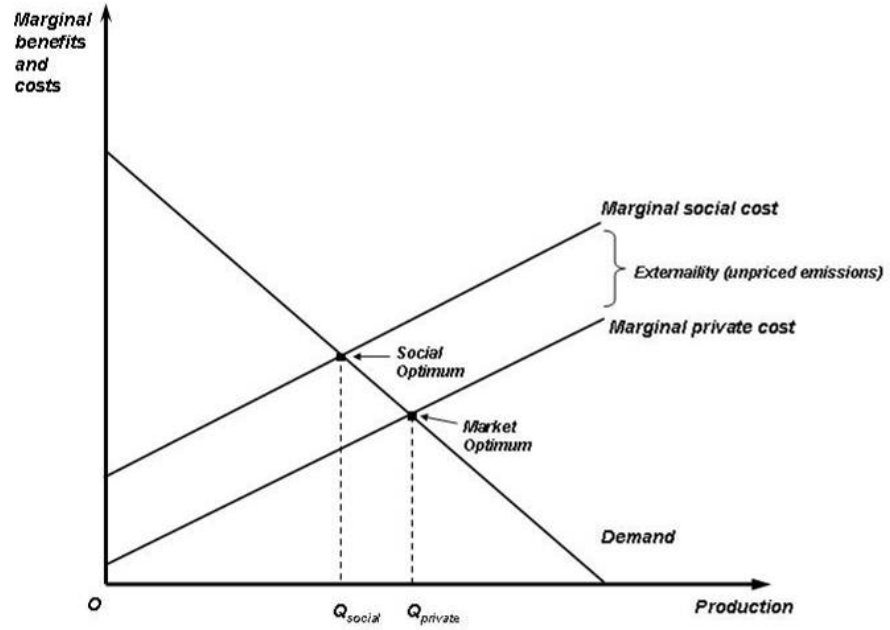
In order to stabilise atmospheric carbon dioxide at 550 ppm, significant cuts in greenhouse gas emissions are required. A well publicised target, and one that the Australian government has agreed to, is that developed countries will need to reduce their emissions by at least 60% below 1990 levels by 2050.

One of the challenges facing primary industries is emissions intensity. Greenhouse gas emissions from the agriculture forest and fishing sector average 9kg per dollar of gross domestic product (9kg/$GDP). This compares to 7kg/$GDP for the energy sector and 0.7kg/$GDP for the Australian economy as a whole (Lenzen 1998, Howden and Reyenga 1999). The introduction of an ETS is likely to be a major challenge for industries with a high emissions intensity. Significant new technologies are required to reduce emissions intensity to enable primary industries sectors to meet the NSW and Australian emissions reduction targets.

Externalities

Greenhouse emissions are a negative externality which arise from the production and consumption of goods and services. Externalities are a source of market failure and arise when market prices do not take into account the full benefits and costs of production and consumption. In the case of electricity production, coal fired power stations contribute to emissions which in turn have negative environmental consequences in terms of global warming. These negative externalities are not reflected in the market prices of electricity even though they impose a cost on society (see Figure 8.2).

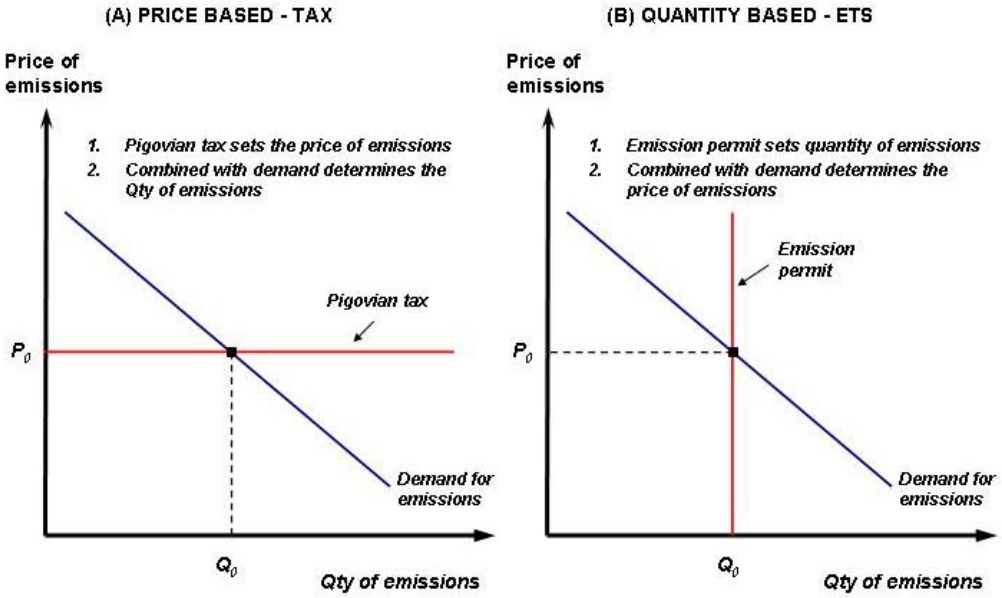
Figure 8.2: Negative externalities create a divergence between the private and social costs of production



A mixture of different policy approaches is being followed by governments to address emission reduction. Chief amongst these are different forms of market-based instruments which attempt to internalise or price, in one way or another, the costs of greenhouse gas emissions. The two main instruments are tradeable emissions rights and taxes. A tax sets the price of emissions but creates uncertainty about the extent of emission reduction. Setting emission rights on the other hand creates certainty about the volume of emissions but creates uncertainty about the price of emissions and hence the marginal costs to society (see Figure 8.3).

There is a long list of pros and cons of taxes versus tradeable emission rights that have been debated at length in the literature. The two instruments have different implications particularly under conditions of uncertainty when there is either limited information about the optimal level of emissions or the marginal costs of abatement. In some cases a hybrid approach is adopted whereby an ETS is put in place but a maximum emissions price is also put in place (a so called safety valve) to provide protection against spikes in carbon prices.

Figure 8.3: Two market based approaches to handling negative externalities



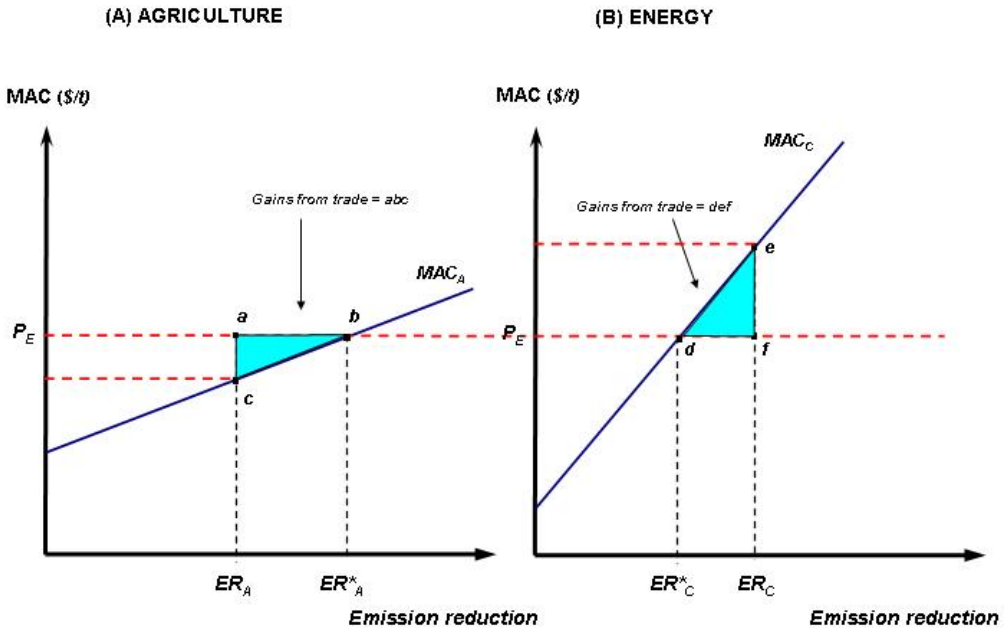
Economic benefits of an ETS

An ETS creates a market mechanism by which the release of emissions incurs a cost, and implementation of abatement measures generates a financial return. The success of emissions trading depends on the establishment of a target for emissions at a level that achieves the mitigation required, while sharing liability amongst the emitters, and enforcing compliance. It allows those emitters who can abate or offset their emissions at low cost to trade their extra emission credits with others who can only do so at a high cost, thus achieving an emissions target in the most cost effective way. An ETS generates benefits to the extent that there are differences in marginal abatement costs faced by market participants.

The benefits of an ETS can be shown with the aid of a stylised example (see figure 8.4). In the left hand panel is the agricultural sector which has marginal abatement costs of MAC_A and an emission reduction requirement of ER_A. In the right hand panel is an energy sector containing coal fired power stations that has marginal abatement costs of MAC_C and an emission reduction requirement ER_C. As shown by the relative slopes, agriculture can abate its emissions at a much lower cost than coal fired power stations ($MAC_A < MAC_C$).

At the market price of emissions P_E, agriculture can profitably undertake additional abatement beyond its requirement of ER_A because the marginal revenue gained from abatement exceeds the marginal cost. Consequently, agriculture increases its abatement to the optimal level of ER^*_A and receives net benefits of *abc*. In contrast, at the market price of emissions P_E, the energy sector is not able to meet its own reduction requirement of ER_C cost effectively. Its optimal level of emission reduction is ER^*_C, substantially less than the reduction requirement. In this case, the energy sector purchases emission rights to cover its obligations. Through the use of an ETS, it receives net benefits of *def* by meeting its emission requirements at lower overall cost.

Figure 4: Economic benefits of an ETS



Reviews of emissions trading

An ETS is likely to be a core policy instrument used by governments to reduce greenhouse gas emissions. The recently elected Commonwealth government has committed itself to the introduction of an ETS by no later than 2010, with design details finalised by the end of 2008. There have been three major studies into the implementation of an ETS in Australia:

- National Emissions Trading Taskforce (NETT) – was established by Ministers of State and Territory Governments in January 2004. It released a discussion paper in August 2006 about the possible design of an ETS. The taskforce argues that emissions trading is a practical, flexible and cost-effective means of achieving an emissions target, particularly for the energy sector.

- Prime Ministerial Task Group on Emissions Trading (PMTGET) – established by the (then) Prime Minister in December 2006. It reported in May 2007 and recommended that Australia introduce a cap and trade system by 2012. It proposed that the agriculture and land use sector emissions be excluded until practical issues associated with measurement and verification are resolved, but that offsets generated by this sector should be included, prior to full coverage of the sector. The Task group also suggested more research be conducted into more rigorous methodologies for plantation products that take into account carbon contained in harvested wood products.

- Garnaut Climate Change Review – commissioned by Australia's State and Territory Governments in April 2007. The review announced in its Issues Paper 1 (concerning land use, agriculture and forestry) that it is likely to support Australia implementing an ETS as part of a suite of policy measures. As part of this review, consideration is being given to whether agriculture and forestry should also be included in an ETS. The Review also released a discussion paper on the design of an ETS on the 20th March 2008. The final report from the overall review is due in September 2008.

Opportunities for mitigation in primary industries

The possible inclusion of agriculture within an ETS clearly increases the importance of primary industries finding ways to enhance emission abatement or sequestration. The "*Mitigation*" theme (section 5) identified the following opportunities:

- Increase biomass production and utilisation from:
  - Forestry and native vegetation
  - Perennial crops & pastures, short rotation crops
  - Algae
  - Waste biomass

- Increased carbon capture and storage in soils and below:
  - CO2 geo-sequestration in deep geological formations ("clean coal");
  - Biochar production by pyrolysis and its application to soils;
  - land use change and conservation farming

- Reduce greenhouse gas (GHG) emissions:
  - Coal mine fugitive methane emissions
  - Soil GHG emissions from farming/forestry practices and land uses;
  - Enteric methane emissions from ruminants;
  - Fossil fuel emissions by replacement with biofuels and bioenergy;
  - Development of Ultra Clean Coal and innovative combustion technologies

Despite significant scope and possible benefits from the involvement of agriculture and forestry sectors in an ETS, many challenges exist to their inclusion including:

- Diffuse nature of sources and sinks – sources and sinks in agriculture, and to a lesser extent in forestry, are diffuse and difficult to measure and verify;

- Scope of inclusion: plantations only Vs full coverage (including native forests);

- Small scale – there are a large number of farm and forestry enterprises in Australia located across diverse climatic conditions. This creates challenges in emission measurement and in constraining transaction costs associated with the management of an ETS;

- Diversity and variability – production and abatement of emissions are highly dependent on biological processes which are variable and significantly influenced by climatic conditions; and

- Many opportunities for mitigation in agriculture are temporary in nature, often influenced by climatic conditions, soil type or management practices and hence require more intensive monitoring systems than other mitigation options.

Action Required

An effective emissions trading scheme will need to be based on scientifically proven emission and sequestration relationships, sound economic principles and a cost-effective transaction and compliance framework. Consequently, much scientific research and development is required to underpin the involvement of various sectors within an ETS.

Similarly, economic analysis is required on the effect of alternative scheme designs on final emissions outcomes and the impact on different primary industry sectors. Such analyses are critical to inform scheme design but also to gauge the effects on different industries and locations.

While forestry has already been involved in emissions trading through the NSW Greenhouse Gas Abatement Scheme (NGAS), there remain fundamental questions about the efficiency of including agriculture within an ETS. Some of issues that have been raised in various reviews and discussion papers include:

- ***Lack of information on current emission levels, potential abatement options and likely abatement costs*** – this is fundamental to considerations of whether agriculture should be included within an ETS both from the viewpoint of the sector but also on the overall efficiency of an ETS from an economy wide perspective. The marginal costs of abatement in agriculture are largely unknown in an Australian context (LWA 2007). Research is required into emission levels and the marginal costs of various abatement options across different agricultural industries and geographic locations.

- ***Capacity to measure and monitor agricultural emissions*** – the characteristics of the agricultural industry make measuring and monitoring of on-farm emissions or sequestration difficult and costly. This is one of the key reasons why agriculture has not been included in any existing ETS to date. Agriculture has the added complication that emissions are affected by climatic conditions which has the potential to change an expected sink into an emission source. Research is required into cost effective ways of measuring and monitoring of emissions.

- ***Transactions costs*** – closely related to difficulties in measuring and monitoring emissions is the likelihood that transaction costs involved in agriculture participating in an ETS are likely to be high. Transaction costs include all costs associated with the management and administration of ETS involvement. There is some potential that transaction costs, on an equivalent CO_2 basis, could represent a reasonable proportion of the market price of emissions. A variety of on-farm practices might aid abatement but it could be quite costly and impractical to measure and verify each one. The magnitude of transaction costs will erode the extent of efficiency gains achieved from including agriculture. It is critical that low-cost generic accounting methods are developed and accepted, to minimise transaction costs and thereby encourage participation.

- ***Trade exposure*** – agricultural industries export around two thirds of their production and generally face elastic demand on world markets. This means that producers have limited ability to pass increased environmental costs, as incurred through an ETS putting a price on emissions, on to consumers. Consequently, participation of Australian agriculture within an ETS might erode the competitiveness of the sector unless similar conditions are imposed on the agricultural production of other producers. Research is required into the potential impact of an ETS on the competitiveness of Australian agriculture[1] and potential policy instruments which could be used to address trade related issues.

- ***Sensitivity of agricultural production to emission prices*** – very little is known about the sensitivity of agricultural land uses to emission prices. Given the potential for substitution between enterprises at a property scale, farm and regional level modelling is required to assess likely changes in profitability and land use.

- ***ETS Design Issues*** – in addition to the above issues, there are also specific design issues that will have a bearing on the overall effectiveness of the scheme as well as the likely impacts on agriculture and forestry. Key factors include:

    - *baseline period for agricultural emissions*[2]

[1] There are also possible distortions within the domestic economy in respect to the treatment of trade-exposed sectors. If there is no crediting for carbon stored in wood products, but at the same time favourable treatment of trade exposed, energy-intensive (steel and concrete) industries under an ETS, there will be distortionary price effects on the domestic market.

[2] Because emissions vary greatly between seasons it is also important to average over at least several years

- *initial allocation of emission rights* (grand-fathering versus auction)

- *overall target set for emission cuts and the phasing in of* cuts

- *coverage of specific agricultural industries within the Scheme* - inclusion of those industries where emissions might be more easily measured (eg livestock) creates a potential resource misallocation given enterprise substitution at a farm level. The efficiency aspects of ETS proposals that cover only a subset of agricultural industries need to be carefully considered (PMTGET 2007).

- *point of obligation* – given the challenges of measuring and monitoring emissions, and likelihood of high transaction costs, there is some debate about whether reporting obligations should be placed either 'upstream' (eg suppliers of inputs like fertiliser manufacturer/distributor) or 'downstream' (processors of outputs like abattoirs or mills) of individual farms. While these options would reduce transaction costs and overcome incentive problems associated with self reporting of activities by individual farms (eg livestock numbers), it would also reduce price signals for farmers to change management practices. The loss of efficiency depends on the extent to which there are significant differences in the emission output of different production systems and practices capable of producing each farm product. The efficiency of applying emission obligations upstream, downstream or at the farm level requires further research.

While many of the above issues have been addressed in the forestry sector, they remain problematic in the case of agriculture and it seems unlikely that agriculture could be initially included within an ETS. The PMTGET proposed that agriculture and land use sector emissions be initially excluded until practical issues associated with measurement and verification are resolved, but that offsets generated by this sector should be included, prior to full coverage of the sector. Some key issues that arise from this proposal include:

- ***Impact of an ETS on input prices*** – even if agriculture is not included in the ETS, the prices of inputs used in agriculture (fuel, electricity, chemicals, fertilisers) will rise as a result of the inclusion of other sectors. The likely impact of an ETS on the price of inputs and the impacts that increases will have on agricultural industries across different regions requires research.

- ***Agriculture as a source of offsets*** – many of the issues raised in relation to agriculture being included within an ETS also have implications for agriculture operating outside an ETS but acting as a source of offsets for included sectors. Research is required into:

  - The technical and economic feasibility of permanent (revegetation of farmland) and temporary sequestration options (changes to grazing and crop management practices)

  - Reducing transaction costs associated with monitoring and reporting of sequestration outcomes (measurement and verification methods, carbon pooling etc)

  - Farm and regional scale modelling to assess likely changes in land use in different regional locations arising from the participation of agriculture in an offsets market.

  - How to move from offsets provider to covered sector.

8.5 Work Already Underway on Emissions trading

The forestry sector has participated in an emissions trading market through the NSW Greenhouse Gas Abatement Scheme and has developed methods and systems which would allow it to participate in a national emissions market.

Carbon accounting standards for afforestation and reforestation are well developed. In 2006 an Australian Standard was developed *AS 4978.1 Quantification, monitoring and reporting of greenhouse gases in forest projects - Afforestation and Reforestation*. Accounting rules to apply to forest offsets under a national emissions trading scheme are currently under consideration by the Commonwealth Government.

There is on-going research into the potential to increase soil carbon levels by changing farm management practices (tillage practices, stubble retention etc). While there is some variability in the capacity of soils to hold carbon, and also difficulties and costs associated with measurement, significant progress has been

made in understanding soil carbon relationships. The National Carbon Accounting Toolbox provides a set of tools for tracking greenhouse gas emissions and carbon stock changes from land use and management. The Toolbox has been operating for several years and is linked to data derived from Australia's National Carbon Accounting System. It has some potential to be used within an ETS to recognise soil carbon changes arising from changes in on-farm management practices. However, the existing tool requires increased parameterisation for a range of soil types, enterprises and management practices. DPI is currently undertaking some of this research for the Commonwealth Department of Climate Change.

NSW DPI has a new project on reviewing existing and proposed methodologies for inclusion of carbon stored in timber products as part of an ETS and for inclusion of wood products as legitimate carbon offsets.

DPI is also undertaking research to quantify enteric methane emissions from beef cattle and sheep. However, this work is at an early stage.

Most work specific to agriculture's overall involvement in an ETS is of a preliminary nature and seeks to outline some of the issues to be considered (see Keogh (2007), Gunasekere, Ford and Tulloh (2007), LWA (2007)).

8.6 Gaps in Current Emissions Trading Work

Technical and economic feasibility of abatement and sequestration options across agriculture and forestry sectors. Little is known about the marginal costs of abatement and sequestration options, particularly in agriculture, and how these might vary across locations and specific industries.

The agricultural sector is not as well positioned as forestry and some time will be required before it could participate in an ETS. While there have been advances in soil carbon accounting, additional work is required in this area and across other areas to establish the linkages between management practices and emission outcomes in a way that efficiently balances transaction costs against measurement accuracy. If this is not possible then agriculture will not be able to play a role in an ETS as either a direct participant or as a source of offsets. This opens up the possibility of agriculture being subjected to greater regulatory costs and perhaps less efficient intervention to address emissions in the future.

Broadscale assessment of economic implications of an ETS on primary industries and on the broader economy. This would include an assessment of the impact of an ETS on the prices of inputs used in agriculture (with or without participation of the sector in an ETS) and how it might affect competitiveness if similar measures are not introduced by competing countries.

Assessment of economic implications of an ETS on particular primary industries across different regions. A key research gap is to gain some sense of the sensitivity of different primary production systems to varying emission prices that might emerge from an ETS.

Assessment of a range of ETS design issues including setting the baseline period for emissions, initial allocation of emission rights (grand-fathering versus auction), phasing in of reductions in rights, coverage of specific industries within the Scheme and point of obligation requirements. A key issue is the allocation of rights to agriculture and forestry at the commencement of an ETS or how these sectors would be phased into the scheme over time. There is limited information to form any judgments about these issues yet they are critical to the performance of these sectors under an ETS.

Assessment of transaction costs associated with monitoring and reporting of emissions, emission abatement and sequestration outcomes and ways that they could be reduced. It is critical that low-cost generic accounting methods are developed and accepted, to minimise transaction costs and thereby encourage participation.

8.7 NSW DPI's Capabilities in Addressing these Gaps

Strengths

- Knowledge of existing abatement and sequestration options and involvement in the development of future options.
- Staff with a breadth and depth of knowledge of primary industries in NSW.
- Strong track record with external funding bodies and potential collaborators.
- Operates closely with the agriculture, forestry and mining sectors and is trusted provider of research and extension advice.
- Experience in GGAS, including development of carbon accounting models for commercial plantation forests, research into carbon accounting methods for low rainfall forests.
- Research into life cycle of wood products, model for carbon accounting in wood products, and research into emissions trading mechanisms for landholders with small forest stands.

Weaknesses

- Deleted from this version

Resources

- Extensive, appropriately skilled human resource base within DPI.
- Research station and laboratory infrastructure
- Network of research sites
- Existing models of farming systems.
- Linkages to research funding bodies.

8.8 Priority Actions for DPI

Note: as this program relates to the issue of "mitigation", it continues the alpha-numeric numbering for other mitigation actions from Section 5.

Program M9: Multifaceted research into the policy implications of an emissions trading scheme on primary industries

This program will:

- review different policy approaches to control of non-point source pollution
- assess the economic implications of an ETS on primary industries including:
  - likely impact of an ETS (irrespective of the inclusion of primary industries) on the price of inputs used in primary industries (fuel, electricity, fertiliser, chemicals) and resultant prices for primary products and food
  - the marginal costs of emission abatement and sensitivity of land uses to emission prices based on the current carbon footprint of key agricultural and forestry sectors and the various mitigation options that are feasible in those sectors
  - likely impact on farm profitability for key agricultural systems
- assess plausible features of an ETS scheme from the perspective of primary industries such as:
  - initial or delayed entry
  - baseline period for recognition of emissions
  - method of allocating emission rights (grand-fathering versus auction)
  - phasing in of reductions in emission rights
  - point of obligation requirements
  - partial or full industry coverage
  - options to minimise transaction costs
- evaluate the role of the mitigation options outlined in Mitigation Programs above in a national emissions trading scheme (ETS)
- engage with key stakeholders on the merits of being included in an ETS and to develop strategies for effective participation
- assess how other environmental priorities could be integrated with the incentives provided by an ETS to achieve multiple environmental benefits (biodiversity, salinity, water quality).

Note: Finding least cost ways of monitoring emissions in primary industries

Developing the underpinning science to cost effectively monitor emissions and mitigation actions in primary industries is a critical aspect of effective participation in an ETS. This issue is addressed in program M1 outlined in the "*Mitigation*" theme.

8.9 Outcomes

- Efficient abatement and sequestration options that can be adopted by primary producers
- Monitoring and reporting systems used in an ETS with lower transaction costs
- Better design and improved understanding of the implications of an ETS in primary industries.

8.10 Links to other themes

- There are strong linkages between research outlined above and the mitigation theme. Strong links exist in evaluating the marginal costs of abatement and sequestration options and in the development of systems which can provide low cost monitoring and reporting of emission outcomes.
- There should also be linkages with impacts and adaptation themes if the biophysical impacts of climate change are to be assessed jointly with changes in the policy environment being contemplated by governments.

8.11 Potential Partners

A credible response to the imperatives of national emissions trading will require a considerable expansion or redirection of resources within NSW DPI.

Institution	Comments
CSIRO	Abatement and sequestration opportunities in agriculture, forestry and mining
ABARE/ABS	Marginal abatement and sequestration costs in agriculture and forestry, regional land use data, input prices
CMAs/DECC	Achievement of multiple environmental benefits through emissions trading
CO2CRC/AGO	Abatement and sequestration opportunities in agriculture, forestry and mining
R&D Corporations	Abatement and sequestration opportunities in agriculture and forestry
Various industry associations (agriculture, forestry and minerals)	Abatement and sequestration opportunities in agriculture, forestry and mining

8.12 Critical Communication/Engagement Requirements

Linkages to other themes particularly mitigation. See Cross Cutting Program C3 for further detail.

8.13 Key Policy Issues to be Addressed

The benefits and costs of agriculture and forestry sectors being part of an ETS or acting as a source of offsets for other sectors covered. See Cross Cutting Programs C1.3 and C3 for further information.

9. Cross Cutting Programs

Three keys issues have arisen across all themes in this report. They are:

- Socio-economic assessment;
- Information, education and training; and
- Policy development.

While these issues have been raised under each theme, the proposed programs to address them are listed here as cross cutting programs. This will simplify the process of determining resource requirements for their implementation. However, it is important that these programs not be established in isolation either of each other, or of other programs to address climate change. Cross disciplinary and cross divisional teams will be required to adequately address the challenge of climate change. This issue is taken up further in the separate recommendation to the BOM on resources.

Program C1: Socio-economic assessment of climate change

Objective: *Assess the economic impact of climate change on primary industry sectors to inform the development of effective policy and guide adaptation and mitigation responses by primary industries.*

The relationship between the cross cutting theme and other themes in the climate change strategy is shown in Figure 1. Work in the cross-cutting theme is based around the economic assessment of the biophysical effects of climate change and the effects of policy responses to climate change on primary industries. A key role of the economics program is to inform choices about the allocation of research and development resources to adaptation and mitigation options and to aid the selection of efficient policies to reduce emissions.

Simultaneous assessment of both biophysical and policy induced effects of climate change has the obvious attraction of completeness. An important second reason however, is that there may be some degree of tension between primary industries adapting to the biophysical impacts of climate change on the one hand, whilst also constraining their level of emissions on the other.

The schematic starts from the identification of climate change scenarios which are jointly determined by biophysical effects (A) and policy settings (B). The economic implications of any scenario depend on the adaptive capacity of primary industries represented by the scope of adaptation (C) and mitigation options (D). Potential changes to primary industries under climate change can be assessed by combining key biological data, production constraints and prices within an optimisation framework. Results of the economic analysis provide input into the setting of policies, the selection of R&D options and consultations with industry. The underlying objective represented in the schematic is to maximise environmental and economic outcomes (E), through the selection of adaptation (C) and mitigation options (D), subject to biophysical effects (A) and policy settings (B).

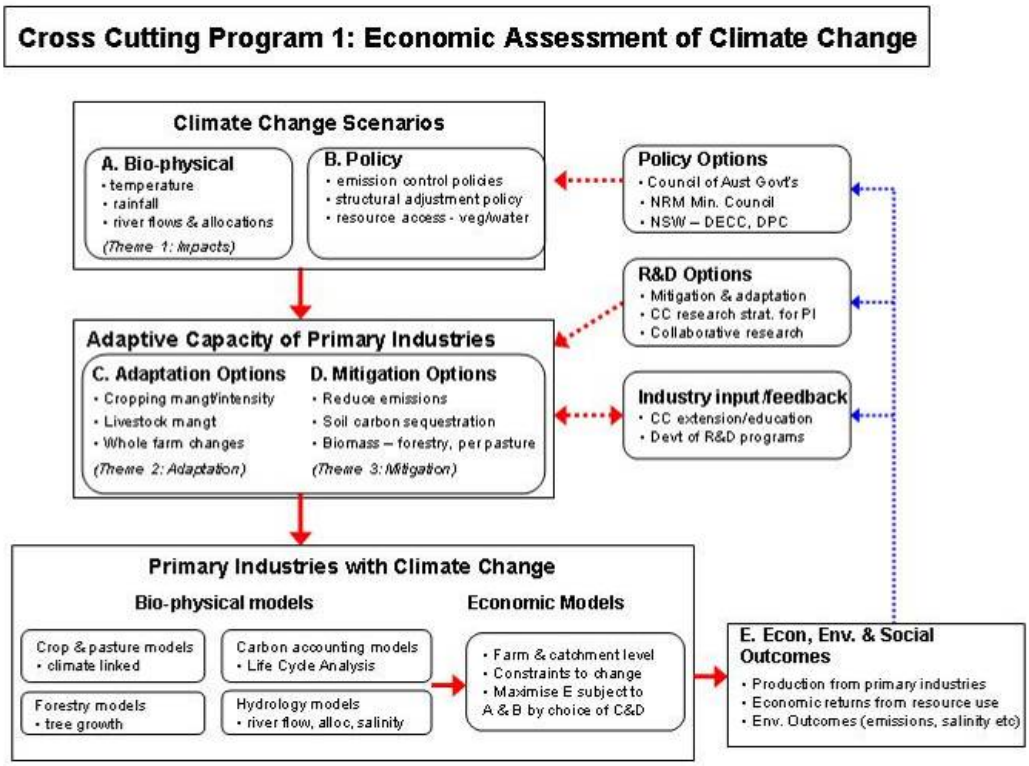


Figure 2: Economics Program

The two major project areas under the cross-cutting theme are discussed below.

Economic Project C1.1 –Quantify the economic impact of changes in climate on primary industries and the potential for adaptation

This project will:

- quantify the economic impacts of projected changes in climate on key primary industry sectors covering both dryland and irrigated systems
- evaluate the economic benefits of adaptation options and consider the importance of any constraints to their adoption
- evaluate policy options to promote transition to alternative industries or forms of land use, in industries where adaptation options are limited.
- provide input into the prioritisation of R,D&E in respect to adaptation
- inform policy makers on structural adjustment issues for those industries worst affected by climate change

Socio-economic Project C1.2 – Assess the economic effects of policies and technologies aimed at reducing emissions from primary industries

This project will:

- assess the economic effects and potential changes in land use under different policies to control emissions from primary industries including:
  - quantity based approaches - emission targets and trading
  - price based approaches – an emissions tax
- assess the economic effects on primary industries of design features of an emissions trading scheme including the allocation of rights, recognition of baseline emissions and the point of obligation for greenhouse accounting (see further detail in Mitigation Program 9)
- determine the economic feasibility of current and longer term mitigation options available to primary industries under different emission policy settings
- provide input into the prioritisation of R,D&E in respect to mitigation

Given the potential scope of work under project areas 1.1 and 1.2, there needs to be some prioritisation of economic resources. The setting of an emissions limit introduces a fundamental change to the operating

environment of primary industries and highlights the need for efficient mitigation options. The effects of policies aimed at reducing emissions are also likely to be more identifiable (more certain), more immediate and more significant than any of the biophysical impacts of climate change. Consequently, the main priority for economic research is in mitigation, in evaluating the economic merits of both policies and technologies.

Outcomes of Economic assessment:
Efficient and effective policies and technologies developed to assist primary industries contribute to emissions reduction targets and best bet options identified for primary producers to adapt to projected changes in climate change.

Program C2: Information, education and training (IET)

Introduction:
NSW DPI is the lead agency supporting the state's primary industries' response to climate change, variability and risk management. It is already supporting adaptation to the changed climate through its core education and extension activities and by instituting key actions from the NSW Greenhouse Plan. At the enterprise level, management of climate risks is one of many management goals and effective extension integrates climate risk management into an holistic management framework.

The goal is that response to climate change is embedded in DPI's core education, extension and communication activities.

Objectives - this cross cutting program for information, education and training (IET) will ensure that NSW DPI:
1. Provides information, education and advice to the full range of DPI clients and stakeholders to enhance understanding of climate risk management including trends due to climate change.
2. Considers feedback from the full range of DPI clients and stakeholders in the continual improvement of DPI policies, programs and partnerships.

Principles:
1. Inclusive and collaborative process with all clients and stakeholders.
2. Comprehensive information based on best science to meet the needs of all audiences.
3. Structured and coordinated information exchange, education and training.
4. Feedback and continual improvement.
5. DPI leading by being the best example while promoting other good examples from industry and communities.

Who - Target audiences
1. Internal DPI
   - All DPI staff: *general information on DPI policy and programs*
   - Key staff with a direct role in climate risk management and community support: *detailed scientific and technical information for impact assessment, adaptation & transition and mitigation.*
2. External to DPI
   - Government - *incl.* Premier/Cabinet, Minister, State/Federal agencies and funding bodies, R&D Corporations, other research institutions: *information on DPI capabilities and programs.*
   - Regional bodies – *incl.* local government, CMAs, RLPBs , Regional Development Boards: *information on potential impacts of climate change on primary industries and opportunities for them to promote best outcomes.*
   - Non-government clients/stakeholders - *incl.* peak industry bodies, producers, service industries & consultants, environmental-NGOs : *information on potential impacts of climate change on primary industries, DPI programs and extension to promote adoption of best management options.*
   - Community: *information on potential impacts of climate change on communities that are supported by primary industries.*
   - Education and information providers - *incl.* TAFE, schools, RTOs, service sector: *training for their staff, course development and access to support materials*

What:
The program will:
In the short Term
- Reassess the climate risk dimensions of all existing extension and education and training programs, such as PROfarm

- develop regional industry case study scenarios to help farmers perceive the consequences of climate change
- Continue “train the trainers” through the Bureau of Meteorology short course on “Climatology”
- Continue “Farmers’ Guide to Managing Climate Risk”
- Produce / review a series of Prime Notes about different aspect of climate change adaptation and mitigation
- Establish a “*Climate Change and Primary Industries*” newsletter to focus attention on key R,D&E and policy initiatives (both within DPI and external). The newsletter will be both electronic and in hard copy with links to other publications such as *Ag Today*, *Bush Telegraph* and *Minfo*
- Inform primary producers of options to reduce their greenhouse gas emissions, sequester carbon and replace fossil fuels with bioenergy
- Communicate the implications of agriculture and forestry participating in a national emissions trading scheme

In the medium term the program will:
- Develop new extension programs to fill identified gaps or extend new knowledge
- develop a basic whole farm enterprise climate change risk management training product
- Develop and promote “ready reckoners” for self directed “carbon dieting”, coping and adaptation strategies
- Continue collaboration with Catchment Management Authorities
- Assess and, if necessary, adapt Tocal internal and external certificate, diploma, short courses, accreditation and skill recognition programs for their climate risk and mitigation content
- Develop case for BOM commitment to maintaining/redesigning “Climate Risk Management in Agriculture” (Primary Industries) awareness raising project under Section 2.4 of the NSW Greenhouse Plan
- Maintain the “*Climate Change and Primary Industries*” newsletter
- Continue to inform primary producers on options to mitigate greenhouse gases (including their possible role in emissions trading)

Resources:
Delivery of most of the activities necessary to implement this plan can be integrated into the routine activities of Divisions. The key additional requirement is training for staff who will have an enhanced role and access by all staff to appropriate technical support materials.

The Agriculture, Biosecurity and Mine Safety (ABMS) Division has reprioritised staff activities to better support this IET plan. A new Resources Planning and Development Unit that includes a dedicated Climate Change Extension Team (1 CR FTE and 3 externally funded FTE) has been created within the Private Forestry and Resources Branch. This team will focus on supporting information providers within and external to DPI. It can also assist with coordination of implementation of this IET Plan under whatever the general governance structure for climate change activities is implemented in NSW DPI. The Resource Management Officers (Land Use Planning) will focus on the regional development outcomes including response to threats and opportunities from climate change providing an additional 1.5 FTE. Core extension and education programs within ABMS already include advice relevant to management of climate change, even though that advice may not be explicitly identified as such. This significant contribution has yet to be quantified but is in the realm of 26 FTEs.

It is propose that three extra positions are appointed to the Climate Change Extension Team to:

Position title	Grade	Position function
IET Training Coordinator	PO1-4	Design and delivery of PROfarm training modules and other course materials
IET Training Support Officer	PO1-4	Support training and course delivery, including administrative support
IET Information Officer	PO1-4	Development of information packages for web and other published formats

Program C3: Policies to address climate change

This program brings together the policy issues highlighted under each theme and includes:
- securing adequate resources to implement this strategy

- coordinating national and state action to address climate change through
  - the COAG Working Group on Climate Change and Water and its 5 sub-groups (water, adaptation, emissions, energy efficiency and renewables)
  - PIMC/PISC
  - The Garnaut review
  - NSW Climate Change CEOs Cluster Group and its 3 coordinating groups (adaptation, emissions, economics)
- informing the establishment of emissions reduction targets for primary industries
- evaluating policy options to achieve emission reduction targets for primary industries
- providing an informed contribution to the debate on establishing a national emissions trading scheme and the possible role of agriculture and forestry
- negotiating access to downscaled GCM data for impact assessment
- reviewing the adequacy of current structural adjustment policy in the light of climate change projections
- developing regulatory responses to increased biosecurity threats
- ensuring adequate capacity to respond to the increased risk of emergency management issues
- negotiating appropriate water access and sharing rules
- reviewing sustainable harvest prescriptions and management strategies for wild harvest fisheries and native forests
- reviewing regulatory controls over mining operations – given the expected increase in severe climate events

References

Astles, K.L. (2007). A systematic approach to estimating ecological risks in marine fisheries. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources. (In Press)

Astles, K.L., Holloway, M.G., Steffe, A., Ganassin, C. and Gibbs, P.J. (2006). An ecological method of qualitative risk assessment and its use in the management of fisheries in New South Wales, Australia. Fisheries Research 82:290-303.

Australian Greenhouse Office (2006). National Greenhouse Gas Inventory 2005. Department of Environment and Heritage, Canberra.

Bioenergy Australia submission to the Owen Inquiry into Electricity Supply in NSW. July 2007

Chan, Yin (2008) Increasing soil organic carbon of agricultural land. *Primefact* no. 735. NSW DPI, Jan.

Cowie, A., Barton, C., Singh, B., Ximines, F. and Stone, C. (2007). Climate change impacts and research priorities for the forestry sector. Paper presented to NSW DPI Priorities Actions for Climate Change Workshop, October 2007.

Department of Agriculture Fisheries and Forests (2007). *Biofuels-bioenergy* (http://www.daff.gov.au/natural-resources/biofuelsbio-energy).

Fairweather, H and Cowie, A. (2007). *Discussion paper: Climate Change Research Priorities for NSW Primary Industries*. Report prepared for Ministerial Advisory Council on Primary Industry Science meeting 18 January 2007.

Farrell, AE, Plevin, RJ, Turner, B,T, Jones, AD, O'Hare, M & Kammen, DM 2006, 'Ethanol can contribute to energy and environmental goals', Science, USA, 311, 5760, pp. 506–508.

Gibbs, P. (2007). Climate change and the fisheries of NSW – a background paper for the NSW Department of Primary Industries. Paper presented to NSW DPI Priorities Actions for Climate Change Workshop, October 2007.

Hacker, R., Bowman, A., Fairweather, H., Hailstones, D., Hegarty, R., Holzapfel, B., Sinclair, K. and Williamson, B. (2007). Climate change impacts and priority actions in the agriculture sector: background paper. Paper presented to NSW DPI Priorities Actions for Climate Change Workshop, October 2007.

Harle, K.J., Howden, S.M., Hunt, L.P. and Dunlop, M. (2007). The potential impact of climate change on the Australian wool industry by 2030. *Agricultural Systems* 93:61-89.

Hill, J, Nelson, E, Tilman, D, Polasky, S & Tiffany, D (2006), Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels: Proceedings of the National Academy of Sciences of the United States of America, National Academy of Sciences, Washington, USA. 103: 30, pp. 11206–11210.

Howden, S. M., and Reyenga, P. J. (1999). Methane emissions from Australian livestock: implications of the Kyoto protocol. *Aust. J. Agric. Res*., Vol 50, 1285-91.

Lenzen, M. (1998). Primary energy and greenhouse gases embodied in Australian final consumption: an input-output analysis. *Energy Policy* Vol. 26, No. 6 pp 495-506.

Morton J (2001). Bioenergy: a future for the Australian forest industry. Forest and wood products Research & Development Corporation.

NSW Department of Primary industries (2007). Climate change – key issues (http://www.dpi.nsw.gov.au/research/topics/climate-change/key-issues).

Prime Ministerial Task Group on Emissions Trading (PMTGET – 2007), Canberra.

Productivity Commission (2008) What role for policies to supplement an emissions trading scheme? *Submission to the Garnaut Climate Change Review*, May.

Scandol, J.P., Holloway, M.G., Gibbs, P.J. and Astles, K.L. (2005). Ecosystem based fisheries management: An Australian perspective. Aquatic Living Resources 18:261-273.

Schlamadinger, BM, Apps, F, Bohlin, L, Gustavsson, G, Jungmeier, G, Marland, K, Pingoud & Savolainen, I 1997, 'Towards a standard methodology for greenhouse gas balances of bioenergy systems in comparison with fossil energy systems', Biomass and Bioenergy, Vol. 13, pp. 359–375.

Stucley CR, Schuck SM, Sims REH, Larsen PL, Turvey ND and B.E. Marino BE (2004). Biomass energy production in Australia Status, costs and opportunities for major technologies. RIRDC Publication No 04/0