Understanding and managing impacts of climate change in relation to government policy, regulation and energy efficiency

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Applied Horticultural Research Pty Ltd

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This project has been funded by HAL using levy funds from the Australian vegetable industry and matched funds from the Australian Government.

The broad objective of this project was to assess the likely impacts of climate change in relation to government policy, regulation and energy efficiency on the Australian vegetable industry in the near and medium term.

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ahr applied horticultural research

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2 Executive Summary

Government policy and regulation

Federal Government policies and regulations in relation to climate change, while intended to have a positive effect on the nation's environmental performance, may at the same time represent a threat to the Australian vegetable industry. This review identifies the potential threats, as well as opportunities, that relate to the current regulatory framework.

The report responds to the following questions on how the vegetable industry may be affected, both directly and indirectly, by the current regulations pertaining to climate change and its management:

1. Why are we managing greenhouse gas emissions?
2. How would a change in government impact the vegetable industry?
3. Why is a price being put on carbon and how will it be determined?
4. What are the vegetable industry's liabilities and opportunities?
5. Do I have to report my emissions?
6. How do I generate carbon credits?
7. How will the carbon price affect my input costs?

Horticultural enterprise costs are estimated to increase by 0.3-0.8% over business-as-usual by 2015. This cost impact includes the carbon price and changes to the Fuel Tax Credits for heavy vehicles. It assumes that no management actions are taken to reduce these impacts.

The subsequent impact on profit will vary considerably between enterprises and industries and modelling suggests that horticultural enterprises could see a reduction in profit of 0.2-1.0%. However, this assumes that costs cannot be passed on by the grower.

Immediate and longer-term impacts of government policy in general: Immediate impacts arise from the introduction of a carbon price under the Federal Government's Clean Energy Act (2011). While vegetable growers have no liabilities under the carbon price nor do they have to report emissions, some up- and down-stream sectors of the vegetable industry will have liabilities.

In the medium-term there are limited opportunities for the vegetable industry to participate in the Carbon Farming Initiative and generate revenue from carbon storage and emission reduction activities. For this to occur, new approved methodologies are required. A number of funding programs administered by DAFF are identified, which could assist the vegetable industry to generate new revenue from carbon credits under the voluntary Carbon Farming Initiative.

One of the main uncertainties is political, both domestic and international. Within Australia there is currently bipartisan support for the 2020 greenhouse gas target and the voluntary involvement of the land-based sector. There is, however, significant disagreement on how to reduce emissions by the required 160 Mt CO_2-e per year. If international agreements are reached, the emissions reduction challenge increases up to 272 Mt CO_2-e per year.

Opportunities for the Vegetable Industry in Climate Change Related Grants and Funding

There is a significant level of funding available to the vegetable industry from national and state-based schemes. At least two growers in Australia, as well as a number of processing companies, have taken advantage of this funding.

The main funding programs are listed here and explained in detail in section 5 of this report:

- Renewable Energy Target – Small-scale Renewable Energy Scheme.
- Energy Efficiency Information grants.
- Clean Technology Food and Foundries Investment Program.
- Low Carbon Australia (NB will merge with the Clean Energy Finance Corporation, July 2013).
- State Energy Efficiency programs.
- Biodiversity Fund.
- Carbon Farming Initiative.
- Carbon Farming Futures.
- Regional Planning for Natural Resources Management (NRM).

For growers, six of these funding programs have been identified to increase energy efficiency, create carbon credits, or adapt to changes in the climate. For industry, six funding programs have been identified to increase energy efficiency, create carbon credits, or adapt to changes in the climate. For up- and down-stream sectors of the vegetable industry, three funding programs have been identified to increase energy efficiency.

Energy efficiency

Energy efficiency is one of those practices that should be adopted irrespective of your views on climate change. You will still be paying electricity and fuel bills so reducing costs wherever possible makes good economic sense.

Energy efficiencies are considered under three broad headings in this report:

1. Pumps and irrigation efficiencies.
2. Reducing cooling costs.
3. On-farm power generation.

The areas with the greatest potential to save money and reduce greenhouse gas emissions in each of these areas are:

Pumps and energy efficiencies: In general, the higher the operating pressure the more energy (cost) is required to run irrigation systems. Across some typical irrigation systems, energy usage ranged from as low as 45 KWh/ML up to 543 KWh/ML. In a Tasmanian example, an energy saving of 66% and a cost savings of $47.12/ML were obtained from moving from a high-pressure travelling gun to a low-pressure centre pivot, due to the reduction in the pressure required. However, the biggest advantage in changing irrigation systems may be in the improvement in crop management and resulting yields and quality. In a NSW example, switching to a low-pressure system saved $50/ha in pumping costs but also resulted in a 20% increase in yield and increases in product quality. Combined, these resulted in a net benefit of $565/ha.

The pump is the heart of the irrigation system; making sure it is the right pump for the job and that it is working properly can save energy costs. However, the gains to be had from optimising pumps are relatively small. Typical improvements in the efficiency of the pump reduce the daily energy use by about 20%. Typical improvements in the efficiency of the motor reduce the daily energy use by 5%.

As a general rule, pump efficiency should be greater than 70%; below this is poor. If you can achieve better than 80% this is excellent, with a maximum of 88% achievable in the field for an end-suction pump. Having a motor that runs as close as practical to full load can increase motor efficiencies by 2-5%. Variable speed pumps have limited application for vegetable growers because irrigation systems are usually running at capacity.

Cooling: The main opportunity for improving refrigeration efficiency is the use of carbon dioxide as a refrigerant gas. Switching from older refrigerants such as R134a to a carbon dioxide (CO_2) based refrigeration plant may already be cost-effective, and new CO_2 based refrigerant plants should become even more cost-effective in future.

The cost of replacing leaked refrigerant is a small part of both operating and total costs, and can also be minimised through regular maintenance. Refrigerant replacement together with maintenance costs account for roughly 10% of total costs. The main cost is electricity (more than 80%) and therefore electricity prices will continue to dominate the total cost of refrigeration.

Carbon dioxide has been used as a refrigerant for decades, and has recently gained significant support in Europe from several different industries. There are a few examples of its use in Australia, but apparently none in the vegetable industry.

On-farm power generation: In the short term, on-farm generation of electricity from vegetable waste and generation of electricity from natural gas (suppled via the grid) are the only two economically viable alternatives to purchasing electricity from the grid. Power generation from vegetable waste can be viable if 10 t/day of organic waste is available and can produce electricity from a little as $84/MWh (LCOE range = $80-$160).

In the longer term, by 2030, biogas electricity generation, natural gas electricity generation, biomass gas generation, solar photovoltaic cells (PV) become economically viable with no subsidies or increases in electricity prices. Wind generation may also be viable, depending mainly on the quality of the local wind resource and hence its capacity factor.

Energy audits: Energy audits are an excellent way of measuring farm energy use and potentially saving money on electricity bills. Audits are expensive, in the order of $10,000 for an average farm, but savings can be considerable and the payback period is commonly about 1-2 years. In addition, there is funding assistance available. Programs that are applicable include:

- Low-carbon Australia with loans or other financial assistance to upgrade key equipment, such as cool-rooms and electric pumps, to increase energy efficiency.
- State-based programs – most States have grants available for making improvements in energy efficiency.

The Australian vegetable industry is in a strong position to deal effectively with climate change. The industry has excellent climate change credentials, is a low emitter of greenhouse gases on a productivity basis, and has one of the lowest carbon and water footprints of any food producer. Vegetable growers also have greater capacity to adapt to change than most other rural industries.

The threats, however, are serious, and the industry should not be complacent. The viability of vegetable production can be affected either by the physical impacts of a changing climate, as outlined in the companion report, or by government policies aimed at addressing climate issues.

3 Introduction

Australian vegetable growers use 121,000 hectares to grow $3 billion of produce, with a further $4.5 billion of associated “up- and down-stream” value add[1]. The industry is characterised by a high level of inputs and management. This results in a high greenhouse gas intensity, at 9.2 t CO_2-e per hectare per year[2].

The Australian vegetable industry has recognised that issues around climate variability and climate change may affect growers and the broader industry. As a result, this review was commissioned in 2013 to provide a comprehensive assessment of the threats and opportunities, and to develop a plan for the future.

The Federal Government recognises the need for Australia’s primary industries to take action against climate change. New initiatives, policy and legislation changes, together with funding programs are all being rolled out in order to provide a platform for the long-term resiliency of the nation’s primary industries. The Australian vegetable industry needs clear guidelines on how to operate effectively in this environment and to benefit from opportunities that exist.

This review addresses the following areas in relation to how climate change might affect the Australian vegetable industry, with a focus on government policy, regulation and energy efficiencies:

1. Identifying and assessing the impacts that government policies and regulations regarding climate change are having, and will have, on vegetable farm businesses and the industry.
2. Investigating the opportunities available for growers through government grants and industry initiatives as well as how the various grants might be made more appropriate and accessible for vegetable levy payers.
3. Identifying and collating information on innovative or efficient options, including energy sources, energy usage and refrigerants, to reduce rising input costs associated with climate change policy implementation.

The *Vegetable Climate* website www.vegetableclimate.com has been developed as part of this overall project.

[1] Wayne Meyer 2005. The Irrigation Industry in the Murray and Murrumbidgee Basins. Technical Report 03/05. CRC for Irrigation Futures.
[2] P. Deuter, 'Scoping Study: Climate Change and Climate Variability - Risks and Opportunities for Horticulture: VG05051', Horticulture Australia, 2006

4 The Vegetable Industry and Government Climate Change Policies and Regulation

The Federal Government climate change policies and regulations can impact on the vegetable industry, growers and the value chain through the newly created carbon pollution liabilities (the carbon price), compliance reporting and voluntary programs.

This report asks the following questions to review how the vegetable industry may be affected, both directly and indirectly, by the current regulations relating to climate change and its management:

1. Why are we managing greenhouse gas emissions?
2. How would a change in government impact the vegetable industry?
3. Why is a price being put on carbon and how will it be determined?
4. What are the vegetable industry's liabilities and opportunities?
5. Do I have to report my emissions?
6. How do I generate carbon credits?
7. How will the carbon price affect my input costs?

Each question provides a short answer, in italics, followed by a more detailed consideration of the area. Details of the specific Regulations and Legislation are provided in Appendices.

The market, via supply chain or consumer expectations, is also playing an increasing role in influencing grower practice with regard to sustainability as outlined in Section 6 . This is also considered in VG12041.

4.1 Why are we managing greenhouse gas emissions?

Climate change is a significant long-term risk. It is prudent to start to reduce greenhouse emissions and begin to plan for the impacts of climate change when making strategic investment decisions. Because of the potential for severe impacts this needs to happen despite the uncertainties.

4.1.1 **Risk management**

For the third year running, climate change was the standout risk for Australia in KPMG's yearly report[3] on risks and opportunities (Figure 1).

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[3] ADC and KPMG (2012). Australia Report 2012 – Risks and Opportunities. Report prepared by ADC in collaboration with KPMG' Australia.

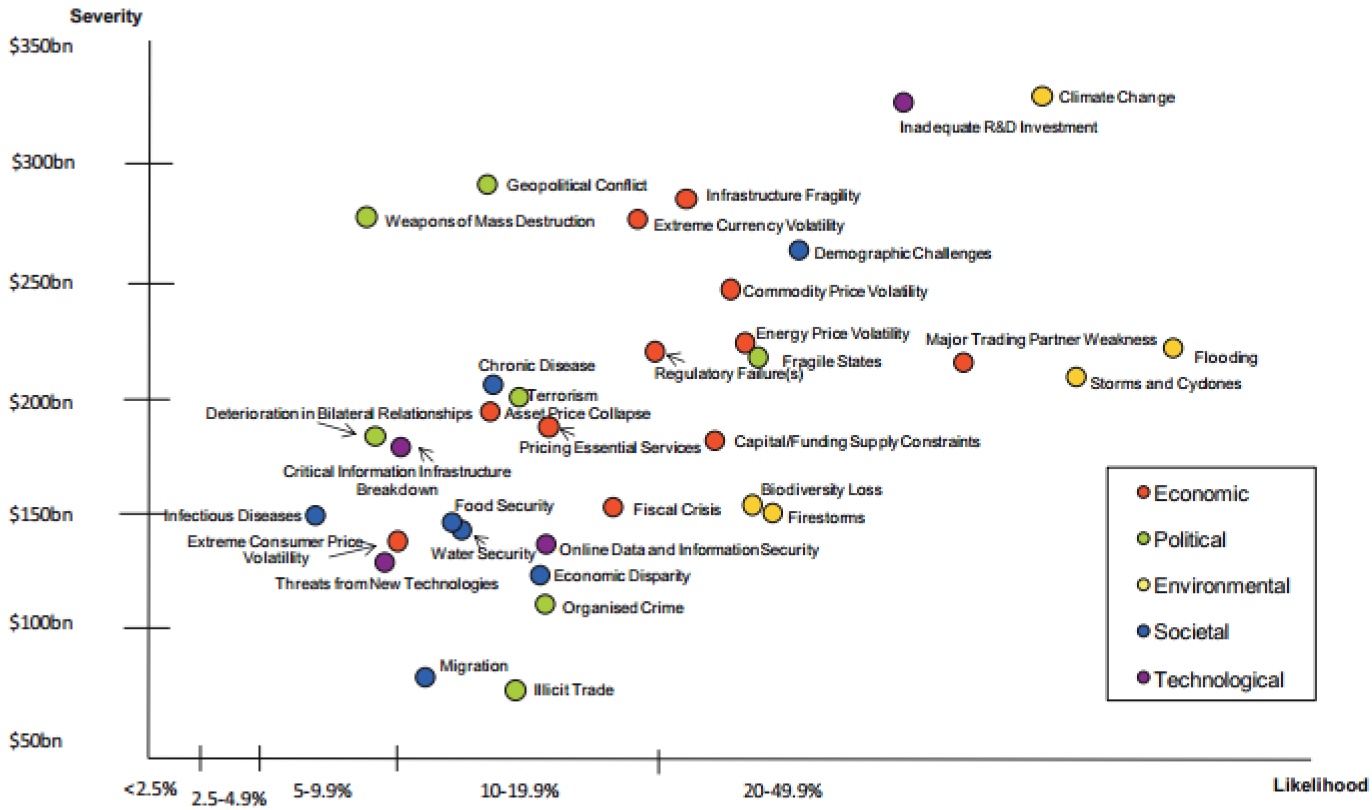

Figure 1. The Australian risk landscape, as per responses of Australian business, government and academia leaders to a survey on the likelihood and impact to the Australian economy of 34 key risk areas across the categories of economic, political, environmental, societal and technological. (Source: ADC and KPMG, 2011).

Climate change topped both the severity and likelihood rankings. The linkages to storms and cyclones, firestorms, flooding, biodiversity loss, food and water security, infectious diseases and infrastructure fragility was also highlighted.

The short- to medium-term responses to climate change by government, businesses and communities outlined in the following questions aims to manage the potential risks associated with climate change.

Deciding on a proper response means dealing with uncertainties. Climate change uncertainty can broadly be summarised as resulting from either the science:

- How much will the climate warm for a given amount of greenhouse gases in the atmosphere (climate sensitivity)? This aspect of uncertainty is at the core of debates on anthropogenic causes of climate change.
- Where, when and how will the climate change?
- How much additional warming could occur due to amplifying effects (positive feedbacks) such as large-scale changes? There is the potential for additional greenhouse gases to be released as the climate changes. For example, in

Australia forests or woodlands may change to grassland if temperature and rainfall changes increase fire intensity and frequency. In the Arctic methane release from the frozen soils could have a large impact.

or how we respond:

- What global action will occur to reduce future greenhouse gas emissions?
- What government policy responses will occur?
- How will businesses and communities respond to policy, voluntary markets and trade mechanisms to reduce emissions?
- What will be the timing and scale of mitigation actions?

Uncertainty and risk are quintessential features of the vegetable industry due to seasonal production and price uncertainties. Climate change introduces more uncertainty into the strategic time horizons. Where should I buy land? Should I invest in a processing plant? How reliable will my water entitlement be? Should I be changing cropping systems? These are strategic decisions which could be affected by changes to the climate.

4.1.2 What we know about the atmosphere and climate

Greenhouse gases in the atmosphere have changed very quickly and to levels not usually seen. Global carbon dioxide concentrations have risen rapidly over the last century (**Figure 2**). Methane, another greenhouse gas, has shown similar increases. The carbon dioxide concentration in 2011 of 393 parts per million (ppm) is much higher than the natural range of 170-300 ppm that has existed in the atmosphere for at least the past 800,000 years and possibly the past 20 million years[4].

The changes in greenhouse gases in the atmosphere are linked to changes in the global climate. Over the past 50 years Australia's climate has changed[5]. Since 1960 the mean temperature in Australia has increased by about 0.7 °C. The long-term trend in temperature is clear, but there is still substantial year-to-year variability of about ±0.5 °C. Some areas have experienced a warming of 1.5 to 2 °C over the last 50 years. Warming has occurred in all seasons, but the strongest warming has occurred in spring (about 0.9 °C) and the weakest in summer (about 0.4 °C).

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[4] National Oceanic and Atmospheric Administration http://www.noaa.gov/

[5] CSIRO and Bureau of Meteorology (2010). State of the Climate. Bureau of Meteorology and CSIRO, Canberra.

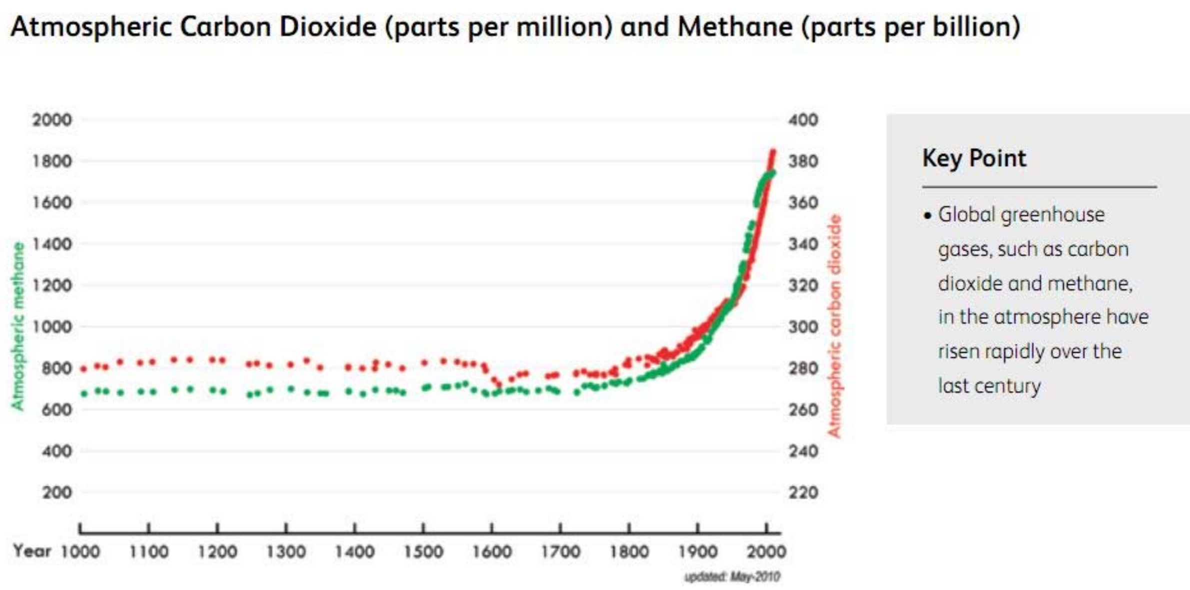

Figure 2. Atmospheric carbon dioxide and methane. (Source: CSIRO and Bureau of Meteorology, 2010).

4.1.3 What could happen to the climate?

What could happen to the climate in the next 50 years and beyond will depend on both how we and the climate system responds. Models manage this uncertainty by producing a range of climate projections to take account of different scenarios, with their associated greenhouse emission projections.

Detailed regional assessments of climate change for six vegetable growing regions are provided in the VG12041 report.

The changes in climate observed over the last 50 years are projected to continue. For Australia, our best estimates are that by 2030, the temperature is projected to warm by about 1°C over Australia for the mid-range emissions scenario (NB. based on current emissions we will exceed the high-growth scenario used by models). Inland areas are likely to experience stronger warming of up to 1.8 °C.

By 2070, average Australian temperatures are projected to increase by about 1.8 °C in a low-emissions scenario, with a range of 1.0-2.5 °C across the country. In a high-emissions case the projected average temperature increase is about 3.4 °C, with a range of 2.2-5.0 °C, relative to 1990.

In south-eastern Australia, El Niño events may tend to become drier and La Niña events may become wetter[6]. For 2030, rainfall is projected to decrease by 2-5% on average, and by about 7.5% by 2070 (compared to 1990). The exception is far northern Australia where little rainfall change is projected. However, changes in rainfall are expected to vary widely across regions and seasons. For example, rainfall in south-western Australia is projected to decline by as much as 40% by 2070. This reduction in rainfall in WA is expected to significantly reduce the amount of runoff water that will in turn reduce the amount of water flowing into the underground aquifer system and above-ground water storages.

Water management and irrigation is an area that will potentially become more important for the vegetable industry in the future, but this may be more due to issues related to water and irrigation, than simply to a lack or oversupply of water.

The vegetable industry is already an efficient user of irrigation water. Water saving application methods such as trickle irrigation and the use of sophisticated soil moisture monitoring equipment has made vegetable producers efficient water users.

Vegetables use about 3.5 ML/ha to produce a crop, one of the lowest rates of all irrigated agriculture and use only 4% of Australia's irrigation water. The financial returns per ML of water applied is higher for vegetables than any other agricultural crop grouping which means that vegetable growers are in a stronger position compared to other industries when water prices rise in times of drought.

Water prices in Australia rose to $1500 per ML during the drought in the late 2000s. Vegetables have a gross value of production per ML of more than $3000 per ML across all irrigated vegetables and while this puts the vegetable industry in a better position relative to all other water users, high water prices remain a major threat to the financial viability of vegetable farming in Australia. The economic analysis covered in the VG12041 report section identifies major increases in the cost of water in severe droughts as being the greatest threat to the economic viability of vegetable production, based on current input costs and returns.

These changes will impact on investments and natural resource decisions made this decade for example, investment in irrigation infrastructure, biodiversity plantings and water management and will have implications for the next 20-30 years.

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[6] CSIRO and Bureau of Meteorology (2007). Climate change in Australia – observed changes and projections. CSIRO and Bureau of Meteorology, Canberra.

4.2 How would a change in government impact the vegetable industry?

There is currently bipartisan support for the 2020 greenhouse gas target and the voluntary involvement of the land-based sector, but disagreement on how to reduce emissions.

In Australia, at the federal level there is bipartisan support for a minimum greenhouse gas emissions reduction target of five per cent of 2000 levels by 2020. This represents a significant estimated abatement challenge of 160 million tonnes carbon dioxide equivalent, over the business-as-usual projected increase (**Figure 3**). Depending on international negotiations there is the potential for Australia's greenhouse gas emissions reduction target to increase to 15 or 25 per cent of 2000 levels by 2020. This would increase the estimated abatement challenge to 216 or 272 million tonnes carbon dioxide equivalent for a 15 or 25% reduction, respectively.

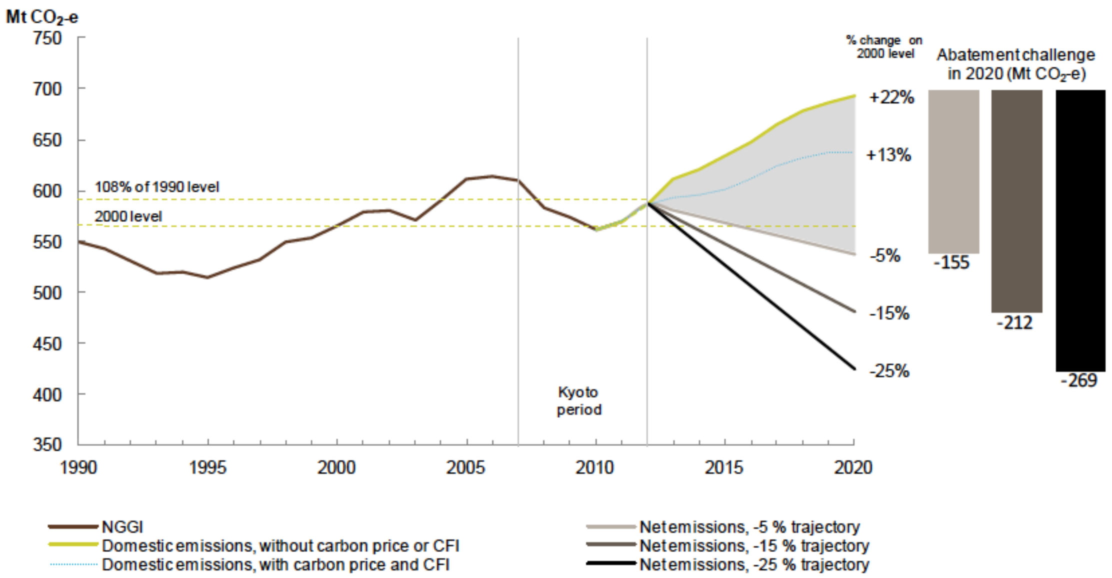

Figure 3. Australian Greenhouse gas emissions, historical and projected, and the 2020 abatement challenges[7].

Although there is considerable difference in how these targets will be met, there is bipartisan reliance on the land-based sector to deliver significant greenhouse gas abatement.

The Australian Government Clean Energy Future Program has implemented a cost to polluters through a market-based system together with significant compensation and support programs, which are detailed in the following questions. The voluntary involvement of the land sector (outlined in 4.4.2) is funded from the revenue from the price on carbon paid by "liable entities" (outlined in 4.4).

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[7] Australia's emissions projections 2012 Department of Climate Change and Energy Efficiency ISBN: 978-1-922003-58-4

The Coalition's current climate policy[8] is to abolish the carbon tax**.** Five climate agencies will go (Clean Energy Finance Corporation, the Energy Security Council, the Climate Change Authority, the Climate Commission and the Global Carbon Capture and Storage Institute). In its place the Coalition will establish a "direct action" Emissions Reduction Fund with a budget of $3.2 billion from the existing tax base. The aim is to reduce by 140 million tonnes per year by 2020, with more than 60% of this reduction expected to come from increases in soil carbon storage. This will match the Gillard government's goal of a 5% reduction in year 2000 levels of pollution. The fund will create financial incentives for companies to reduce their emissions levels. Furthermore, the Coalition will:

- Use the fund to support direct action on forestry, energy efficiency, and recycling.
- Establish 'Clean Energy Hubs' in the Latrobe, Hunter and central Queensland regions.
- Invest $100 million each year so as to encourage solar energy in households.
- Establish 125 mid-scale solar projects and 25 geothermal or tidal power 'micro' projects.
- Initiate bio-sequestration of carbon - essentially, storing carbon in soils.

Table 1. Summary of the major federal party climate policy positions[9].

	Political Party	
Policy area	Labour	Coalition
Emissions reduction target	Unilateral 5% cut from 2000 levels by 2020. Possible 15-25% reduction depending on action of other countries. Will be guided by, but not necessary beholden to, review by the Climate Change Authority of emission reduction targets and trajectories. Commitment to reduce emissions by 80% by 2050.	Unilateral 5% cut from 2000 levels by 2020. No further commitments or 2050 commitment. Would scrap the Climate Change Authority
Carbon price	Continuation of $23/t CO_2-e fixed price until 1 July 2015, followed by a market based price linked to the European carbon trading scheme (currently pricing carbon at $5/t CO_2-e)	Committed to immediately repeal of the carbon tax. Proposed to cut emission through sequestration, carbon capture and storage and $3 billion "Emission Reduction Fund".
Renewable Energy Target	Target of 41,000 GWh by 2020. RET now to be reviewed every 4 years instead of two to give investors more certainty.	Greg Hunt has said that "The coalition is not proposing and has not proposed any changes to the target". The RET would be reviewed every two years under a Coalition government.
Clean Energy Finance Corporation	Clean Energy Finance Corporation, established in June 2012, will drive investment of $2 billion a year over 5 years to support renewable energy and	Committed to scrapping the Clean Energy Finance Corporation

[8] http://www.nationals.org.au/Portals/0/main%20site/10-02-02%20The%20Coalition's%20Direct%20Action%20Plan%20-%20Policy.pdf
[9] Adapted from http://cpd.org.au/2013/05/promisewatch-2013-climate-change/

	low emission projects.	
Solar Energy	Now winding back solar multiplier program introduced to support the solar PV industry. Has not yet announced policy on national feed in tariff.	Proposes $100 million per year to support expansion of solar PV energy. Opposes a national feed in tariff.
Carbon Farming Initiative	Incentives to encourage farmers and landowners to store carbon in trees and soil, covers some reforestation, legacy waste emissions from landfill, manure management in intensive livestock production and savanna fire management. Scheme could also include improved fertiliser use and avoided deforestation. Funded from the carbon tax.	Overall support for Carbon Farming Initiative. Funding to come from existing tax base.

4.3 Why is a price being put on carbon and how will it be determined?

A carbon price has been created by the Federal Government's Clean Energy Act (2011). The price is initially fixed, but from 1 July 2015 the price will be set by the market. Factors such as: Australia's targets, and hence the cap; linkages to international markets; the amount of permits issued by the government; industries' efforts to reduce emissions; and the success of offset programs such as the Carbon Farming Initiative will influence the price.

The carbon pricing mechanism is an emissions trading scheme that puts a price on Australia's carbon pollution. It was introduced by the clean energy legislation and applies to Australia's top 500 carbon emitters (called liable entities). A range of legislation and regulations were required to establish the price on carbon pollution; these are outlined in Appendix I.

Under the mechanism liable entities (those emitting more than 25,000 tonnes CO_2-e per year) must pay a price for the carbon emissions they produce. This covers approximately 60 per cent of Australia's carbon emissions including from electricity generation, stationary energy, landfills, wastewater, industrial processes and fugitive emissions. The Clean Energy Regulator maintains a publicly available database of liable entities (LEPID).

There are two stages to the carbon pricing mechanism:

- Fixed price – the carbon price is fixed for the first three years. In 2012–13 it is $23 per tonne of carbon pollution, in 2013–14 it is $24.15 per tonne and in 2014–15 it is $25.40 per tonne. Liable entities can purchase units up to their emissions levels.
- Flexible price – from 1 July 2015 the price will be set by the market. Most units will be auctioned by the Clean Energy Regulator who will begin auctioning units from the

first half of 2014, in the lead-up to the flexible price. The number of units the Government issues each year will be limited by a pollution cap set by regulations.

The Climate Change Authority will provide expert advice on the carbon price and other Australian Government climate change mitigation initiatives including:

- The carbon pricing mechanism.
- Emissions caps under the carbon price.
- Emissions reduction targets and carbon budgets.
- The Renewable Energy Target.
- The Carbon Farming Initiative.
- The National Greenhouse and Energy Reporting System.

The Clean Energy Regulator administers Australia's carbon pricing mechanism.

4.4 What are the vegetable industry's liabilities and opportunities?

Vegetable growers have no liabilities under the emissions trading scheme. There are a number of opportunities to increase energy efficiency and create carbon credits (Section 3).

Some up- and down-stream sectors of the vegetable industry may have liabilities. There are also opportunities for many of these larger suppliers and processors to increase energy efficiency.

4.4.1 Liabilities

Under the Clean Energy Act 2011 agriculture is not a covered sector under the carbon pricing mechanism. As a result vegetable growers will generate no liabilities for the greenhouse gases emitted in the course of growing their crops.

However, some up- and down-stream sectors of the wider vegetable industry may have liabilities based on the amount of CO_2-e emitted. In addition to electricity producers the vegetable industry suppliers or processors that are a liable entity include:

Fertilisers	-Incitec Pivot Ltd
	-Orica Ltd
Packaging	- Amcor Packaging Pty Ltd
	- Visy Pulp and Paper Pty Ltd
Processing	-Simplot Pty Ltd

Companies like Woolworths and Coles are committed to reducing emissions. Woolworths are committed to a 40% reduction in carbon emissions on project growth levels by 2015, maintaining 2006 levels; A 25% minimum reduction in carbon emissions per square meter

for all new stores compared to existing stores; and a 25% reduction in carbon emissions per carton delivered by Woolworths-owned trucks by 2012[10].
Coles are committed to significant energy savings in their stores across Australia[11].

The impact of this and other aspects of climate change policies on the input cost for the vegetable industry is discussed below in section 4.5.

4.4.2 Opportunities for emission reductions and sequestration

The vegetable industry and growers have a number of opportunities to reduce the impact of climate change on the sector.

These opportunities fall broadly into two categories:

1. Programs and grant schemes to increase energy efficiency and hence decrease emissions and costs.

2. Creation of carbon credits.

This section provides an overview of the opportunities with section 5 providing details of the programs and grants and section 4.6 providing details on how carbon credits can be generated.

Agriculture, through avoidance of emissions and carbon sequestration, can play a part in Australia's greenhouse gas mitigation activities. In 2009 the primary industries were the second-highest emitting sector after the electricity, gas and water sector[12]. Agriculture, fisheries and forestry accounted for 19.5% (109.8 Mt CO_2-e) of Australia's net greenhouse gas emissions (565 Mt CO_2-e) in 2009.

Agriculture accounted for 78% of the direct emissions from primary industries in 2009. These emissions were dominated by livestock (68.5%), with soil management (16.9%) and savannah burning (14.3%) accounting for most of the remaining emissions.

The agriculture sector is the dominant national source of both methane and nitrous oxide, accounting for 58% (65.3 Mt CO_2-e) and 75% (19.5 Mt CO_2-e), respectively, of the net national emissions in 2009.

The importance of the primary industries in cost-effectively reducing emissions and the broad range of abatement options is highlighted in Australia's carbon abatement cost curve (**Figure 4**). This figure highlights the potential cost, or savings as indicated by a negative

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[10] http://woolworths.com.au/wps/wcm/connect/Website/Woolworths/About+Us/Our+Planet/
[11] http://www.coles.com.au/About-Coles/Environment.aspx
[12] Department of Climate Change and Energy Efficiency (2011). Australia's National Greenhouse Accounts National Inventory by Economic Sector. Department of Climate Change and Energy Efficiency, Canberra,.

value (mainly blue), of undertaking an abatement activity, and the greenhouse gas savings (Mt CO_2-e) possible. Of direct relevance to the vegetable industry are:

- Motor systems (pumps).
- Biofuel (from crop residues).
- Refrigeration efficiency (on-farm storage and the cool-chain).
- Soil carbon.

Initial climate action has focused on those activities where there is a positive payback , ie a negative cost. As the abatement challenge increases (See **Figure 3**) then the costs will rise.

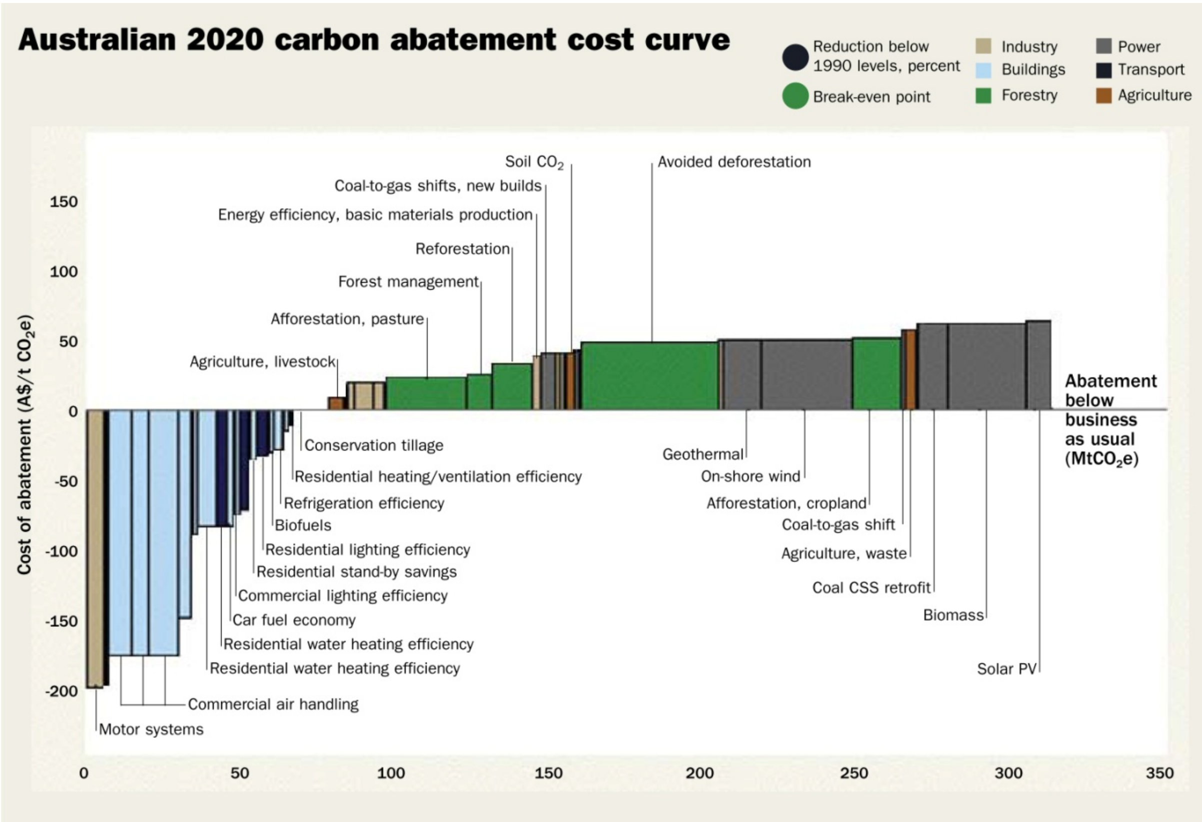

Figure 4: Australia's 2020 greenhouse gas abatement cost curve for a range of abatement options. The horizontal axes (and width of each option) indicate the amount that could be reduced per year in tonnes carbon dioxide equivalent (t CO_2e). The height represents the cost, both negative and positive, of avoiding one tonne of carbon dioxide equivalent for this option, relative to a business-as-usual case. Negative and positive costs indicate either a net financial benefit or cost, respectively, over the lifecycle of the abatement option. (Source: McKinsey and Company Australia, 2008).

4.5 Do I have to report my emissions?

As agriculture is not covered by the emissions trading scheme, vegetable growers are not required to report emissions under the National Greenhouse and Energy Reporting scheme (see Appendix II for details of the legislation and regulations).

For those vegetable industry suppliers or processors that are a liable entity (Section 2.4.1) reporting will be required under the National Greenhouse and Energy Reporting scheme.

4.5.1 Estimation of agricultural emissions

Agricultural emissions are still required for the National Greenhouse Accounts to track Australia's emissions and report under international agreements. For agriculture these are estimated by the National Carbon Accounting System (NCAS). Land-based emissions and sequestration of greenhouse gases arise from changes in management such as soil preparation, fertiliser use, harvesting, clearing and burning. A significant proportion of Australia's land-based emissions occur as non-carbon dioxide gases, in particular methane from livestock production and nitrous oxide from fertiliser application.

Actively growing forest systems remove carbon dioxide from the atmosphere through photosynthesis. Growing forests act as a long-term carbon sink by storing carbon in the trees, debris and soils. In 2008, removals associated with reforestation activities were estimated to be approximately 23 Mt of carbon dioxide (based on forests planted since 1990), effectively reducing national emissions by almost 4 per cent.

Accurate accounting of the emissions and removals of greenhouse gases from the land requires knowledge of the dynamics of carbon (for carbon dioxide and methane emissions) and nitrogen (for nitrous oxide emissions) in the landscape. The growth and life cycles of forests and agricultural crops, climate, soils, land-cover change and land management are all important components of a comprehensive emissions accounting system.

The NCAS estimates emissions from the land sector through a system that combines:

- Thousands of satellite images to monitor land use and land-use change across Australia since 1972, which are updated annually.
- Monthly maps of climate information, such as rainfall, temperature and humidity.
- Maps of soil type and soil carbon.
- Databases containing information on plant species, land management, and changes in land management over time.
- Ecosystem modelling - the Full Carbon Accounting Model (FullCAM).

4.6 How do I generate carbon credits?

Participation in the Carbon Farming Initiative is voluntary; landholders can choose whether or not to be involved. Credits can be generated by either storing carbon or reducing greenhouse gas emissions. This area is developing rapidly.

4.6.1 The Carbon Farming Initiative

The Carbon Farming Initiative (CFI) allows farmers and other land managers to earn carbon credits by storing carbon or reducing greenhouse gas emissions on the land. (The legislation and regulations covering CFI are outlined in Appendix III).

Activities that count towards our national target under the Kyoto Protocol, including reforestation, avoided deforestation and reducing emissions from livestock, manure, fertiliser and waste deposited in landfills before 1 July 2012, can earn Kyoto Australian Carbon Credit Units (ACCUs). These activities can be used to meet liabilities under Australia's carbon price mechanism.

Some CFI activities are not included in our greenhouse accounts under the Kyoto Protocol and do not count towards our national target. These include soil carbon, feral animal management, improved forest management and non-forest revegetation. Through the CFI, these activities can earn non-Kyoto ACCUs and be sold into the voluntary market.

In much the same way as financial markets trade in different currencies, carbon markets trade different types of carbon credits. For example, carbon permits generally are issued by governments as part of a carbon pricing mechanism and carbon offsets are generated by abatement projects through schemes such as the CFI.

Each carbon credit represents one tonne of carbon dioxide equivalents (CO_2-e). Abatement from all sorts of activities, including those that reduce methane or nitrous oxide emissions, can be measured in tonnes of CO_2-e. This standardisation allows the credits from different activities to be traded more easily.

Carbon credits may be traded and used to meet mandatory obligations and voluntary commitments.

Under Australia's carbon price mechanism, about 500 companies have a mandatory obligation to pay for or offset their direct emissions using certain types of carbon credits. There are other carbon price mechanisms overseas, including the European Union Emissions Trading Scheme.

Carbon credits are also bought by individuals and organisations wishing to voluntarily offset their emissions. This is referred to as the voluntary carbon market. Some companies choose to participate in Australia's carbon neutral program, which is administered by Low Carbon

Australia. These companies estimate their carbon footprint, reduce their emissions and offset the remainder using carbon credits that comply with the Australian Government's National Carbon Offset Standard.

4.6.2 How to generate carbon credits

For a farmer to generate carbon credits there are a number of conditions to be met. These are broadly outlined below.

4.6.3 The legal right to undertake the project

In most cases, the land owner or lessee has the right to undertake a CFI project. If your project is a sequestration project, you will also need to hold the applicable carbon sequestration right and have the consent of eligible interest holders.

4.6.4 An available methodology

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

4.6.5 Activities over and beyond your legal requirements

The offset activities you are considering must be over and beyond those required by either State or Federal laws.

4.6.6 On the Positive List, not on the Negative list

The Positive List identifies activities that are deemed to go beyond common practice in the relevant industry or environment. The Negative List identifies activities that are excluded from the CFI in circumstances where there is a risk that the activity will have a material adverse impact on one or more of the following:

- The availability of water.
- The conservation of biodiversity.
- Employment.
- The local community.
- Land access for agricultural production.

4.7 How will the carbon price affect my input costs?

The main impact of the carbon price will be on the cost of electricity and after 2014, transport. The cost of on-farm fuel use, fertiliser and chemicals are not expected to increase due to the carbon price. What impact this has on grower profits will be determined by the ability to pass on these costs. Domestically this may be possible, but not in the international market.

4.7.1 Farm input costs

Energy is a major factor in the cost of many farm inputs. The main impact of the carbon price will be on the cost of electricity. As the price of carbon increases, the price of electricity will rise. For vegetable growers this will impact on the running costs for high electricity-use equipment such as electric pumps and cool room refrigeration systems.

It is unlikely that the cost of fertilisers and crop chemicals will rise directly, as fertilisers and chemicals are internationally priced. However, it is possible that associated costs of road freight delivery and spreading may increase. These potential cost pressures will flow through once the carbon price becomes applicable to heavy vehicles from 2014.

Packaging can be a significant cost for vegetable growers. The major suppliers of packaging, Amcor and Visy, are both covered by the carbon price. This may directly impact on the price of package. Indirect influence, via electricity and transport costs may also add pressure to the costs of packaging.

4.7.2 Fuel Tax Credits

Agricultural businesses will not have to pay a carbon price on the fuel they use on-farm. The fuel tax credits for agriculture will remain at 100 per cent of the effective fuel tax for these industries. Hence, major on-farm fuel costs such as diesel pumps and tractor running costs will not be affected. However, heavy on-road vehicles will face a carbon price on the fuel they use from 1 July 2014. Fuel used by railways and aircraft will also have a carbon cost imposed on it, and will have cost pressures leading to a possible increase in rail and air freight costs.

4.7.3 Processes

Downstream processors such as vegetable processors will face higher energy costs and potential emission costs. For example, the vegetable processor Simplot and package manufacturers Amcor and Visy are liable entities and therefore required to pay the carbon price. ABARES has identified that post-farm transport and processing costs will also be impacted by a carbon price[13]. These additional costs will be passed back to farmers in the form of higher processing costs and/or lower farm prices.

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[13] Tulloh, C, Ahammad, H, Mi, R, Ford, M (2009), '*Effects of the Carbon Pollution Reduction Scheme on the economic value of farm production*, Australian Bureau of Agricultural and Resource Economics, *Issues Insights* 09.6, June 2009.

4.7.4 Overall impact

No modelling has been undertaken specifically for the vegetable industry. For a range of horticultural enterprises, modelling has estimated costs to increase by 0.3-0.8%[14], over business-as-usual by 2015. For broad acre agriculture, business costs may increase by 1.4-2.1%[15]. This cost impact was assessed three years after the introduction of the carbon price and includes changes to the Fuel Tax Credits for heavy vehicles. It assumes that no management actions are taken to reduce the impacts.

The subsequent impact on profit will vary significantly between enterprises and industries. The modelling suggests that horticultural enterprises could see a reduction in profit of between 0.2-1.0%. However, this assumes that costs cannot be passed on by the grower. For sectors of the vegetable industry that supply the domestic market, there may be scope to pass these additional costs on, reducing the carbon price impact on enterprise profit. This will be determined by market conditions and supplier agreements. Where growers compete on the world market, or where product substitution from overseas can occur, the ability to pass on these costs is limited, and enterprise profit will more likely be reduced.

[14] The impacts of the carbon price on Australian horticulture. Lene Knudsen, Dave Putland & Rod Strahan. AH11019 Final report. May 2012.

[15] The carbon tax - what does it mean for grain and livestock producers? Mick Keogh, Australian Farm Institute, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2012/03/The-carbon-tax-what-does-it-mean-for-grain-and-livestock-producers

5 Opportunities for the Vegetable Industry in Climate Change Related Grants and Funding

Funding opportunities for the vegetable industry are available to respond to:

1. The ***immediate*** impacts of government climate change policies on input costs for growers and processors, (mainly energy efficiency programs).
2. The ***medium-term*** opportunities for vegetable growers to participate in the Carbon Farming Initiative and generate revenue from carbon storage and emission reduction activities.
3. The ***long-term*** possible changes in climate and how this might impact on 'my enterprise', the region and the industry.

The entire vegetable sector – growers, industry and processors – have opportunities to access five programs to increase energy efficiency, five programs to create carbon credits, and one program to adapt to changes in the climate (**Table 2**). Of the 11 funding areas identified in this report, six are relevant to growers, six are relevant to the wider industry and three are relevant to the up- and down-stream sectors of the vegetable industry. The programs and opportunities for the vegetable industry are outlined in detail below.

5.1 Summary Table

Table 2. Summary of funding opportunities available to vegetable growers, industry and processors from a range of mainly Federal Government programs. Where possible an indication of the available funds is provided via the green bar. (Bar indicates % of funds remaining)

	Program		Vegetable industry Opportunities	Funds & timeframe		Target		
						Grower	Industry region	Processor
Immediate	Renewable Energy Target – Small-scale Renewable Energy Scheme		Access payments of $1,696 - $2,208 for the installation of solar water heaters, heat pumps, solar panel systems, small-scale wind systems, or small-scale hydro systems.	Ongoing		✓		
	Energy Efficiency Information grants		Seek funding to develop and provide information, advice and tools to increase energy efficiency on-farm and reduce costs.	$40 million 2012-2017			✓	✓
	Clean Technology Food and Foundries Investment Program		The food-processing sector of the vegetable industry has the opportunity to improve its energy efficiency and cut costs through accessing grants under this program.	$200 million 2012-2017				✓
	Low Carbon Australia (NB will merge with the Clean Energy Finance Corporation, July 2013)		Obtain finance and advice to invest in energy efficiency upgrades.	Ongoing $85 million investment fund		✓		✓
	State Energy Efficiency programs		In most States programs are available to provide assistance to businesses to audit and improve their energy efficiency. Refer to Table 4 for details.	Various		✓		
	Biodiversity Fund	Round two	The current call targets urban waterways and coastal environments. With the vegetable industry being a major landowner in the peri-urban and coastal areas there is an opportunity for growers to obtain funding to restore or revegetate parts of their properties not used for production.	$946 million 2012-2018		✓		

Medium term	Carbon Farming Initiative		In the medium term, opportunities may exist for the vegetable industry in the areas of: oil management to increase soil carbon stores; nitrogen fertiliser management and nitrous oxide emissions reductions; biochar as an addition to soil to increase soil carbon and using crop residues as feedstock in the biochar process; and biofuels from crop residues. Methodologies will be required for these opportunities to be realised. Funding of $20 million is available for the development of methodologies.	Ongoing		✓	✓	
	Carbon Farming Futures	Filling the Research Gap	Partner with appropriate research providers to obtain funding for research into emerging abatement technologies, strategies and innovative management practices that reduce greenhouse gas emissions, sequester carbon and enhance sustainable agricultural practices in the vegetable industry.	$201 million 2012-2016			✓	
		Action on the Ground	Lead, or develop consortiums, for projects that trial and demonstrate on-farm management practices and technologies that can reduce agricultural greenhouse gas emissions and/or increase carbon sequestered in soil within the vegetable industry.	$99 million 2012-2016		✓	✓	
		Extension and Outreach	Fund development of specific extension material and extension providers, and develop industry or regional extension programs, to assist growers to participate in the Carbon Farming Initiative.	$48 million 2012-2016			✓	
Long term	Regional Planning for Natural Resources Management (NRM)	Streams 1 & 2	Engage with NRM “clusters” to: 1. Ensure regional-level climate information is relevant to the vegetable industry. 2. Better understand the potential impact and adaptation options for a range of plausible climate projects.	$43.9 million 2012-2017			✓	

5.2 Renewable Energy Target – Small-scale Renewable Energy Scheme

5.2.1 Overview

The Small-scale Renewable Energy Scheme (SRES) creates a financial incentive for owners to install eligible small-scale installations such as solar water heaters, heat pumps, solar panel systems, small-scale wind systems, or small-scale hydro systems. These systems create Small-scale Technology Certificates (STCs) that can be sold to Renewable Energy Target liable entities, such as electricity retailers.

Under the Federal Government's Small-scale Renewable Energy Scheme, when you install an eligible system, you may claim a set number of these STCs. This number is based on the amount of electricity in megawatt hours (MWh):

- Generated by your small-scale solar panel, wind or hydro system over the course of its lifetime of up to 15 years; or
- Displaced by your solar water heater or heat pump over the course of its lifetime of up to 10 years.

5.2.2 Opportunities for the Vegetable Industry

Growers can access support for the installation of small-scale renewable energy systems through the SRES. The table below sets out the indicative level of support, across Australia, that would be provided through creation and sale of tradable STCs under the SRES for a 3kW solar panel system. Typically, installers manage the sale of the STCs and offer a discount on the price of an installation to reflect the expected value.

Table 3. Approximate level of support for solar panels offered under the Small-scale Renewable Energy Scheme

City	Approximate level of support	
	STCs	Value
Adelaide	62	$1,984
Brisbane	62	$1,984
Canberra	62	$1,984
Darwin	69	$2,208
Hobart	53	$1,696
Melbourne	53	$1,696
Perth	62	$1,984
Sydney	62	$1,984

Powering ahead with solar panels

Linton Brimblecomb, who grows vegetable crops including broccoli, sweet corn, onions and green beans, plus dryland grains, pulses and lucerne on 688 hectares in South East Queensland, had this to say about solar energy generation:

"In 2010, my brother and I decided to invest in solar panels to generate electricity for our farms in St George and the Locker Valley.

For us, it made good economic sense and was just another way of protecting our business against foreseeable changes in power costs, not to mention the touted carbon tax, which was a bit of an unknown.

After a bit of research we realised that solar panels were not widely used in our areas and, if they were, they were often attached to sheds and were not being used as effectively as they could be.

Luckily we were able to source a very handy engineer who was able to knock us up a system which was able to track the sun as it moves across the sky. This meant that the panels would always be in full sunlight and would be able to generate max power. The solar panels are connected to an axle which a small, self-sustaining motor turns hourly.

So far we can generate 270 kilowatts a day during summer and about 170 kilowatts a day during winter, which is more than we need to power irrigation pumps, our sheds and houses. Whatever is left, we sell back to the grid.

People always ask me whether it is affordable and sustainable. Given electricity prices at the moment, we predict it will probably take about 5 years to pay for itself.

Like everything new, panels will get cheaper as the technology becomes more used and supply becomes greater—so I only foresee that in light of growing power prices, solar is a cheap way to secure and sustain your business, not to mention that it is good for the environment."

5.3 Energy Efficiency Information Grants

5.3.1 Overview

The Energy Efficiency Information Grants will provide up to $40 million to industry associations and non-profit organisations that work with small and medium businesses to provide information on the smartest ways to use energy.

The Energy Efficiency Information Grants will help industry associations and non-profit organisations to provide practical, tailored energy efficiency information to small and medium businesses and community organisations.

The program aims to:

- Minimise energy consumption and costs for small and medium business and community organisations.
- Assist Australian small and medium businesses to improve their competiveness.

Projects could include developing:

- Tools and training to enable organisations to understand their energy use.
- Targeted information products on how organisations can save energy.
- Ongoing support services to improve organisational energy management.

5.3.2 Relevant Projects and Opportunities for the Vegetable Industry

Under round one of the program, 28 applications seeking a total of $20 million were successful. These included a number of applications with relevance to the vegetable industry, such as: Dairy Australia – Smarter energy use on Australian dairy farms ($1,000,000); South Australian Wine Industry Association – Development of the 'Winery Energy Saver Toolkit' ($208,660); The Australian Meat Industry Council, The Australian Meat Processor Corporation and The National Meat Industry Training Advisory Council – An Engagement, Extension and Education Program for Small-Medium Enterprises delivering to the Red Meat Industry, Supply Chain and related Communities ($528,250).

Given the potential for significant energy use by growers, for pumping and cool storage, there is an opportunity for the vegetable industry to seek funding from this program. The second round closed on the 20 December 2012. A third round is not currently listed.

5.4 Clean Technology Food and Foundries Investment Program

5.4.1 Overview

The Clean Technology Food and Foundries Investment Program is a $200 million competitive, merit-based grants program that supports Australian food and foundry manufacturers to invest in energy-efficient capital equipment and low-emission technologies, processes and products. The program will provide funding over a six-year period from 2011-12 to 2016-17. The program is administered by AusIndustry.

Eligible projects must improve the carbon and energy efficiency of the applicant's manufacturing process. Eligible project activities are capital investment and associated implementation activities that generate carbon and energy savings through:

- replacement or modification of existing manufacturing plant, equipment and processes; and/ or
- changes to energy sources for the existing or replacement manufacturing plant or processes.

5.4.2 Relevant Projects and Opportunities for the Vegetable Industry

A total of $47.3 million in grants has been awarded for a range of energy efficiency measures in the food and foundry sectors. These include a number of vegetable processing companies: Simplot Australia Pty Limited ($331,428); Edlyn Foods Pty Ltd ($33,239); Kagome Foods Australia Pty Ltd ($374,950); and D.T.R. Holdings Pty Ltd ($300,000).

The food-processing sector of the vegetable industry has the opportunity to improve its energy efficiency and cut costs by accessing support under this program.

5.5 Low Carbon Australia

5.5.1 Overview

Low Carbon Australia provides finance solutions and advice to Australian business to encourage action on energy efficiency and cost-effective carbon reductions. Improving energy efficiency is the most cost-effective and immediately available way to reduce your carbon footprint. With Low Carbon Australia’s help, business, industry and government will see energy-efficiency gains that will mean reduced energy costs for an improved bottom line.

5.5.2 Linkages with other programs

Low Carbon Australia supports other energy efficiency programs, such as the Clean Technology Food and Foundries Investment Program. Low Carbon Australia can assist in obtaining finance and technology input for projects.

5.5.3 Relevant Projects and Opportunities for the Vegetable Industry

Low Carbon Australia’s Energy Efficiency Program can provide finance and advice to vegetable industry participants ready to invest in energy-efficiency upgrades. A number of financial options are available to reduce or remove upfront capital costs such as: loans; operating leases; finance leases; on-bill financing; and Environmental Upgrade Agreements.

Growers may be able to obtain loans or other financial assistance to upgrade key equipment, such as cool-rooms and electric pumps, to increase energy efficiency.

Food processing industries looking to utilise energy from biogas capture projects to save energy costs and reduce emissions can take advantage of project finance through Low Carbon Australia, which has been specially tailored to meet industry and biogas project needs. Low Carbon Australia's strategic alliance with Quantum Power is designed to help industries realise their biogas projects.

5.6 State-based Energy Efficiency Programs

In most States there are energy efficiency programs. These are summarised in the Table 4 below.

Table 4. Summary of State energy efficiency programs

State	Program Information	Department
NSW	Energy Saver provides: a subsidised energy assessment; a personalised Energy Action Plan; coordination assistance of up to four hours, where required, to help implement energy-saving improvements; help accessing funding support for specific energy-efficiency upgrades through the NSW Energy Savings Scheme.	Environment and Heritage
Tas	The Renewable Energy Loan Scheme will assist eligible businesses to purchase and install renewable-energy generation facilities or manufacture renewable-energy technology. The loan scheme includes low-interest loans under the $30 million Renewable Energy Loan Fund.	Economic Development, Tourism and the Arts.
Vic	The Victorian Energy Efficiency Target can save businesses money through creating certificates when energy-efficiency improvements are made to your business. There are now 15 categories of energy-saving activities covered by the VEET scheme, including 4 specifically tailored to the business sector: motors; refrigerated display cabinets; refrigeration fans; and commercial lighting.	Essential Services Commission
Qld	ecoBiz is a free eco-efficiency program which provides tools, training and detailed information to assist Queensland businesses to become more efficient. ecoBiz can help your business improve efficiencies and reduce resource use for financial and environmental benefits. Businesses that complete the program and reassess their eco-efficiency may be recognised as ecoBiz partners.	Environment and Resource Management
SA	Resource Efficiency Assistance Program is for medium to large businesses (more than 20 employees) to measure their resource usage through auditing waste, energy, water, systems and plant efficiency. For small businesses the S1K project is available.	Zero Waste SA

WA	No programs currently available.	
NT	ecoBiz NT is an environmental partnership program that helps Territory businesses adopt resource-efficient practices that are good for the financial bottom line as well as for the environment. Participating businesses may also become eligible for significant ecoBiz NT grants to assist in implementing eco-efficiency initiatives. Grants of up to $20,000 (on a dollar-for-dollar basis) are available to assist eligible businesses with eco-efficiency improvements.	Business
ACT	No programs currently available.	

5.7 Biodiversity Fund

5.7.1 Overview

The Biodiversity Fund is an ongoing program with an initial allocation of $946 million over six years. The overall objectives of the Biodiversity Fund are to help land managers establish, manage and enhance native vegetation on their land, increase our stores of carbon in the landscape and, in so doing, maintain ecosystem function and improve the resilience of our ecosystems to the impacts of climate change.

5.7.2 Relevant Projects and Opportunities for the Vegetable Industry

In round one, 317 projects were funded at a total of $271 million. The majority of projects involved revegetation in the more extensive inland agricultural regions.

Round two specifically targets urban waterways and coastal environments. With the vegetable industry being a major landowner in the peri-urban and coastal areas, there is an opportunity for growers to obtain funding for restoring or revegetating area of parts of their properties not used for production. Applications close 10 April 2013 for projects smaller than $2 million, with larger projects requiring an expression of interested to be submitted by 12 March 2013.

5.8 Carbon Farming Initiative

5.8.1 Overview

The Carbon Farming Initiative (CFI) allows farmers and other land managers to earn carbon credits by storing carbon or reducing greenhouse gas emissions on the land (see Section 2.6 for further details). These credits, known as Australian Carbon Credit Units (ACCUs), can be sold to people and businesses wishing to offset their emissions.

The value of ACCUs eligible to be used under the carbon price mechanism could be around $23 during the fixed price period (2012-2015). Participation in the CFI requires significant project management, compliance and reporting, which could take 30-50% of the revenue.

5.8.2 Connection with other Programs

5.8.2.1 The CFI links with the Biodiversity Fund. The Biodiversity Fund can be used to add additional biodiversity features to CFI environmental planting projects. The CFI is dependent on the Carbon Farming Futures program for new knowledge and understanding to develop new methodologies such reducing nitrous oxide emissions from nitrogen fertiliser.

5.8.3 Opportunities for the Vegetable Industry

As outlined in section 3.6 an approved methodology is required to estimate the carbon sequestered or emissions reduced. Currently there are three methodologies approved for agriculture, which are limited to methane destruction from animal manure, and four methodologies approved for vegetation, two relating to environmental plantings and two related to native forest/savannah management. As a result there are limited opportunities for the vegetable industry in the short term.

In the medium term opportunities may exist for the vegetable industry in the areas of:

- Soil management to increase soil carbon stores.
- Nitrogen fertiliser management and nitrous oxide emissions reductions.
- Biochar, both as an addition to soil to increase soil carbon and using crop residues as feedstock in the biochar process.
- Biofuels from crop residues.

For these opportunities to be realised new methodologies will be required. Work is underway in the Carbon Farming Futures program to develop the knowledge, tools and understanding to underpin these methodologies.

5.9 Carbon Farming Futures

5.9.1 Filling the Research Gap

5.9.1.1 Overview

Filling the Research Gap is investing $201 million over 6 years (2012-2017) to support research into emerging abatement technologies, strategies and innovative management practices that reduce greenhouse gas emissions from the land sector, sequester carbon and enhance sustainable agricultural practices.

Filling the Research Gap builds on DAFF's Climate Change Research Program which ran from 2008-2012. Research projects target research gaps pertaining to abatement technologies and practices. The research priorities are: reducing methane emissions; reducing nitrous oxide emissions; sequestering carbon; improving modelling capability; and adapting to climate change and its associated climate variability.

5.9.1.2 Connection with other Programs

Research outcomes will underpin the development of new methodologies that land managers can use to participate in the CFI. Section 3.4 outlines the critical role these methodologies play in enabling farms to generate carbon credits under the CFI.

5.9.1.3 Relevant Projects and Opportunities for the Vegetable Industry

There were no research projects of direct relevance to the vegetable industry funded in round one.

Some 240 proposals were received for round two of the Filling the Research Gap, which closed in January 2013. It is likely that there will be funded projects of relevance to the vegetable industry.

The vegetable industry has the opportunity to partner with appropriate research providers to obtain significant research funding that specifically addresses the needs of the sector. Of the $201 million allocated, $47 million has been committed in round one. A similar amount is likely to be committed in round two, leaving approximately $100 million available for subsequent rounds through to 2017. Given the current priorities of the program the most likely areas of relevance to the vegetable industry would be:

- Nitrogen fertiliser management and nitrous oxide emissions reductions.
- Soil management to increase soil carbon stores (in round 2 there is a specific priority for *"the effect of management practice on soil carbon content in intensive, high input systems"*).
- Farm systems design and analysis.
- Adaptation to climate change with its associated climate variability.

5.9.2 Action on the Ground

5.9.2.1 Overview

Action on the Ground is investing up to $99 million of grant funding in on-farm projects over six years. Action on the Ground supports landholders, research, industry, non-government, government and farmer 'care' and 'grower' groups/organisations to come together to trial and demonstrate management practices and technologies on-farm that can reduce agricultural greenhouse gas emissions and/or increase carbon sequestered in soil.

5.9.2.2 Connection with other Programs

Action on the Ground's on-farm projects demonstrate the emerging opportunities for land managers to participate in the Carbon Farming Initiative (Section 4.6.1). Action on the Ground also provides a link between research programs and farms. Projects under Action on the Ground "scale-up" and reality-test research results in real farming situations.

5.9.2.3 Relevant Projects and Opportunities for the Vegetable Industry

The vegetable industry has the opportunity to lead, or develop consortiums, for Action on the Ground projects that specifically address the needs of the sector. Of the $99 million allocated, $25.2 million has been committed in round one, leaving approximately $74 million available for subsequent rounds through to 2017.

It is likely that the priority areas for round 2 of relevance to the vegetable industry would be similar to that of Filling the Research Gap and include:

- Nitrogen fertiliser management and nitrous oxide emissions reductions.
- Soil management to increase soil carbon stores.
- Testing of farm systems design.
- Practices which help adaptation to climate change.

There was a shift in emphasis to adaptation research projects in round two. This may also occur in round two of Action on the Ground.

5.9.3 Extension and Outreach

5.9.3.1 Overview

Extension and Outreach is investing $48 million to assist farmers, land managers and key influencers to reduce land-sector greenhouse gas emissions, sequester carbon in the landscape and participate in the CFI by:

- Providing technical information and support about integrating carbon management into whole-farm planning and farm performance.

- Sharing new research and farm techniques for the property and farm business, including those generated through the Carbon Farming Futures programs.
- Increasing communication resources and channels available;
- Creating tools and information systems to improve knowledge of land-sector emissions.
- Enhancing productivity and environmental sustainability.

The Extension and Outreach funding aims to deliver information that is clear, consistent and current for farmers, land managers and their key influencers using a mix of traditional and new extension services.

The Extension and Outreach program has three funding components:

- Information, tools and extension activities.
- Extension providers and service delivery.
- Targeted industry and regional initiatives.

Details of the three components are provided in Appendix VI.

5.9.3.2 Connection with other Programs

The Extension and Outreach connects strongly with the Filling the Research Gap and Action on the Ground programs to communicate these outcomes to the wider farming community and work one-on-one with farmers on how to generate carbon credits under the CFI.

5.9.3.3 Relevant Projects and Opportunities for the Vegetable Industry

The vegetable industry has the opportunity to lead, or develop consortiums, for Extension and Outreach projects that specifically address the needs of the sector. A total of $64 million has been allocated to the three components with no projects currently funded. The program is running an open-call for projects, with assessment times to be set through the year. The first assessment closed on the 19th December 2012.

There is a number of opportunities for the vegetable industry to seek funding to develop specific extension material (component 1), fund extension providers (component 2) and develop industry or regional extension programs (component 3).

In particular, there may be an opportunity to obtain funding for existing IDOs to become skilled up in the CFI and be funded to deliver one-on-one advice to growers. This might take the form of applying for an overarch project, which includes all three of the components above and covers, for example, 20% of an IDO’s salary. The package would then integrate and deliver the climate change and variability information to the vegetable industry, together with other productivity or sustainability information.

5.10 Regional Natural Resource Management Planning for Climate Change Fund

5.10.1 Overview

Regional natural resource management (NRM) organisations will be supported to update existing regional NRM plans to guide planning for climate change impacts on the land and to maximise the environmental benefits of carbon farming projects.

Funding of $43.9m over five years will be utilised for this fund. The fund will help to guide where biosequestration projects should be located in the landscape to maximise the benefits for biodiversity, water and agricultural production. The fund is divided into two streams.

5.10.2 Stream 1 NRM organisations planning for climate change impacts on the land and maximising the environmental benefits of carbon farming projects.

Funding supports the revision of existing regional NRM plans to help identify where in the landscape climate change adaptation and mitigation activities should be undertaken. Stream 1 has $28.9m for a five-year period. This stream will be administered by the Department of Sustainability, Environment, Water, Population and Communities.

Stream 1 will assist regional NRM organisations to:

- Update existing regional NRM plans to incorporate climate change mitigation and adaptation information and approaches.
- Use best-available information to plan for the impacts of climate change.
- Help guide the location and nature of biodiversity and carbon farming activities in the landscape.

The first round of applications closed on the 26 February 2013.

5.10.2.1 Connection with other Programs

Stream 1 NRM planning for climate change aims to identify priority landscapes for carbon plantings and strategies to build landscape integrity and guide adaptation and mitigation actions to address climate change impacts on natural ecosystems. As such it will provide a regional planning framework for the expected land use changes that are expected to arise in the shorter term from the CFI and in the long term from direct climate change impacts. Under the Carbon Farming Initiative, applicants for eligible offset projects will need to identify consistency with the relevant regional NRM plan.

Stream 1 also connects with the Biodiversity Fund by supporting planning that will help guide the types and locations of activities, primarily reforestation activities and the management of remnant vegetation.

5.10.2.2 Relevant Projects and Opportunities for the Vegetable Industry

There are currently no funded projects. Round one applications for regional NRM organisations closed on 6 February 2013.

This is a NRM planning fund. The opportunity for the vegetable industry will be limited to a regional watching brief and contribution to the planning process where relevant. There is more opportunity and relevancy in the Stream 2 projects outlined below.

5.10.3 Stream 2 NRM organisations planning for climate change impacts on the land and maximising the environmental benefits of carbon farming projects.

Stream 2 will provide $15 million over four financial years for coordination of research to produce regional-level climate change information to support medium-term regional NRM and land-use planning. This stream will be administered by the Department of Climate Change and Energy Efficiency (DCCEE).

Stream 2 will deliver:

- **Regional climate projections** for the whole of Australia. The projections will focus on the elements of climate change of highest priority to NRM groups. CSIRO will lead the NRM projections project, in collaboration with the Bureau of Meteorology (BoM). The NRM projections project will build on the 'Climate Futures' approach, developed by CSIRO, to simplify the communication and management of the growing range of global and regional climate change projections data. The Climate Futures approach involves identifying a small number of future climates that are representative of the range of plausible climate change outcomes simulated by climate models.
- **Impacts and Adaptation Grants Program** for research institutions' partnerships with regional NRM organisations to deliver information on climate change, its impacts and potential adaptation responses, and provide guidance on how to use that information in NRM planning through the NRM Climate Change Impacts and Adaptation Research Grants Program (Impacts and Adaptation Grants Program). This component has $8 million over four financial years. For delivery, the 56 NRM regions have been grouped into eight 'clusters'. The clusters are designed according to common characteristics in relation to land use, climate and how these are anticipated to change (**Figure 5**). Applications closed on 27 September 2012 with successful projects yet to be made public.

Figure 5. NRM Climate Change Impacts and Adaptation clusters.

5.10.3.1 Connection with other Programs

Stream 2

5.10.3.2 Relevant Projects and Opportunities for the Vegetable Industry

Successful projects for each of the eight "clusters" have yet to be made public. The clusters of greatest relevance to the vegetable industry are:

- East Coast.
- Southern Slopes (including Tasmania).
- Murray Basin.

By engaging in these clusters, via steering/industry groups, the vegetable industry will have the opportunity to better understand the potential impact and adaptation options for a range of plausible climate projects. This could be achieved by having input into what is the most relevant regional-level information (e.g. water availability, extreme temperature events, storm incidences) arising from the plausible climate change scenarios for the medium term. Based on these climate projects the vegetable industry will be able to have input into how NRM planning can facilitate any adaptation required.

6 Energy efficiency

Energy efficiency is one of those practices that should be done regardless of whether you think you are going to be affected by changing weather patterns or not. You will still be paying electricity and fuel bills – so why not make the savings and reduce your costs?

There is a number of opportunities to improve energy efficiency on-farm and reduce the impact of increasing energy prices. This section focuses on two of the key energy users, irrigation and cool rooms.

Shopping around for a better energy deal

In addition to potential savings through improving energy efficiency, there are changes occurring in the energy marketplace that can also reduce costs. The electricity market is currently undergoing reform to introduce greater flexibility and transparency under the National Energy Customer Framework[16]. The aim of this national reform is to ensure customers have consistent information on energy pricing and terms and conditions, which promotes competition in the market place.

Currently South Australia, Tasmania and ACT are part of the National Energy Customer Framework, allowing customers to compare the offerings of a range of retailers[17], based on their usage patterns. In Tasmania the increased flexibility has resulted in more competition and improved prices for many growers. New South Wales is expected to join the scheme in July 2013, with Queensland and Victoria joining in 2014.

For larger electricity users care should be taken to examine both the fixed costs, i.e. the network tariff, and the variable costs, i.e. the per KWh cost. Because of the highly variable electricity usage patterns associated with irrigation, due to seasonal, rainfall and cropping cycles, the way in which the network tariff is applied can have a major impact on the overall cost of electricity.

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[16] http://www.ret.gov.au/energy/energy_markets/national_energy_customer_framework/Pages/NationalEnergyCustomerFramework.aspx

[17] http://www.energymadeeasy.gov.au/

Energy efficiency fast becoming the new black

In November 2012 Mackay Sugar, the country's second-biggest sugar miller, flicked the switch on its new $120 million co-generation plant and start supplying electricity to Queensland's regional power grid. The miller ramped up output and by February 2013 it was producing enough energy to power 30% of Mackay (38MW), as well as powering its Racecourse Mill and adjacent refinery.

The plant incinerates fibre left after crushing sugar cane. Its power exports will reduce the region's coal-fired carbon dioxide emissions by about 200,000 tonnes a year, while earning the company renewable energy certificates and payment for the electricity itself. (Sydney Morning Herald, November 14, 2012)

6.1 Improving irrigation efficiency

Moving and pressurising water requires a lot of energy. As a result irrigation is the major energy user in growing vegetables.

For most growers, improving productivity, i.e. increasing the revenue for the amount of energy used, is more important to the bottom-line than simply improving the energy efficiency and reducing energy costs. With this in mind, much of what has been learnt about improving water efficiency is also applicable to improving energy efficiencies in the vegetable industry[18]. Managing irrigation well delivers improvements in water productivity ($/ML) through increases in yield and/or quality and hence revenue per ML of water applied. In a similar way improving energy productivity ($/KWh) will be more about increases in yield and/or quality and hence revenue per KWh of energy used. This productivity approach will be a stronger motivator than simply reducing the cost, whether it is for water or energy.

There are three areas where irrigation improvements could increase energy productivity or reduce energy usage, these being:

- Crop management.
- Irrigation system design and maintenance.
- Pump efficiency.

[18] Hickey, M., Hoogers, R., Singh, R., Christen, E.W., Henderson, C., Ashcroft, W., Top, M, O'Donnell, D., Sylvia, S., and Hoffman, H. (2006). Maximising returns from water in the Australian Vegetable industry: National Report.

To increase energy productivity, improving crop management will produce the biggest gains and should be the focus of the grower. Good irrigation system design and maintenance also has the potential to deliver some energy productivity gains.

To reduce on-farm energy use, improving either pump efficiency or irrigation system design and maintenance will deliver similar levels of improvement. For example, in a survey of 16 vegetable growers in the Peel-Harvey valley, half the potential saving came from fixing up the irrigation system and the other half from optimising pump and motor performance[19].

A wide range of irrigation tools have been developed to assist growers, consultants and designers to improve irrigation management[20]; many of these will also be applicable for improving energy productivity or reducing costs.

6.1.1 Crop management

The biggest gains in productivity will come from improving crop management. By focussing on crop management, including irrigation, crop yield and quality and hence revenue can be optimised for the amount of energy required to apply irrigation. The potential gains can be large, as illustrated by the ten-fold variation in water productivity across 39 citrus growers (Figure 6). Converting these to energy productivity (using the values in **Figure 6**) produces a range of 0.4 to 3.5 t/100KWh of electric use for irrigation. No similar figures are available for vegetable crops but this ten-fold variation in water productivity and energy productivity would be expected across different farms.

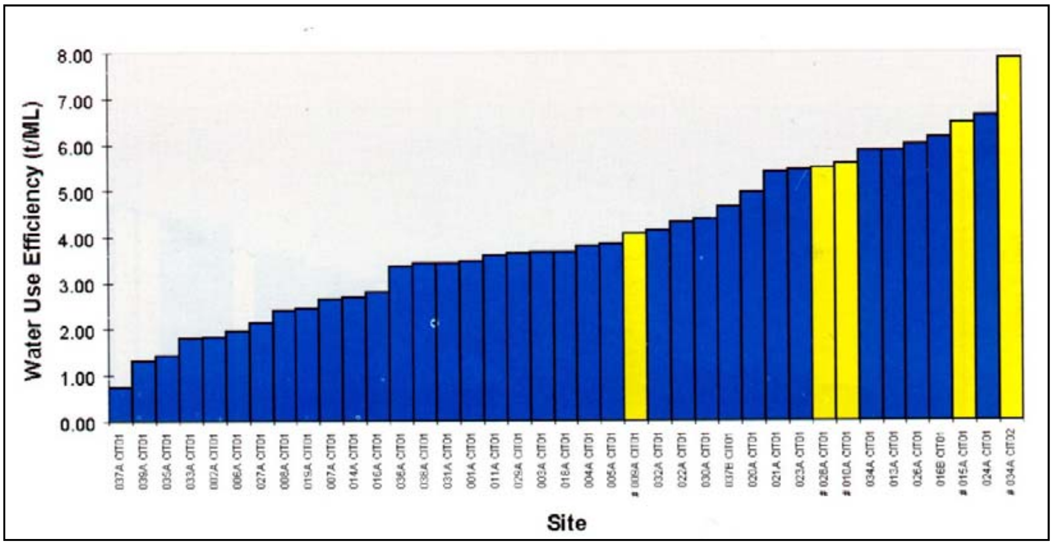

Figure 6. Water productivity of citrus (t/ML) from 39 irrigated farms in the Riverland and Sunraysia

[19] S Milai Survey of Irrigation Efficiencies on Horticultural Properties in the Peel-Harvey Catchment Technical Report 119

[20] Murray Chapman, Liz Chapman, and David Dore, 2008. National Audit of On-farm Irrigation Information Tools. Final report prepared for the Australian Government Department of the Environment, Water, Heritage and the Arts.

Table 5. Typical electricity requirements for pumping a ML of water for a range of irrigation systems with varying water sources and operating pressures. Note these figures will vary depending on the specifics of the irrigation system (adapted from[21]).

Irrigation system		Total operating head (m)	Electricity required (KWh/ML)
Furrow	river	10	45
	bore	45	204
Pivot or linear move (low pressure)		40	181
Drip/micro		50	226
Spray	river	55	258
Spray	bore	65	294
	Traveller river (medium pressure)	85	385
	bore (medium pressure)	90	407
	high pressure	120	543

Irrigation scheduling is an important aspect of improving crop productivity. There are many guides to irrigation scheduling including *Managing Water for Yield and Profit*[22] and *Understanding Irrigation Decisions*[23].

6.1.2 Good irrigation system design and maintenance

Good irrigation system design and maintenance has the potential to both lift productivity and reduce energy costs.

Productivity can be improved by improving distribution uniformity to ensure the entire crop receives the right amount of water. Distribution uniformity is a measure of how uniformly an irrigation system applies water. In the Lockyer Valley vegetable crop growth, quality and yield has been found to be closely correlated to distribution uniformity[24]. By getting the

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[21] Peter Smith and Alan Richards, 2003. How much does it cost to pump? Agfact E5.10, first edition, January 2003.
[22] Jenny Jobling, Gordon Rogers, Alison Anderson, Andrea Vicic 2008. Managing Water for Yield and Profit. A training guide for Irrigators in the Australian Vegetable Industry. AHR Training Pty Ltd.
[23] Kelvin Montagu, Ben Thomas, Geoff Thomas, Evan Christen, John Hornbuckle, Craig Baillie, Chris Linehan, Peter Smith, Fabian Gallo, Sam North, Wayne Meyer, Richard Stirzaker, Peter Cornish. 2006. Understanding Irrigation Decisions - From Enterprise Planning to the Paddock. Land & Water Australia and IF Technologies Pty Ltd.
[24] Scott Barber & Steven R. Raine 2002. Using commercial distribution uniformity and yield data to improve irrigation management. International Water & Irrigation, 22,17-22.

irrigation spacing, layout, pressure and nozzle right, distribution uniformity and subsequently yields can be improved without any additional water or energy costs (**Table 6**). In the Lockyer valley improving the distribution uniformity could boast yields by 7 to 14% without any additional water or energy use, thereby increasing productivity.

Table 6. Irrigation performance and potential agronomic gains through improving distribution uniformity (DU) in the Lockyer Valley (adapted from[9]).

Crop	Irrigation system	Measured Distribution uniformity	Seasonal irrigation (ML/ha/yr)	Potential agronomic gain if DU>90%
Cauliflower	Solid set	70%	2.5	7%
Sweet corn	Big gun traveller	72%	>3.0	14%
Lettuce	Solid set	70%	1.1	13%

Low distribution uniformity will result in sections of the crop being over-watered, while other areas are under-watered. Many growers compensate by irrigating to satisfy the area with the lowest application rate. As a result irrigation run times are greater than would be required if distribution uniformity were high.

In WA the additional power used to overcome poor distribution uniformity in vegetable production was estimated to increase power consumption by an average of 700KWh/ha/year across 16 vegetable growers, with the worst irrigation system adding an additional 2,000KWh/ha/yr to the power consumption of one grower[25].

Energy costs can also be reduced by ensuring the irrigation system is running at the designed pressure and flow rate, or changing the irrigation system to reduce the required pressure. Poor system design can increase energy consumption considerably.

Of the 16 vegetable properties in WA, nine were found to have acceptable system designs, while the other seven had problems due to incorrect pipe sizes or the design not adjusting for changes in elevation. These design or installation problems are compensated for by increasing the pumping pressure and hence the energy costs to apply the same amount of water. As can be seen in **Table 5**, the more pressure the more energy required.

There is a large range of energy use between irrigation systems. Across some typical irrigation systems energy usage ranged from as low as 45 up to 543 KWh/ML (**Table 5**). In the Tasmanian example below (**Table 7**), an energy saving of 66% and a cost savings of

[25] S Milai Survey of Irrigation Efficiencies on Horticultural Properties in the Peel-Harvey Catchment Technical Report 119

$47.12/ML can be obtained from moving from a high-pressure travelling gun, to a low pressure centre pivot, due to the reduction in the pressure required [26].

Table 7. Potential energy savings of converting from a travelling gun to a centre pivot system due to reduced pressure requirements in Tasmania[12] (using a mix of 11 hours off-peak and 5 hours peak power).

	Travelling gun	Centre Pivot
Hydraulics (m)		
End pressure	52.0	14.0
Friction loss		
in irrigator or hose	28.0	0.7
mainline	4.1	2.8
sundry	7	7
Static head	7	7
Total head	106.1	39.5
Pump duty	17.1 l/s @106.1m	18.5 l/s @ 39.5m
Pump efficiency	66%	81%
Motor efficiency	92%	92%
Cost per hour		
off-peak	$3.22	$1.06
peak	$7.33	$2.41
Runtime (hr/day)	15	15
Total KWh/day	443	146
Cost per day	$64.77	$21.27
Cost per ML	$70.16	$23.04

[1]off-peak – 10.9KWh; peak – 24.8 KWh

However, the biggest advantage in changing irrigation systems may be in the improvement in crop management and resulting yields and quality. For example, in NSW replacement of a travelling gun with a centre pivot produced an energy saving of around $50/ha[18]. But the real benefit was a 20% increase in yield and increases in product quality. Combined, these resulted in a net benefit of $565/ha.

6.1.3 Efficient pumping

The pump is the heart of the irrigation system. Making sure it is the right pump for the job and that it is working properly can save energy costs. But across the irrigation industry typically half of all pumps are found to be not operating efficiently. As a result energy costs are higher than they need to be.

[26] James Curran. Power Bills and Energy Efficiency for Irrigation.

The pump performance is determined by both the pump and motor performance. Overall, the pump performance is more important than the motor in determining net efficiency (**Table 8**). Typical improvements in the efficiency of the pump reduce the daily energy use by 19% and cost by $7.91/ML; typical improvements in the efficiency of the motor reduce the daily energy use by 3% and costs by only $0.80/ML.

The following section looks at how energy use can be reduced by improving the efficiency of both the pump and motor.

Table 8. The energy and cost savings of two pumps with contrasting pump efficiencies[27]. (Pump duty of 40l/s at 60m head; using a mix of 11 hours off-peak and 5 hours peak power.)

	Improving only pump efficiency		Improving only motor efficiency	
	Pump 1	Pump 2	Pump 3	Pump 4
Pump efficiency	65%	80%	80%	80%
Motor efficiency	91%	91%	90%	93%
KW @ pump	36.2	29.4	29.4	29.4
KW @ meter	39.8	32.3	32.7	31.7
KW/h	39.8	32.4	32.7	31.6
Runtime (hr/day)	16	16	16	16
Total KWh/day	637	518	523	506
Cost per day[1]	$97.20	$78.98	$79.85	$77.28
Cost per ML	$42.19	$34.28	$34.66	$33.54

[1]off-peak – 10.9KWh; peak – 24.8 KWh.

Working out the operating cost and efficiency of existing pumps is reasonably straightforward (see [28,29,30]). By measuring a pump's performance, and then monitoring it each year, growers will be able to make informed decisions on energy savings.

6.1.3.1 The pump

The initial pump efficiency will be determined by how well the pump duty (the flow rate and operating pressure) is matched to the requirements of the irrigation system. Get this wrong and ongoing energy use and costs will mount quickly.

The original design should include information on the system flow-rate and pressure and how efficient the pump is when operating under these conditions via the pump curve. Once

[27] James Curry. Irrigation pump efficiency. Agricultural Resource Management.
[28] Alan Richards & Peter Smith 2003. How efficient is your pump? Agfact E5.11, first edition November 2003.
[29] James Dee 2011. Selecting the right pump for an irrigation system. Farmnote 333.
[30] Pumping efficiency. Growcom SE17, November 2004.

a pump is installed the operating conditions can be measured and the pump efficiency checked.

It is good practice to measure pump efficiency in the commissioning phase of new systems to ensure the system, including the pump, is working as specified. This can pick up any problems and ensure energy use and running costs are minimised. Problems can include suction pipe diameter too small, lift too great and air entering the system (cavitation). These problems can drastically impact on a pump's performance[31].

Over time a pump's efficiency will decrease. By periodically measuring the pump's efficiency, and comparing this to the manufacture's pump curve, the grower can decide when repair or replacement is cost-effective. This decision will involve a trade-off between increased energy use, and hence running costs, and the capital cost of the repair or replacement.

Appropriate maintenance is also required to maintain the efficiency of the pump. Problems with pumps can occur in the suction line, such as a blocked inlet, or a pipe damaged or crushed, or a build-up of deposits. On the pump, worn impellers and bearings, and seal and gland losses can all reduce the pump's efficiency. Having a maintenance schedule and monitoring the performance of the pump will ensure these losses in performance remain at a tolerable level.

The pump efficiency can be affected by: matching of the pump to the irrigation system; design of the pump station; and maintenance. As a general rule, pump efficiency should be greater than 70% at duty; below this is poor. If you can get better than 80% this is excellent, with a maximum of 88% achievable in the field for an end-suction pump.

6.1.3.2 The motor

The motor that drives the pump will affect the net efficiency. Matching the right motor to the system will improve net efficiency. Electric motors increase in efficiency as they near full load. An electric motor operating at only 50% of full load will not be as efficient as one operating at close to 100% of full load. Aiming to have a motor that runs as close as practicable to full load can increase motor efficiencies by 2 to 5%.

As of Oct 2001 all three-phase electric motors from 0.73 to 185 kW, either manufactured or imported into Australia, must comply with minimum energy performance requirements as set out in AS/NZS 1359.5-2000. This regulation was made even more stringent in April 2006, when the previous high-efficiency level became the new minimum standard. As a result all

[31] Michael Reynolds, Rod Jackson, Janelle Montgomery, Stuart Bray 2008. Improving Pump Installation for Efficiency: A case study. Cotton CRC.

post-2006 three-phase electric motors are typically 2 – 3% more efficient than those prior to 2001.

Most irrigation pumps run at full speed no matter the load on the system. This can be very inefficient, particularly when a wide range of flow rates and pressures are needed, e.g. where flow rate varies due to different irrigation types or varying block size, or pressure varies considerably. A more energy-efficient system uses a variable speed drive to slow the motor speed to match the varying end-use requirements. If the irrigation-system flow rate or pressure does vary then variable speed drivers can reduce energy use.

6.2 Refrigeration technologies and related options

Parkside Energy conducted a high-level review of energy efficiency opportunities with particular emphasis on the cost effectiveness and practicality of the different technologies considered. Energy efficiency opportunities are likely to be site-specific and reliant on the crops grown, the currently installed equipment and local weather conditions, among other factors.

6.2.1 Types of refrigeration used in the vegetable industry:

A review of current and future technologies, as well as interviews with growers, showed that there are essentially three forms of refrigeration technology used in the industry. These are:

6.2.1.1 *Hydro cooling*

This technology cools produce from ambient conditions to typically 3-4^{o}C through the direct contact with chilled water. The cooling process is intentionally rapid, usually taking half an hour or less, so as to maximise the freshness of the delivered produce. Hydro cooling typically has the following features:

- It is only appropriate for some produce, and is seldom if ever used for leafy produce.
- The chilled water is produced via refrigeration.
- The produce can be placed in contact with the chilled water in a number of ways, including immersion and water sprays.

6.2.1.2 *Vacuum cooling*

In this case, cooling is achieved by applying a vacuum on a sealed volume in which the produce is stored. This causes evaporation of water inside the sealed volume, with the energy required to cause this evaporation reducing the temperature of both the air and the produce ultimately to 3-4^{o}C. The water source can either be a sump and/or water on the surfaces of both the produce and the rest of the sealed volume. Once again, the cooling process is intentionally rapid, usually taking half an hour or less, so as to maximise produce freshness. Vacuum cooling typically has the following features:

- Relative to hydro cooling, it is less damaging to produce but has greater upfront investment. It is therefore mainly used for fragile produce, in particular leafy produce. As its cost falls, it is becoming more common and used for a greater range of produce.

- Electrically driven vacuum pumps are the main energy-consuming device in vacuum coolers. These are a mature technology for which only incremental future improvements are likely.

- There are also so-called ‘hydro-vac’ devices available for which the user has the option of either hydro or vacuum cooling produce.

6.2.1.3 *Cool rooms with refrigerative cooling*

These rooms are insulated and almost always driven by an electrically powered refrigeration cycle that uses a conventional refrigerant. They are used both for cold storage between harvest and transport, as well as cooling to 3-4^{o}C from ambient. The refrigeration plant in cool rooms has the following features:

- Refrigeration plant is a mature technology. Several refrigerants are in use today, commonly R22 (which is being phased out due to its ozone depleting potential), R134a and R404A.

- The refrigerants R134a and R404a do not significantly affect ozone depletion, but have high global warming potentials (GWPs) of 1300 and 3260 respectively[32]. As of 1st July, 2012, synthetic greenhouse gas refrigerants are taxed using the current carbon price and the above GWPs.

6.2.2 Opportunities for reducing energy consumption and associated greenhouse gas emissions in relation to cool rooms

There are two main opportunities to reduce energy consumption and associated greenhouse gas emissions. These are:

- Use of CO2 as a refrigerant gas.

- Improved insulation.

6.2.3 Application of advanced refrigeration technologies for hydro cooling and cool rooms – use of CO_2 as a refrigerant

The main opportunity for improving refrigeration efficiency is the use of carbon dioxide as a refrigerant gas.

Perhaps surprisingly, CO_2 has the benefits of negligible greenhouse impact relative to current, synthetic greenhouse gas refrigerants, whilst also enabling smaller evaporator and condenser systems due to its improved heat transfer[33] relative to these refrigerants. Its

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[32] Australian Federal Government – Department of Sustainability, Environment, Water, Population and Communities, 2013, “Equivalent price for synthetic greenhouse gases”, http://www.environment.gov.au

[33] American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2013, “ASHRAE Handbook Online”, https://handbook.ashrae.org/, last accessed 19/04/2013

primary drawbacks are a currently lower coefficient of performance (COP), mainly due to the less developed compressor technology, as well as its higher system pressures and therefore higher system cost. It has been used as a refrigerant for decades, but has recently gained significant support in Europe in several different industries. There are some limited examples of its use in Australia, but apparently none in the vegetable industry. The CO_2 system does release CO_2 into the cool room, it is contained within the sealed refrigeration system.

When investing in new refrigeration plant, a grower will most likely compare the performance of continuing to use current plant against the total cost of the new investment. An example of such comparisons is given in **Table 9**, which shows a net present value (NPV) analysis of three refrigeration plants: a paid-off plant running on R134a, a new plant running on R134a and a new plant running on CO_2. Given the several refrigerants and different plant in use, these calculations are only representative.

Table 9 shows that the paid-off R134a plant has the lowest NPV over the 15 years from 2013. However, if the CO_2 plant is able to achieve a lower capacity factor due to its better heat transfer, it may already be cost-effective relative to a new R134a plant. Importantly, refrigerant replacement is a small part of the total NPV in all cases. This is still the case if R404a, with its higher global warming potential, was instead used. Electricity prices account for more than 80% of operating costs and the total NPV. Plant costs are secondary, with refrigerant replacement and O&M together accounting for roughly 10% of total NPV.

This importance of electricity prices in the total cost of ownership suggests that more active management of electricity contracts is worthwhile. However, both interviewees suggested that electricity pricing between retailers was very similar, leaving little room for negotiation. Nonetheless, this may change in future and so is something that should always be considered.

A lesser known feature of CO_2 based refrigeration is its relatively high temperature of heat rejection; roughly $120^{o}C$. Waste heat recovery from these plants may therefore be useful, particularly in applications where large quantities of hot water are required. In this case, the overall energetic and financial performance of such plants is significantly increased. Nonetheless, such an example is not discussed in this report since hot water requirements on-site appear to be limited.

As the CO_2 plant improves, the 2030 modelling shows that it becomes more desirable. Once again, these improvements are not due to the increased carbon price of 50 $\$/t_{CO2}$ [34] making the synthetic greenhouse gas refrigerants more costly. When considering new plant only, the CO_2 plant has lower NPV than the R134a plant for both optimistic and pessimistic

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[34] Australian Federal Government – Treasury, 2013, "Modelling a carbon price, http://carbonpricemodelling.treasury.gov.au/carbonpricemodelling/content/update_report.asp

scenarios. This suggests that a transition to CO_2 based refrigeration may occur in coming years.

Table 9: NPV analyses of selected refrigeration plant in 2013 and 2030 (in 2013 $)

	R134a new plant		R134a paid off		CO2 new plant	
	opt.	pess.	opt.	pess.	opt.	pess.
2013						
Total plant cost ($/kW_e)	500	1000	0	0	550	1250
COP	3.0	2.5	2.5	2.0	2.5	2.0
Refrigerant price without carbon price ($/kg)	50	100	50	100	10	50
Refrigerant price with carbon price ($/kg)	80	130	80	130	10	50
Total plant cost, refrigerant included ($/kW_e)	580	1108	67	87	558	1283
Electricity price ($/MWhr)	200	300	200	300	200	300
Capacity factor	0.25	0.25	0.25	0.25	0.20	0.25
Annual electricity costs, $/(kW_e.yr)	438	657	438	657	350	657
Leakage rate (%/yr)	0.0	0.3	0.0	0.3	0.0	0.3
Leakage cost ($/kW_e.yr)	0	32	0	26	0	10
FOM ($/kW_e.yr)	25	25	25	25	25	25
Total annual running cost $/(kW_e.yr)	463	714	463	708	375	692
Discount rate	0.05	0.10	0.05	0.10	0.05	0.10
Total NPV ($/kW_e)	**5306**	**6434**	**4806**	**5385**	**4447**	**6513**
2030						
Total plant cost ($/kW_e)	500	1000	0	0	500	1000
COP	3.0	2.5	3.0	2.5	3.0	2.5
Refrigerant price without carbon price ($/kg)	50	100	50	100	10	50
Refrigerant price with carbon price ($/kg)	115	165	115	165	10	50
Total plant cost, refrigerant included ($/kW_e)	615	1138	115	138	510	1042
Electricity price ($/MWhr)	250	350	250	350	250	350
Capacity factor	0.25	0.25	0.25	0.25	0.20	0.25
Annual electricity costs, $/(kW_e.yr)	548	767	548	767	438	767
Leakage rate (%/yr)	0.0	0.3	0.0	0.3	0.0	0.3
Leakage cost ($/kW_e.yr)	0	41	0	41	0	13
FOM ($/kW_e.yr)	25	25	25	25	25	25
Total annual running cost $/(kW_e.yr)	573	833	573	833	463	804
Discount rate	0.05	0.10	0.05	0.10	0.05	0.10
Total NPV ($/kW_e)	**6442**	**7334**	**5942**	**6334**	**5306**	**7115**

6.2.4 Improved cool room design and insulation

This is a small opportunity where the system is designed and installed properly. Where this is not the case, it is mainly an issue of improved design, and so is best addressed through the application of better industry standards rather than the introduction of new or enabling technology. Many cool rooms have "leakage" of cold air from badly bunded flooring, doors being opened for significant periods and poor seals. Repairing these deficiencies is one area where growers can make cost-saving changes for very little capital investment e.g. plastic blinds in doorways.

6.2.5 Summary of opportunities in improving refrigeration efficiencies

The main opportunity for improving refrigeration efficiency is the use of carbon dioxide as a refrigerant gas.

Switching from older refrigerants such as R134a to carbon dioxide based refrigeration plant may already be cost-effective and new CO_2 based refrigerant plants should become even more cost-effective in future.

The cost of replacing refrigerant leakage is a small part of both operating and total costs, and can also be minimised through regular maintenance. Refrigerant replacement plus O&M costs together account for roughly 10% of total costs. The main cost is electricity (more than 80%) and therefore electricity prices will continue to dominate the total cost of refrigeration.

6.2.6 Assumptions used in refrigeration analysis

- All plant is assumed to have a 15-year life, consistent with discussions with the growers.
- Total Plant Cost TPC ($/kW): This is the cost of building and commissioning the plant. These ranges are based on interviews with growers and industry specialists. In 2013, the CO_2 plant is at best 10% more expensive than the new R134a plant, and 25% more expensive at worst. All new plant has the same cost by 2030.
- Coefficient of Performance (COP): This is the refrigerating power per unit of electrical energy. These ranges are typical of these refrigeration plants[35]. In 2013, the new R134a plant has the highest COP, with the old R134a plant and the CO_2 plant having lower COPs The COP of the all plants is modelled as equal by 2030 given improvements in CO_2 compressor technology.
- Refrigerant price ($/kg): These are retail prices. It is emphasised that synthetic greenhouse gas refrigerant retail price rises due to imposition of the carbon tax are contentious amongst growers, and some suppliers of refrigerant have been accused of price gouging. The refrigerant retail pricing without carbon pricing is the author’s judgement of typical retail prices prior to this tax, based on interviews with growers and

[35] American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2013, “ASHRAE Handbook Online”, https://handbook.ashrae.org/, last accessed 19/04/2013.

industry specialists and also from the public literature[36]. The retail pricing with the carbon tax included is that obtained using the Federal Government's GWP and current carbon pricing[37]. The estimated prices for the CO_2 refrigerant are more uncertain. CO_2 is an industrial gas that is widely used in many industries at costs that are significantly lower than that stated. However, it is expected that refrigerant suppliers will charge a premium for several reasons. Fortunately, CO_2 replacement is a small part of the total operating costs, and so this assumption has little impact on the overall analysis.

- Electricity prices ($/MWhr): This range is based on interviews with growers and public information, and assumes price rises in 2030 relative to 2013.
- Capacity factor: The capacity factor is the average power consumed by the plant in a given year relative to its rated capacity. In this example, the refrigeration plant only runs about 20-25% of the year. This will be higher in other cases.
- Leakage rate (%/yr): Refrigerant leakage varies significantly amongst installed plant, and depends on many factors including plant age and maintenance scheduling. It is unlikely that any plant does not leak. The pessimistic limit of 30% per year is an upper bound, with 10-15% commonly seen in the literature[38 39].
- Operating and maintenance costs ($/kW$_e$yr): These include labour and equipment.
- The (real) discount rate (%): The discount rate is the product of the debt rate times the percentage of debt financing plus the equity return rate times the percentage of equity financing. The stated range assumes equal equity-financed and bank-financed new plant.

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[36] Victorian Farmers Federation, 2013, "VFF calls on ACCC to investigate refrigerant price hikes", http://www.vff.org.au/common_php/get_file.php?id=2155, last accessed 19/04/2013.
[37] Australian Federal Government – Department of Climate Change and Energy Efficiency, 2013, "AEMO 100% Renewables Study, http://www.climatechange.gov.au/government/initiatives/aemo-100-per-cent-renewables/aemo-scoping-document.aspx, last accessed 19/04/2013.
[38] American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2013, "ASHRAE Handbook Online", https://handbook.ashrae.org/, last accessed 19/04/2013.
[39] Intergovernmental Panel on Climate Change (IPCC), 2013, "Special Report: Safeguarding the Ozone Layer and the Global Climate System", www.ipcc.ch/pdf/special-reports/sroc/sroc_full.pdf, last accessed 19/04/2013.

6.3 On-farm Power generation from biogas

Anaerobic digestion of wastes is a process similar to that which occurs in the human gut. Organic materials are broken down, resulting in the production of solid wastes, liquid wastes, and gas. In this case the solid and liquid wastes are useful fertilisers, while the gas can be used for electricity generation.

To generate biogas, organic materials are macerated so that pieces are <5mm size, seeded with specific bacteria and warmed under anaerobic conditions in a large digester. As the bacteria need oxygen to survive, they source it from the organic materials. Suitable materials include carbohydrates, oils, sugars and natural fibre. This is referred to as the "volatile solid" (VS) component of the feedstock.

Digestion produces a range of breakdown products, including alcohols, organic acids and carbon dioxide. Specialized methanogenic bacteria then break down these compounds further, producing methane gas. Biogas generally contains about 50 – 60% methane, most of the remainder being CO_2. The biogas can be readily turned into electrical power using a generator. Heat produced by burning biogas can be used to continue heating the digester (**Figure 7**).

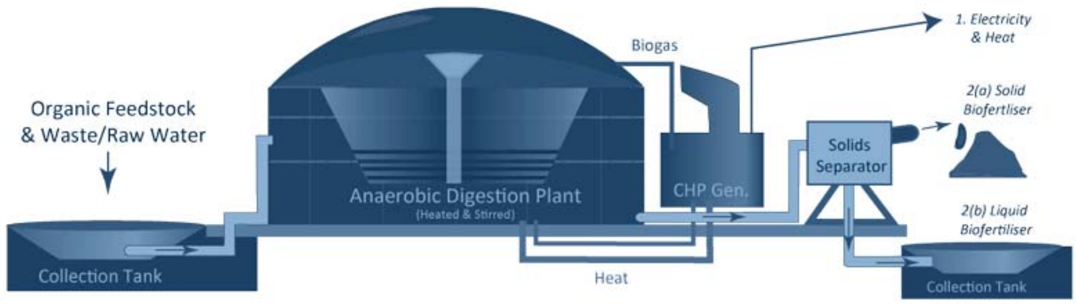

Figure 7 - Biogas generation plant (from Utilitas[40])

Biogas production technology originally grew from the need to dispose of municipal wastes, manure and sewage, so much of the published literature relates to these sources of organic material. However, as the technique not only stops organic wastes entering landfill but also generates electricity, it is increasingly used in agriculture. For example, there are already more than 6,500 biogas plants in Germany alone, the majority of which are medium sized, farm-based systems generating about 300kWh electricity per day. One reason for this is the

[40] Utilitas, 2013, http://www.utilitas.com.au/, last accessed 19/04/2013

high gas production possible when a range of different organic materials are added to the digester, including high nitrogen sources, preventing the mix becoming too acid[41].

6.3.1 Potential benefits of Biogas to vegetable growers

Vegetable wastes are particularly suitable for anaerobic digestion as they have high moisture contents (75-90%) and are extremely biodegradable[42]. Production of biogas is high (**Table 10**), being up to 7x more than that produced by pig or cow manure alone. Many studies have demonstrated that the technology is feasible. For example, a study of fruit and vegetable wastes from the Mexico City Central Market showed that 0.42m^3 biogas could be produced for each kg volatile solids (VS) (8-18% total weight) of vegetable waste supplemented with buffering salts and nitrogen[43]. Another study reported 0.58m^3 biogas production per kg VS from a mixture of carrots, beans and eggplant[44].

Table 10. Biogas potential of different crops[45]

Crop	Biogas (m^3/kgVS)	Methane content
Sugar beet	0.75	53
Fodder beet	0.78	53
Corn	0.61	52
Corn cobs and husks	0.67	53
Wheat	0.68	54
Grass	0.56	54

As well as gas, the process generates a mixture of solid and liquid waste referred to as biogas slurry. This can be diluted, supplemented with phosphorus, iron and other balancing

[41] Agdag Agdag, O.N., Sponza, D.T., 2005. Co-digestion of industrial sludge with municipal solid wastes in anaerobic simulated landfilling reactors. Process Biochem. 40:1871–1879.
[42] Bouallagui, H., Touhami, Y., Ben Cheikh, R., Hamdia, M. 2005. Bioreactor performance in anaerobic digestion of fruit and vegetable wastes: review. Process Biochemistry. 40:989–995
[43] Garcia-Pena, E.IU., Parameswaran, P., Kang, D.W., Canul-Chan, M., Krajmalnik-Brown, R. 2011. Anaerobic digestion and co-digestion processes of vegetable and fruit residues: process and microbial ecology. Bioresource Technology. 102:9447-9455.
[44] Sridevi, V.D., Srinivasan, S.V., Kayalvizhi, R., Bhuvaneswari, R. 2012. Studies on conversion of carbohydrate content in the mixture of vegetable wastes into biogas in a single stage anaerobic reactor. Research Journal Chemical Sciences. 2:66-71.
[45] Weiland, P. 2010. Biogas production: current state and perspectives. Applied Microbiology and Technology. 85:849-860.

nutrients, and used as part of a hydroponic solution[46]. It can also be used as a mulch or soil conditioner, or applied through fertigation. For example, application of biogas slurry with humic acid increased productivity of capsicums, tomatoes and cucumbers by 12%, 47% and 20% respectively[47]. As nutrients such as N, P and K are preserved during anaerobic digestion, the composition of solid and liquid outputs from the system will strongly reflect the feedstock materials.

Biogas generation was not previously considered viable in Australia due to the high price of the equipment required and the low cost of power. However, as electricity costs have risen so the price of anaerobic digestion equipment has decreased; it is now about one-fifth of the cost of several years ago.

6.3.2 Materials and equipment required

Anaerobic digestion systems vary in complexity; there are both single- and multiple-stage digesters and static and continuous processing system (**Figure 8**). They can also vary widely in scale; simple anaerobic digesters are widely promoted for use in the third world to provide light and heat for cooking, while others are multimillion dollar systems designed to process huge volumes of municipal waste. The main part of an anaerobic digestion system is basically a tank and pipes, with the more complex part involving how the gas is used.

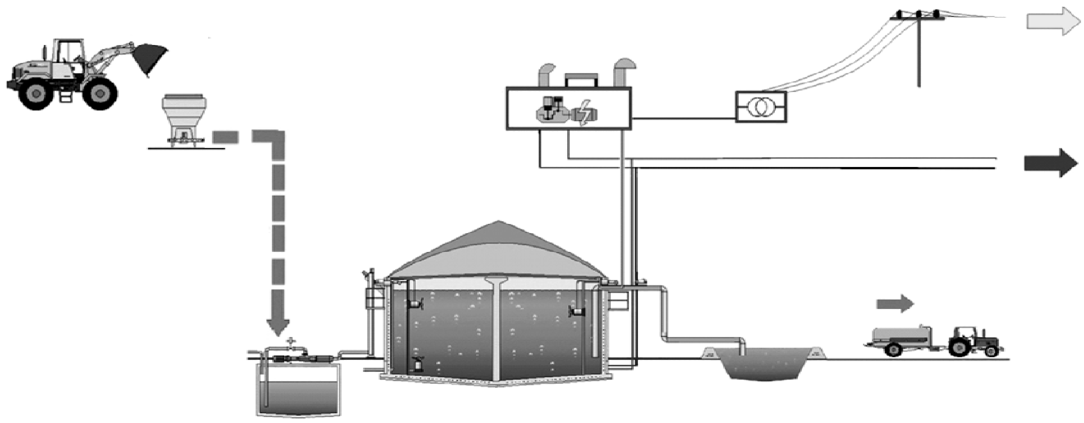

Figure 8 Continuous stirred reactor biogas plant.

The system also requires continual inputs of organic materials to function well. It is likely that the minimum size system would require at least 10t / day of raw materials, although it could be more if materials have a low VS content (lettuce, for example). Intake can also vary

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[46] WenKe, L., QiChang, Y., LianFeng, D., RuiFeng, C., WanLai, Z. 2011. Nutrient supplementation increased growth and nitrate concentration of lettuce cultivated hydroponically with biogas slurry. Acta Agriculturae Scandinavica. 61:391-394.
[47] TongGuo, G., Nan, C., WeiQun, L., BaoZhen, L., HongLi, Y. 2011. Agricultural Science and Technology. 12:567-570.

so as to increase during peak periods. While it is possible to shut down the system entirely (over winter, for example) it would then take some weeks lead-time to restore operation (J. Keskar, pers. com.).

Any aerobic digestion system needs to be designed to deal effectively with the quantity and type of feedstock that will be used. It should also be matched with the farms' energy demands. One useful characteristic of biogas is that it can be accumulated in storage and used when needed. For example, if electricity use is highest during the day due to packhouse / refrigeration requirements, then gas can be accumulated overnight and used to generate electricity to meet that demand. Moreover, it is possible to link the biogas generator with the refrigerant system used for coolstores so as to directly heat refrigerant materials and power compressors. Alternatively, biogas could be accumulated during the day and used to heat greenhouses overnight.

6.3.3 Economic viability of biogas generation

Electricity costs are generally presented as the "levelised cost of energy" (LCOE). The LCOE takes into account the initial capital required as well as the costs of continuous operation, fuel, and maintenance over the lifetime of the equipment.

The current average retail electricity prices at the farm gate are typically in the range of $200-300 / MWhr, with off-peak and peak rates usually about $150-350 / MWhr.

A reasonable average retail price for electricity is about $230 / MWh and can be compared directly with LCOE values.

The LCOE for biogas is currently $80 - $160 / MWh, with farm wastes at the lower end due to their suitability for this process. The actual cost depends on a range of factors, but for vegetable waste is usually at the lower end of this range. This cost includes the cost of capital and operation of the plant. This costing does not include placing any value on the solid digestate, which is high in nutrients and an excellent fertilizer.

Electricity from biogas compares favourably with the current average retail cost of electricity ($230 / MWh) and is slightly more than natural gas generation ($61 - $87 / MWh).

Despite the apparent competitiveness of biogas energy compared to conventional coal-fired power stations, electricity returned to the grid only earns $50 - $70 / MWh, below the cost of production. For this reason biogas is only likely to be economically viable if the energy produced is used on-site, rather than returned to the main grid.

The minimum size for a digester is a 100 kW system and this would need between 10-20t of vegetable waste per day to run. The exact amount depends on the nature of the organic waste, and this would need to be assessed.

The Company Utilitas, which designs and operates anaerobic digesters suitable for the vegetable industry, has produced an economic analysis of a 200 kW system, which could process around 40t vegetable waste per day. The capital costs would be $3.2 million and this system would produce electricity at an LCOE of $84 per MWh.

This investment would be recovered in approximately 4 years, or even less if the digestate produced has economic value (**Table 11**). This is consistent with results reported by Cascone *et al.*[48], who also suggested that the costs of establishing an anaerobic digester would be returned within 4 years. In that study, wastes from a 20Ha cherry tomato operation were used to generate 1,480 MWh per year, including both electrical and thermal energy.

Table 11. Indicative economics for a continuous 200 kW anaerobic digestion system suitable for a vegetable grower / processor (supplied by Utilitas)

Indicative economics for a 200 kW anaerobic digestion system	
Total project cost	$3,173,618
Vegetable waste treated	15,148 t/pa
Commodities produced annually	
Biogas	34,572 GJs
Electricity generated by biogas	4,055 MWh
Large generation certificates	4,055
Digestate (fertilizer or soil conditioner)	29,735 t
Costs and Revenues	
Annual operating cost (incl. 60,000 h engine overhaul)	$97,829
Annual savings on electricity costs (est. average cost of 21c/kWh)	$829,282
Potential value of digestate	$376,693
Internal Rate of Return	
No value on digestate	26%
Value on digestate	38%
Greenhouse gas emissions avoided	14,243 t
Cost of electricity (LCOE)	
Electricity produced by biomass generator	$84/MWh

It is estimated that a large vegetable farm would produce 30t / day waste during peak season, reducing to closer to 10t / day during winter. In addition, it may be possible for farms to link with other operations so as to add manures, abattoir wastes or other organic materials into the feedstock. Such additions have the potential to further improve the efficiency of the process and increase biogas production[43]. This suggests that an anaerobic digestion facility could be a viable option for many farms.

[48] Cascone, G. ; D'Emilio, A. ; Buccellato, E. ; Beccali, M. ; Trupia, S. 2008. Biogas and electrical power cogeneration through anaerobic digestion of vegetable residual from tomato greenhouse cultivation. Agricultural and biosystems engineering for a sustainable world. International Conference on Agricultural Engineering, Hersonissos, Crete, Greece, 23-25 June, 2008

6.4 Economic analysis of on-farm electricity generation options.

This section undertakes a net present value (NPV) analysis of specific electrical power generation technologies that are suitable for on-site power generation. The form of NPV analysis chosen is the so-called 'Levelised Cost of Electricity (LCOE)', which is the required average price of the electricity generated over the plant life such that the NPV sum of its cash flows is zero. The LCOE incorporates all of the costs involved in operating a plant, and can be compared to retail electricity prices at the farm gate. Assumptions used in the LCOE analysis are given on page 72. This analysis does not include biogas electricity generation since this has been addressed separately in section 6.3.3

6.4.1 Natural gas generation

This is proposed to be a natural gas fuelled electrical generator running on a reciprocating engine. Such technology is already in widespread production at capacities of 10kW to 1MW.

- Capacity factors: The optimistic and pessimistic capacity factors represent baseload and more intermittent generation (for example, balancing against an operating refrigerator), and so bracket those likely to be seen on-site.
- Thermal efficiency, total plant cost and FOM: These are estimates based on Parkside Energy's experience in this field.
- Fuel prices: Current natural gas prices for intermediate-scale users are bracketed by these optimistic and pessimistic values.

6.4.2 Liquefied petroleum gas (LPG) generation

This is proposed to be essentially the same technology as the natural gas fuelled electrical generator above, but now running on LPG. Again, such devices are already in widespread production.

- Capacity factors, thermal efficiency, total plant cost and FOM: These are as for the natural gas generation above.
- Fuel prices: LPG delivered to the farm gate is significantly more expensive than typical LPG prices in cities. The optimistic price of 30$/GJ is equal to roughly 75c/lt, which is 10-20c/lt higher than LPG typical prices in central Melbourne and Sydney. Some fuel suppliers appear to charge almost twice this for delivery.

6.4.3 Natural gas fuel-cell generation

A fuel cell is an electrochemical device that generates electricity directly from the oxidation of a fuel. In this modelled case, natural gas fuels a so-called 'solid oxide fuel cell' (SOFC). Uptake of SOFCs has been limited to niche applications to date.

- Capacity factors: These are as for the natural gas generation above.
- Efficiency, total plant cost and FOM: SOFCs are more efficient than internal combustion engines, such as that above, but they are also significantly more costly, far less tolerant of fuel impurities and generally less robust.
- Fuel prices: These are as for natural gas generation above.

6.4.4 Biomass generation

Biomass generation is assumed to be via the combustion of biomass material in the boiler of a steam turbine plant. This is a mature technology today, with several plants operating nationally.

- Capacity factors: These are equal to 80% for both the optimistic and pessimistic cases. This facility is therefore not intended to be intermittent and would therefore likely be located in a region with several fuel suppliers.
- Thermal efficiency: Steam turbine plants typically have lower thermal efficiency than internal combustion engines, with the ranges stated based on Parkside Energy's experience in this field and other, public studies[49 50].
- Total plant cost and FOM: These were based on recent Australian Federal Government literature[49].
- Fuel prices: The optimistic fuel price is modelled as zero for the case where the fuel is farm waste and the cost of gathering and preparing the fuel is small. The pessimistic limit is the same as the higher bound for natural gas, and higher but comparable to that presented in other, public studies[49 50].

[49] Australian Federal Government – Bureau of Resources and Energy Economics, 2012, "Australian Energy Technology Assessment, http://www.bree.gov.au/publications/aeta.html, last accessed 19/04/2013.
[50] Electric Power Research Institute (EPRI), 2012, "Program on Technology Innovation: Integrated Generation Technology options",http://www.epri.com

6.4.5 Wind turbines

Farms currently feature wind turbines of a wide range of sizes, with capacities of 10kW to 2MW not uncommon. The presented LCOEs in this study are assumed to represent turbines in the range 100kW to 2MW, which is expected to be the main growth market in future.

- Capacity factors: These vary significantly, with the 40% optimistic limit representing the best wind sites nationally[51]. The 10% pessimistic limit represents location at a poor site, which unfortunately is expected to be common for many, smaller, current installations.
- Total plant cost and FOM: These are based on estimates in other, public studies[49 50].

6.4.6 Solar photovoltaics (PV)

A current trend is the appearance of larger solar PV installations in both urban and rural settings, with installed capacities often in the range 100kW to MWs. This size range is considered plausible on-site for growers.

- Capacity factors: These vary significantly, depending on the site, with the stated ranges obtained from publically available studies[49 50].
- Total plant cost and FOM: These are based on estimates in other, public studies[49 50].

The current average retail electricity prices at the farm gate are typically in the range 200-300 $/MWhr, with off-peak and peak rates varying over approximately 150-350 $/MWhr.

6.4.7 Results of economic analysis of on-farm power generation

The analysis of the current financial situation shows that a natural gas fuelled generator would be consistently financially viable at current prices (Figure 9). (The current carbon price, which has been ignored in this report due to uncertainty in its future, only adds roughly 10-15 $/MWhr to this cost.) This option relies on a grid connection to natural gas and means that it would be feasible only for farms close to urban centres, including protected-cropping operations.

[51] Australian Federal Government – Department of Climate Change and Energy Efficiency, 2013, "AEMO 100% Renewables Study, http://www.climatechange.gov.au/government/initiatives/aemo-100-per-cent-renewables/aemo-scoping-document.aspx

Most growers do not have access to the gas network on-site, forcing them to use LPG or diesel for their on-site, engine-based power generation. As Figure 9 shows for LPG, these fuels are significantly more expensive, and so only appropriate for backup power.

The modelled 2030 scenario is markedly different. The modelled improvements in plant performance and plant cost now result in several technologies – natural gas, biomass and solar PV – becoming consistently financially viable even if average retail electricity prices remain in the range 200-300 $/MWhr. Wind may also be viable, depending mainly on the quality of the local wind resource and hence its capacity factor. (A price on carbon has again been ignored. This only affects the natural gas engine plant, the sole viable non-renewable plant, with the Federal Government's currently modelled 'core' 2030 carbon price of roughly 50 $/t$_{CO2}$ [52] only adding approximately 30 $/MWhr to the LCOE of this plant.)

Importantly, this analysis finds that several of these on-site power generation technologies may become viable without any form of incentive in the coming years. Such incentives currently include a price on carbon, renewable energy certificates (RECs) and feed-in-tariffs, all of which face an uncertain future as discussed above. Increases in retail electricity prices will further encourage their uptake. Overall, this analysis therefore presents a positive view of future, on-farm power generation options in Australia.

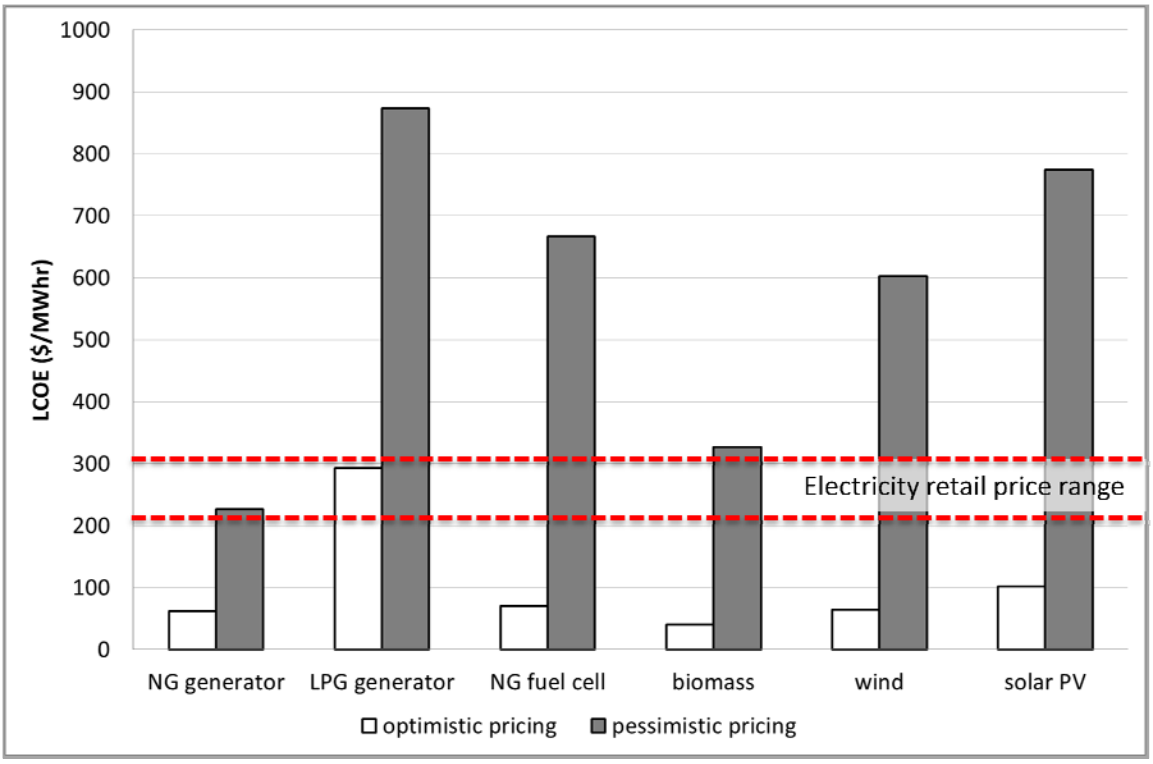

Figure 9: Estimated LCOEs ($/MWhr) for specific on-site technologies in 2013.

[52] Australian Federal Government – Treasury, 2013, "Modelling a carbon price, http://carbonpricemodelling.treasury.gov.au/carbonpricemodelling/content/update_report.asp, last accessed 19/04/2013

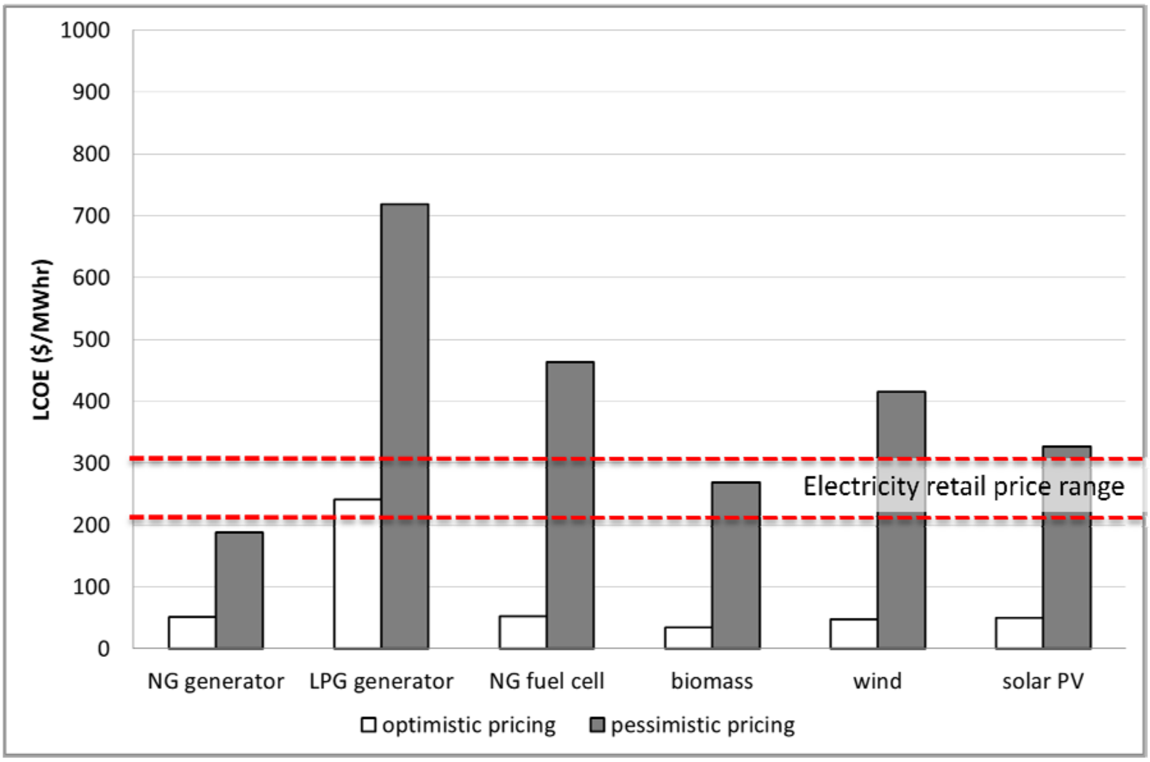

Figure 10: Estimated LCOEs ($/MWhr) for specific on-site technologies in 2030 (in 2013).

Table 12: Key inputs for the LCOE calculations in 2013 and 2030 (in 2013 $)

	capacity factor		thermal efficiency		total plant cost ($/kW)		FOM ($/kWyr)	fuel price ($/GJ)	
	opt.	pess.	opt.	pess.	opt.	pess.		opt.	pess.
2013									
NG generator	0.80	0.25	0.35	0.25	1000	1500	25	5	10
LPG generator	0.80	0.25	0.35	0.25	1000	1500	25	30	60
NG fuel cell	0.80	0.25	0.55	0.40	3000	10000	25	5	10
biomass	0.80	0.80	0.30	0.15	3000	6000	25	0	10
wind	0.40	0.10	n/a	n/a	2000	4000	50	0	0
solar PV	0.30	0.10	n/a	n/a	2500	5000	50	0	0
2030									
NG generator	0.80	0.25	0.43	0.31	820	1229	25	5	10
LPG generator	0.80	0.25	0.43	0.31	820	1229	25	30	60
NG fuel cell	0.80	0.25	0.67	0.49	2019	6730	25	5	10
biomass	0.80	0.80	0.37	0.18	2459	4917	25	0	10
wind	0.40	0.10	n/a	n/a	1346	2692	50	0	0
solar PV	0.30	0.10	n/a	n/a	942	1884	50	0	0

6.4.7.1 The following assumptions are used in this LCOE analysis:

- Total Plant Cost TPC ($/kW): This is the cost of building and commissioning the plant. It is accounted for as an initial lump sum in year 0. The TPC of all thermal plant is modelled to improve at 1% p.a. from 2013 to 2030, whilst TCPs of the fuel cell, wind and solar PV are modelled as improving at 2%, 2% and 5% p.a. respectively. These assumed learning rates result in 2030 LCOEs that are comparable to publically available studies, when the same inputs are used[53] [54].
- Efficiency: This is the electrical energy output per unit fuel energy. The efficiency of all thermal plant and the fuel cell is modelled to improve at 1% p.a. from 2013 to 2030.
- Operating and maintenance costs ($/MW): These include labour and equipment.
- Fuel costs ($/GJ): These span typical current ranges.
- Depreciation: We assume linear depreciation over the book life. The book life is also assumed to be equal to the debt life and plant life.
- The (real) discount rate (%): The discount rate is the product of the debt rate times the percentage of debt financing plus the equity return rate times the percentage of equity financing. This modelling assumes equal debt-to-equity financing, with the real equity and debt rates 2% higher and 2% lower respectively than the stated real discount rates.
- Capacity factor: The capacity factor is the average power generated by a plant in a given year relative to its rated capacity.
- Inflation: This was set at zero in this analysis to avoid distortion of many years of inflation.
- Income taxes: This was set at zero in this analysis since growers are unlikely in most cases to earn significant income from electrical power generation in the first instance, but rather offset their on-site electricity consumption.
- Incentive programmes: This analysis does not assume a carbon price, renewable energy certificates (RECs), feed-in-tariffs or any other incentive because of the significant uncertainty in their future. The current Opposition has pledged to end the carbon price should it be elected later this year. The issuing of RECs is currently scheduled to end in 2020. Feed-in-tariffs, particularly for solar PV, have been reduced significantly in all States in recent years.

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[53] Australian Federal Government – Bureau of Resources and Energy Economics, 2012, “Australian Energy Technology Assessment, http://www.bree.gov.au/publications/aeta.html, last accessed 19/04/2013.

[54] Electric Power Research Institute (EPRI), 2012, “Program on Technology Innovation: Integrated Generation Technology Options”, http://www.epri.com

6.4.8 Summary of opportunities for on-site power generation

Current option 1: Biogas power generation

The LCOE for Biogas is currently $80 - $160 / MWh, with farm wastes at the lower end due to their suitability for this process. The actual cost depends on a range of factors, but for vegetable waste is usually at the lower end of this range. This cost includes the costs of capital and operation of the plant. This costing does not include placing any value on the solid digestate, which is high in nutrients and an excellent fertilizer.

This compares favourably with the current average retail cost of electricity ($230 / MWh) and is slightly more than natural gas generation ($61 - $87 / MWh).

Returning electricity to the grid earns only $50 - $70 / MWh so biogas is likely to be economically viable only if the energy produced is used on-site. Gas can be stored for short periods, and the generator set to run only when required, reducing the need to feed electricity into the grid.

Biogas generation is a mature technology and has been used successfully in Europe for more than 30 years; there are 6500 plants operating in Germany alone. Recent increases in the cost of electricity mean that biogas generation is now viable.

A 200 kW system, which could process around 40t vegetable waste per day. The capital costs would be $3.2 million and this system would produce electricity at an LCOE of $84 per MWh.

The minimum size of system is a 100 kW plant, which requires between 10 and 20 t waste per year. A large vegetable farm would produce 30t / day waste during peak season, reducing to closer to 10t / day during the off-season. In addition, it may be possible for farms to link with other operations so as to add manures, abattoir wastes or other organic materials into the feedstock. Such additions have the potential to further improve the efficiency of the process and increase biogas production. This suggests that an anaerobic digestion facility could be a viable option for many vegetable farms.

Current option 2: Energy generation from natural gas

At current electricity prices of $200-300 / MWhr (average $230 / MWh) natural gas fuelled power generation is potentially feasible. Many growers do not have access to the gas network on site, forcing them to use the significantly more expensive LPG or diesel for backup power. However, this may be a viable option for protected-cropping operations, or farms located close to urban centres.

Future options (2030) for power generation

In the future, the modelled 2030 scenario is markedly different from the current situation. Improvements in plant performance and plant costs over the next 15-20 years mean that several technologies will become consistently financially viable even if average retail electricity prices remain in the range of 200-300 $/MWhr. These options include:

- Biogas electricity generation.
- Natural gas electricity generation.
- Biomass gas generation.
- Solar photovoltaic cells (PV).

Wind may also be viable, depending mainly on the quality of the local wind resource and hence its capacity factor.

Importantly, several of these on-site power generation technologies may become viable without any incentives. Such incentives currently include a price on carbon, renewable energy certificates (RECs) and feed-in-tariffs, all of which face an uncertain future. Overall, this analysis therefore presents a positive view of future, on-farm power generation options in Australia.

6.5 Energy audits

Energy audits are an excellent way of measuring farm energy use and potentially saving money on electricity bills. Audits are expensive, in the order of $10,000 for a detailed level 2 audit of a large-scale vegetable farm, but savings can be considerable, and the pay-back period is commonly about 1-2 years. In addition, there is funding assistance available. Applicable programs include:

- Low carbon Australia with loans or other financial assistance to upgrade key equipment, such as cool rooms and electric pumps, to increase energy efficiency (section 5.5.3).
- State-based programs – most States have grants available for making improvements in energy efficiency. Refer to section 5.6 for details.

A recent project that audited nine irrigation farms in Tasmania[55] made the following conclusions:

- Total energy bills (electricity + fuel) varied from $35,000 to $156,000 per year, with the average being just over $80,000 per year. Electricity bills accounted for an average 64% of the total energy bill or nearly $52,000 per year.
- Irrigation accounted for 70-80% of farm energy costs.
- The average energy index for irrigated areas was 1,268 kWh/ha ($216/ha).
- For those irrigation systems with flow meters installed, energy indices were calculated at between 200 kWh/ML and 500 kWh/ML, or about $35/ML to $85/ML. Variations depended on pump/irrigation sets efficiencies and the Total Dynamic Heads for those pumps.

Improving energy efficiency may be one of the fastest, cheapest and easiest ways to reduce farm energy expenditure and greenhouse gas emissions.

6.5.1 Types of energy audits

There are three main types of energy audits used for assessing farm energy use[56]. These are:

[55] Hydro Tasmania consulting
[56] Water and Energy audits: Development of a framework and tools for packing shed water and energy audits McHugh, A.D., Clarke, J. Erol, C. and Eberhard, J. National Centre for Engineering in Agriculture University of Southern Queensland (2010)

6.5.1.1 Energy Audit Method Level 1: Preliminary Audit (Overview of the Total Energy Consumption On-site, Whole Farm Approach)

This is the simplest and cheapest form of energy audit. A whole-of-farm approach is usually adopted. This involves collating all the energy use data from the farm, including the total fuel (diesel, petrol and other fuels) and the total electricity energy consumed. It is generally expected that these figures will be available from the farm receipts. The total energy uses are then divided by the total farm production to derive the energy insensitivities of the site. Usually no additional tools are required for this level of audit.

6.5.1.2 Energy Audit Method Level 2: Standard/General Audit (Itemised Farm Approach)

Level two energy audits generally involve breaking down the total energy usage on the farm into energy used in each farming operation. A level 2 will usually consist of a bowser and electricity meter-box type measurement for all processes, and with specific "spot" measurements for the key processes. It may also involve in-depth farmer interviews to identify the major energy usages.

6.5.1.3 Energy Audit Method Level 3: Detailed Audit (Specific Operation Investigation)

The aim of level three energy audits is to investigate ways to improve the efficiency of a specific operation. Typically, level 3 audits would focus where the greatest energy consumption has been identified from level 2. This will usually involve a range of different sensors to measure the performance of different machines. Examples of sensors used may include (irrigation head) pressure, flow rate, engine RPM, tractor travel speed, torque, load and temperature etc. A data logger may be required to record the data over a considerable period of time. A level 3 energy audit may be necessary to certify a product/farming operation and to establish the energy-star rating and labelling scheme.

6.5.2 Tools available to assist with energy audits

6.5.2.1 EnergyCalc

EnergyCalc was developed for cotton/grain production by the National Centre for Engineering in Agriculture, University of Southern Queensland (http://kmsi.nceaprd.usq.edu.au/). It is a software tool originally developed by NCEA to quantify operational/direct energy inputs on farm and to determine greenhouse gas emissions due to energy uses. EnergyCalc assesses direct on-farm energy use, costs and the greenhouse gas emissions (GHGs) associated with diesel, petrol, LPG and electricity consumption. EnergyCalc examines energy use across key processes within a production system and can be used to evaluate farming practices such as tillage, spraying, irrigation and post harvest. This enables both the total energy inputs and the energy usage of each production processes to be assessed. EnergyCalc has been used to identify opportunities to reduce operational energy inputs and associated greenhouse gas emissions in the cotton and grain industry. EnergyCalc can also be used by farmers to benchmark their performance with peer farmers and best practices in order to identify opportunities for reduced energy costs. The above softwares will be particularly useful in estimating energy use in level 2 energy audits.

6.5.2.2 Nursery industry energy calculator

The Australian nursery industry in collaboration with the University of Southern Qld has developed a renewable energy calculator. The tool is based on the EnergyCalc[57] tool.

The Renewable Energy Calculator is available online via the NGIA website[58] and is free. The tool was designed for use by the nursery industry but would also be useful for vegetable growers. The tool will help calculate the current energy load within a business and calculate the renewable energy required to offset the energy cost.

6.5.2.3 Energy Self Audit Tool – Hydro consulting Tasmania[59]

The energy efficiency self-audit tool is aimed at enabling farmers to conduct a basic energy audit of their farm, establish their historical energy use, develop energy use benchmarks, set energy-saving targets, and identify and implement energy-saving measures to meet those targets. It is in the form of a booklet that can be downloaded from http://www.farmpoint.tas.gov.au

[57] http://kmsi.nceaprd.usq.edu.au/
[58] Renewable Energy Calculator http://www.energycalc.ngi.org.au/
[59] Energy Self Audit Tool for Tasmanian Farmers. Hydro Tasmania Consulting.

6.6 Farm case studies

The following case studies help to illustrate typical vegetable farming operations in Australia, and how they might be able to improve their energy efficiencies.

6.6.1 Case study 1: Carrot packing shed, Queensland

A carrot-packing operation near Kalbar in the Fassifern valley was audited[60]. It is a medium size facility with average annual output of 5,500 tonnes of packaged carrots and a total throughput of 7,857t (30% rejects). The facility also has a limited graded beetroot (tonnage unknown) capability. This level 2 audit considered the main office, product receiving area, topping and bin loader, beetroot line, vegetable polisher and cooler, carrot-sizer and packing line, medium carrot line, baby carrot pack line, refrigeration and loading dock.

Postharvest carrot production is very intensive and consequently 46.3 kWh (364130 kWh/7857t) of rated energy was used per tonne of carrot. However, by comparison with other highly intensive industries such as cotton ginning at 53 kWh/bale (national average) it appears normal. Information from Tasmania indicated that carrot processing consumes 42 kilowatt hours (kWh) of energy per tonne of carrots washed, which was marginally less than that used at this site in Queensland. However, only 70% of carrot throughput was packaged and sent to market and therefore rated energy consumed per tonne of packaged carrot was 30% higher (66.2 kWh/t).

Suggested actions:

1. According to the power company's annual billing account, consumption was 78.8kWh/t of carrots packaged. There is justification to conduct a level 3 audit on selected motors in the main carrot packaging line, which should include the cooler and vegetable polisher.
2. Detailed monitoring of the power and energy of individual motors may reveal unacceptable load factors and may also determine if the power factor for the enterprise is acceptable (>0.85). However, considering energy consumption for total throughput of carrot is similar to other facilities the expense may not be warranted.

[60] Water and Energy audits: Development of a framework and tools for packing shed water and energy audits McHugh, A.D., Clarke, J. Erol, C. and Eberhard, J. National Centre for Engineering in Agriculture University of Southern Queensland (2010)

6.6.2 Case study 2: A 300-hectare vegetable farm, Victoria

This grower operates a 300-ha vegetable farm in Victoria, on which both leafy and non-leafy vegetables are produced. It is one of the larger operations in Australia. Overall, this grower is open to new investment and new ideas, and has a longer-term view of investment. However, he also emphasises the importance of focusing on the core business, in particular on not letting new technologies over-complicate operations. Key features of this farm are as follows.

2. *Operational*

- Year-round harvesting and loading to market.
- Does not have metered electricity consumption data on individual refrigeration and cooling plant, and therefore consumption data are only estimates.
- Contestable electricity contracts with peak and off-peak rates.

3. *Investment and financing*

- Finances new plant using equity, bank loans and leasing.
- Investment decision-making made in terms of total cost saving to operation over the longer term. A payback period of 10 years or more is acceptable.
- Often, investment is driven not by payback but by competition.
- Recognises that their being a relatively big operation allows them to finance investments that many could not make.

4. *Refrigeration and cooling systems*

- Has a range of refrigeration and cooling processes:
  - 2 hydrovac units for cooling all produce to 2-4^{o}C. The non-leafy vegetables are hydro cooled whilst the leafy vegetables are vacuum cooled.
  - 3 conventional cool rooms of different sizes with forced air and conventional refrigerants.
- All leafy produce goes through the vacuum cooler and then into the cool rooms for 24-48 hours prior to shipment.

5. *On-site power generation*

- On-site power generation is standby only, using a diesel generator. It is not large enough to power the entire facility in the event of a blackout.
- Has LPG delivered to power forklifts.
- Has previously considered wind but did not go ahead with it.

- Is currently looking at purchasing a larger diesel generator for standby and perhaps peak shaving.

6. *Waste resource availability*

- Does not have good data on this, since all produce is harvested and packed in the field with non-compliant produce left on the field and put back in the soil.
- The fraction of sowed units becoming non-compliant varies a lot. At the moment, up to 40% is non-compliant. Other times it is only 5%.

Suggested actions:

1. This grower would benefit from a level 3 energy audit to determine energy use by the various aspects of the farming and handling operation, and to identify opportunities to reduce power consumption.
2. This grower was not able to allocate his energy expenditure to the different uses, since there is no separate metering. This is a very common situation for vegetable farms, and why detailed audits are needed.
3. Apply for assistance under the Victorian Energy Efficiency Target, which has schemes tailored to reducing energy use from electric motors, refrigeration fans and commercial lighting.

6.6.3 Case study 3: Corn and brassicas grower, NSW

This grower operates a farm of 56ha in New South Wales, growing corn and cabbage. This grower has a more conservative approach to investment, but is still very interested in ways to reduce his total costs. Key features of this farm are as follows:

1. *Operational*

- Cabbage sowing begins in September and ends in February. Harvesting runs from January to June.
- All corn is sowed in a day in December and harvested 100 days later.
- The farm has contestable electricity contracts with peak and off-peak rates: off-peak 18c/kWhr; peak 32c/kWhr; and shoulder 28 c/kWhr.
- The grower estimates that he easily spends a total of $50K p.a. on energy for refrigeration, truck fuel, water pumps, tractors and forklifts. Roughly half of this is spent on diesel to transport produce to customers in Sydney. The costs of running refrigerators in the cool room are a few per cent of his total operating costs of roughly $10K, and just one cost of many.
- Water pumps are much bigger users of energy than cool rooms. These run a lot at night, and up to 14 hours per day at the hottest time of year.
- LPG is delivered for use in the forklifts at about 90c/lt with $100 per year bottle-hire.
- The grower thinks there is little point in changing energy retailers since they charge similarly.

2. *Investment and financing*

- Overall, this grower takes a relatively conservative approach to borrowings.
- Investment is financed using equity and bank loans but not leasing.
- Investment decision-making is made in terms of total cost saving over a 5-6 year period at most.
- Since staffing is his highest cost, investment in automation tends to have the best payback.

3. *Refrigeration and cooling systems*

- Corn is not refrigerated.
- The grower understands that cabbage won't vacuum-cool because it is too dense.
- Cabbage is cooled in a $280m^3$ cool room with $30hp_e$ of compressors running on standard refrigerants. These run for 12-18 hours overnight, roughly 5 days per week from 01/01 to 30/06 each year, with each cool down costing in the range of $50-100.

4. On-site power generation

- There is currently no power generation on-site.
- He was going to put solar on-site, but since the Government changed the rules it is no longer deemed worthwhile.
- A neighbour has a wind generator and is very disappointed with it. It is not producing the amount of energy that he was told it would.
- The grower is very interested in natural gas. The local town has a gas network but it does not extend to his property. Delivery therefore makes it as expensive as diesel.

5. Waste resource availability

- He does not have precise data on this because all non-compliant produce is left on the field.
- This year's yield for both crops is good, estimated at 90-95%. Generally corn is at this level, but yield for cabbage can go down to 80% or lower.
- Only a small proportion of waste does not get left on the field.

Suggested actions:

1. The annual energy cost of $50,000 would make an energy audit viable, with a payback period of 2 years feasible.
2. Apply for assistance under the NSW Energy Saver plan, which provides: a subsidised energy assessment; a personalised Energy Action Plan; coordination assistance of up to four hours, where required, to help implement energy-saving improvements; and help to access funding support for specific energy-efficiency upgrades through the NSW Energy Savings Scheme.

7 Conclusions

7.1 Government policy and regulation

Government policy and regulation

Federal Government policies and regulations in relation to climate change, while intended to have a positive effect on the nation's environmental performance, may at the same time represent a threat to the Australian vegetable industry. This review has identified the significant potential threats, as well as opportunities, that relate to the current regulatory framework.

The report has responded to the following questions on how the vegetable industry may be affected, both directly and indirectly, by the current regulations relating to climate change and its management:

1. Why are we managing greenhouse gas emissions?
2. How would a change in government impact the vegetable industry?
3. Why is a price being put on carbon and how will it be determined?
4. What are the vegetable industry's liabilities and opportunities?
5. Do I have to report my emissions?
6. How do I generate carbon credits?
7. How will the carbon price affect my input costs?

1. Why are we managing greenhouse gas emissions? Climate change is a significant long-term risk. It is prudent to start to reduce greenhouse emissions and begin to plan for the impacts of climate change when making strategic investment decisions. Because of the potential for severe impacts this needs to happen despite the uncertainties.

2. How would a change in government impact? There is currently bipartisan support for the 2020 greenhouse gas target and the voluntary involvement of the land-based sector, but disagreement on how to reduce emissions. There is bipartisan reliance on the land-based sector to deliver significant greenhouse gas abatement. The Coalition's current policy is built upon 'direct action', offering incentives for polluters to reduce their emissions by providing taxpayer funds from the existing tax base. There appears to be Coalition endorsement of the Carbon Farming Initiative, which was passed in a separate bill to other parts of the overall Clean Energy Future legislative package. However, in opposition the Coalition has committed to winding back other aspects of the carbon-pricing regime if brought to power at the next election. This removes the carbon price revenue for the Carbon Farming Initiative.

3. How is a price being put on carbon and how will it be determined? A carbon price has been created by the Federal Government's Clean Energy Act (2011). The price is initially fixed, but from 1 July 2015 the price will be set by the market. This price will be influenced by factors such as: Australia's targets, and hence the cap; linkages to international markets; the number of permits issued by the government; industries' efforts to reduce emissions; and the success of offset programs such as the Carbon Farming Initiative.

4. What are the vegetable industry's liabilities and opportunities? Vegetable growers have no liabilities under the emissions trading scheme. There are a number of opportunities to increase energy efficiency and create carbon credits (Section 3). Some up- and down-stream sectors of the vegetable industry do have liabilities and some of these costs may flow on to vegetable producers. These are:

- Electricity producers.
- Fertiliser suppliers: Incitec Pivot Ltd; Orica Ltd.
- Packaging companies: Amcor Packaging Pty Ltd; Visy Pulp and Paper Pty Ltd.
- Vegetable processing: Simplot Pty Ltd.

5. Do I have to report my emissions? Vegetable growers do not have to report emissions. Larger vegetable industry suppliers or processors may be required to report emissions. Overall industry emissions are estimated by the National Carbon Accounting System (NCAS) to produce Australia's National Greenhouse Accounts and reported internationally.

6. How do you generate carbon credits? Participation in the Carbon Farming Initiative is voluntary; landholders can choose whether or not to be involved. Credits can be generated by either storing carbon or reducing greenhouse gas emissions.

7. How will the carbon price affect my input costs? The main impact of the carbon price will be on the cost of electricity and after 2014, transport. The cost of on-farm fuel use, fertiliser and chemicals are not expected to increase due to the carbon price. What impact this has on grower profits will be determined by the ability to pass on these costs. Domestically this may be possible, but not in the international market.

No modelling has yet been undertaken specifically for the vegetable industry. However, for a range of horticultural enterprises, modelling has estimated costs to increase by 0.3-0.8%, over business-as-usual by 2015. This cost impact was assessed three years after the introduction of the carbon price and includes changes to the Fuel Tax Credits for heavy vehicles. It assumes that no management actions are taken to reduce the impacts.

The subsequent impact on profit will vary significantly between enterprises and industries. The modelling suggests that horticultural enterprises could see a reduction in profit of 0.2-1.0%. However, this assumes that costs cannot be passed on by the grower.

Immediate and longer-term impacts of government policy in general: Immediate impacts arise from the introduction of a carbon price under the Federal Government's Clean Energy Act (2011). While vegetable growers have no liabilities under the carbon price, nor do they have to report emissions, some up- and down-stream sectors of the vegetable industry may have liabilities.

In the medium-term there are limited opportunities for the vegetable industry to participate in the Carbon Farming Initiative and generate revenue from carbon storage and emission reduction activities. For this to occur, new approved methodologies are required. A number of funding programs administered by DAFF are identified, which could assist the vegetable industry to generate new revenue from carbon credits under the voluntary Carbon Farming Initiative.

One of the main uncertainties is political, both domestic and international. Within Australia there is currently bipartisan support for the 2020 greenhouse gas target and the voluntary involvement of the land-based sector. There is, however, significant disagreement on how to reduce emissions by the required 160 Mt CO_2-e per year. If international agreements are reached, the emissions reduction challenge increases up to 272 Mt CO_2-e per year.

7.2 Opportunities for the Vegetable Industry in Climate Change Related Grants and Funding

There is a significant level of funding available to the vegetable industry from national and state-based schemes. At least two growers in Australia, as well as a number of processing companies, have taken advantage of this funding.

The main funding programs are listed here and explained in detail in section 5 of this report:

- Renewable Energy Target – Small-scale Renewable Energy Scheme.
- Energy Efficiency Information grants.
- Clean Technology Food and Foundries Investment Program.
- Low Carbon Australia (NB will merge with the Clean Energy Finance Corporation, July 2013).
- State Energy Efficiency programs.
- Biodiversity Fund.
- Carbon Farming Initiative.
- Carbon Farming Futures.

For growers, six of these funding programs have been identified to increase energy efficiency, create carbon credits, or adapt to changes in the climate. For industry, six funding programs have been identified to increase energy efficiency, create carbon credits, or adapt to changes in the climate. For up- and down-stream sectors of the vegetable industry, three funding programs have been identified to increase energy efficiency.

7.3 Energy efficiency

Energy efficiency is one of those practices that should be adopted irrespective of your views on climate change. You will still be paying electricity and fuel bills so reducing costs wherever possible way makes good economic sense.

Energy efficiencies have been considered under three broad headings in this report:

1. Pumps and irrigation efficiencies.
2. Reducing cooling costs.
3. On-farm power generation.

The areas with the greatest potential to save money and reduce greenhouse gas emissions in each of these areas are:

Pumps and energy efficiencies: In general, the higher the operating pressure the more energy (cost) is required to run irrigation systems. Across some typical irrigation systems, energy usage ranged from as low as 45 KWh/ML up to 543 KWh/ML. In a Tasmanian example, an energy saving of 66% and a cost savings of $47.12/ML were obtained from moving from a high-pressure travelling gun to a low-pressure centre pivot, due to the reduction in the pressure required. However, the biggest advantage in changing irrigation systems may be in the improvement in crop management and resulting yields and quality. In a NSW example, switching to a low-pressure system saved $50/ha in pumping costs but also resulted in a 20% increase in yield and increases in product quality. Combined, these resulted in a net benefit of $565/ha.

The pump is the heart of the irrigation system; making sure it is the right pump for the job and that it is working properly can save energy costs. However, the gains to be had from optimising pumps are relatively small. Typical improvements in the efficiency of the pump reduce the daily energy use by about 20%. Typical improvements in the efficiency of the motor reduce the daily energy use by 5%.

As a general rule, pump efficiency should be greater than 70%; below this is poor. If you can achieve better than 80% this is excellent, with a maximum of 88% achievable in the field for an end-suction pump. Having a motor that runs as close as practical to full load can increase motor efficiencies by 2-5%.

Cooling: The main opportunity for improving refrigeration efficiency is the use of carbon dioxide as a refrigerant gas.

Switching from older refrigerants such as R134a to carbon dioxide (CO_2) based refrigeration plant may already be cost-effective, and new CO_2 based refrigerant plants should become even more cost-effective in future.

The cost of replacing leaked refrigerant is a small part of both operating and total costs, and can also be minimised through regular maintenance. Refrigerant replacement together with maintenance costs account for roughly 10% of total costs. The main cost is electricity (more than 80%) and therefore electricity prices will continue to dominate the total cost of refrigeration.

Carbon dioxide has been used as a refrigerant for decades, and has recently gained significant support in Europe from several different industries. There are a few examples of its use in Australia, but apparently none in the vegetable industry.

On-farm power generation: In the short term, on-farm generation of electricity from vegetable waste and generation of electricity from natural gas (suppled via the grid) are the only two economically viable alternatives to purchasing electricity from the grid. Power generation from vegetable waste can be viable if 10 t/day of organic waste is available and can produce electricity from a little as $84/MWh (LCOE range = $80-$160).

In the longer term, by 2030, biogas electricity generation, natural gas electricity generation, biomass gas generation, solar photovoltaic cells (PV) become economically viable with no subsidies or increases in electricity prices. Wind generation may also be viable, depending mainly on the quality of the local wind resource and hence its capacity factor.

Energy audits: Energy audits are an excellent way of measuring farm energy use and potentially saving money on electricity bills. Audits are expensive, in the order of $10,000 for an average farm, but savings can be considerable and the payback period is commonly about 1-2 years. In addition, there is funding assistance available. Programs that are applicable include:

- Low-carbon Australia with loans or other financial assistance to upgrade key equipment, such as cool-rooms and electric pumps, to increase energy efficiency.

State-based programs – most States have grants available for making improvements in energy efficiency. The Australian vegetable industry is in a strong position to deal effectively with climate change. The industry has excellent climate change credentials, is a low emitter of greenhouse gases on a productivity basis, and has one of the lowest carbon and water footprints of any food producer. Vegetable growers also have greater capacity to adapt to change than most other rural industries. The threats, however, are serious, and the industry should not be complacent. The viability of vegetable production can be affected either by the physical impacts of a changing climate as outlined in the companion report[61], or by government policies aimed at addressing climate issues.

[61] VG12041 Understanding and managing impacts of climate change and variability on vegetable industry productivity and profits.

8 Appendices

8.1 Appendix I. Details of the Relevant Legislation and Regulations for the Carbon Pricing Mechanism

To implement the carbon pricing mechanism the following legislation and regulations were required (All legislation is available on ComLaw):
Clean Energy Act 2011
National Greenhouse and Energy Reporting Act 2007
Clean Energy (Consequential Amendments) Act 2011
Climate Change Authority Act 2011
Regulations relevant to the Carbon Pricing Mechanism
Concise descriptions

8.1.1 Clean Energy Act 2011

The Clean Energy Act 2011 sets up the carbon pricing mechanism and provides for industry assistance programs, the Jobs and Competitiveness Program and the coal-fired electricity generation assistance package.

It also contains rules for who is covered by the carbon pricing mechanism, what sources of carbon pollution are included, the surrender of emissions units, caps on the amount of carbon pollution from 1 July 2015, international linking, monitoring, enforcement, and appeal and review provisions.

8.1.2 National Greenhouse and Energy Reporting Act 2007

The National Greenhouse and Energy Reporting Act 2007 (NGER Act) establishes the legislative framework for the NGER scheme, which is a national framework for reporting greenhouse gas emissions, greenhouse gas projects and energy consumption and production by corporations in Australia.

8.1.3 Clean Energy (Consequential Amendments) Act 2011

The Clean Energy (Consequential Amendments) Act 2011 makes amendments to other laws to ensure that the carbon pricing mechanism is integrated with existing regulatory schemes and processes, including the National Greenhouse and Energy Reporting (NGER) scheme, the Carbon Farming Initiative (CFI), the Australian National Registry of Emissions Units (ANREU), the regulation of financial services and competition and consumer laws.
A number of procedural Acts implement those aspects of the carbon pricing mechanism that require persons to pay money. These Acts are:
Clean Energy (Unit Shortfall Charge–General) Act 2011
Clean Energy (Unit Issue Charge–Fixed Charge) Act 2011
Clean Energy (Unit Issue Charge–Auctions) Act 2011
Clean Energy (Charges–Excise) Act 2011
Clean Energy (International Unit Surrender Charge) Act 2011

Ozone Protection and Synthetic Greenhouse Gas (Manufacture Levy) Amendment Act 2011
Ozone Protection and Synthetic Greenhouse Gas (Import Levy) Amendment Act 2011

8.1.4 Climate Change Authority Act 2011

The Climate Change Authority Act 2011 establishes the Climate Change Authority from July 2012. The Climate Change Authority is to conduct reviews under the:
Clean Energy Act 2011
Carbon Credits (Carbon Farming Initiative) Act 2011
National Greenhouse and Energy Reporting Act 2007, and
Renewable Energy (Electricity) Act 2000.

8.1.5 Regulations relevant to the Carbon Pricing Mechanism

The following regulations and legislative instruments are particularly relevant for the Carbon Pricing Mechanism:

8.1.5.1 Clean Energy Regulations 2011

These include a range of provisions necessary for the operation of the Carbon Pricing Mechanism, including details of the Jobs and Competitiveness Program and application requirements for a range of decisions under the Kyoto Protocol.

8.1.5.2 Australian National Registry of Emissions Units Regulations 2011

These include details of the operation of the Australian National Registry of Emissions Units as it applies to the Carbon Farming Initiative and the carbon pricing mechanism.

8.1.5.3 National Greenhouse and Energy Reporting Regulations 2008

8.2 Appendix II. Details of the Relevant Legislation and Regulations for National Greenhouse and Energy Reporting

The National Greenhouse and Energy Reporting Act 2007 (NGER Act 2007) establishes the legislative framework for the NGER scheme, which is a national framework for reporting greenhouse gas emissions, greenhouse gas projects and energy consumption and production by corporations in Australia.

Several legislative instruments sit under the NGER Act. The purpose of each of these legislative instruments is described below.

The National Greenhouse and Energy Reporting Regulations 2008 set out the details that allow compliance with, and administration of, the NGER Act. For example, the Regulations specify the information that must be provided in reports under the NGER Act and the way that provisions of the NGER Act must be applied. (Commenced 1 July 2008.)

The National Greenhouse and Energy Reporting (Measurement) Determination 2008 describes the methods that reporting entities must use to estimate their greenhouse gas emissions, energy production and energy consumption. (Commenced 1 July 2008.)

The National Greenhouse and Energy Reporting (Audit) Determination 2009 contains the requirements for preparing, conducting and reporting on greenhouse and energy audits. (Commenced 7 January 2010.)

The National Greenhouse and Energy Reporting (Auditor Registration) Instrument 2012 specifies the qualifications that an auditor must have to be registered under the NGER Act. (Commenced 31 Nov 2012.)

The NGER Act 2007 also supports the carbon pricing mechanism that was created by the Clean Energy Legislative Package. Entities that report for the purposes of the carbon pricing mechanism do so under the provisions of the NGER Act.

8.3 Appendix III. Details of the Relevant Legislation and Regulations for the Carbon Farming Initiative

Participants in the Carbon Farming Initiative must comply with their obligations under the following Acts and Regulations:

Carbon Credits (Carbon Farming Initiative) Act 2011 (the CFI Act)
Carbon Credits (Carbon Farming Initiative) Regulations 2011 (the CFI Regulations)
Criminal Code Act 1995, Schedule (the Criminal Code)
Australian National Registry of Emissions Units Act 2011
Australian National Registry of Emissions Units Regulations 2011
National Greenhouse and Energy Reporting Act 2007
National Greenhouse and Energy Reporting Regulations 2008

Participants are also bound by the rules set out in the relevant methodology determination for the project, as well as other relevant legislation such as the Corporations Act 2001 (Cth) which governs the handling of financial products in the market, including Australian carbon credit units.

The Clean Energy Regulator is responsible for monitoring and enforcement. The Clean Energy Regulator powers include:

- The power to require a person, by written notice, to provide information or documents, or to provide copies of documents where the Clean Energy Regulator reasonably believes that a person has information or a document relevant to the operation of the CFI Act or CFI Regulations.
- The power of inspectors to enter premises to determine whether the CFI Act, the CFI Regulations and related provisions of the Criminal Code have been complied with or to substantiate information provided under the CFI Act, CFI Regulations or related provisions of the Criminal Code. An inspector's powers include the ability to search, examine, take measurements, conduct tests and inspect and copy documents. However, an inspector can only enter premises with the consent of the occupier or under a monitoring warrant.
- The power to require a person to appoint a registered greenhouse and energy auditor to carry out an audit of a project proponent's compliance (or the compliance of a person who was a project proponent) with one or more aspects of the CFI Act, CFI Regulations or related provisions of the Criminal Code.

8.4 Appendix IV. Details of the Relevant Research Projects under DAFF's Climate Change Research Program

8.4.1 Carbon and sustainability—A demonstration on vegetable properties across Australia

Lead organisation

Horticulture Australia Limited

Consortium member organisations

Department of Primary Industries, Victoria

Queensland Department of Agriculture, Fisheries and Forestry (formerly Department of Employment, Economic Development and Innovation)

Growcom

Status

Completed project under the Climate Change Research Program

Objectives

This demonstration project focused on three key objectives to increase the understanding by the vegetable supply chain of the market requirements for greenhouse gas (GHG) emissions management and sustainable vegetable production, and to provide information for industry to be able to address these market requirements. These three objectives were to:

- Identify how soil carbon is an important part of the overall sustainability picture for the Australian vegetable industry.
- Understand GHG emissions and demonstrate their management in the vegetable supply and marketing chain.
- Develop information products for the vegetable farming community to help vegetable growers manage GHG emissions.

Location

Five demonstration sites were established on four vegetable production farms on the east coast of Australia. The four farms were located in the following regions:

- Melbourne (Boneo and Werribee), Victoria.
- Granite Belt, Queensland.
- Lockyer Valley, Queensland.

Key activities

This project used static sampling chambers to study greenhouse gas (GHG) emissions from various farming practices aimed at reducing emissions.

In Victoria three on-farm demonstration sites focused on the effect of fertiliser management on GHG emissions, productivity and profitability. Treatments included application rate, stabilised fertilisers (e.g. ENTEC® Nitrophoska, Alzon®, Perlka®), nitrification inhibitors and organic amendments (e.g. chicken manure). Treatments were applied to broccoli and lettuce crops on commercial farms over two years, where GHG emissions and crop yield were monitored.

Four trials were undertaken at Amiens in Queensland (Granite Belt) under overhead sprinklers on a Tenosol soil (Australian classification system). Experiments investigated the effect of controlled release fertilisers, stabilised fertilisers, fertigation, biochar, manure and minimum tillage on GHG emissions, yield and profitability. Crops included mini cos, celery and Chinese cabbage.

A fourth trial site was established on a heavy black soil at Forest Hill in the Lockyer Valley, Queensland. This site compared GHG emissions between standard urea (normal grower practice) and urea treated with a nitrification inhibitor.

The project also included desktop research and interviews with representatives from major retailers (Woolworths, Coles, and Metcash/IGA). This was done to build an understanding of the interests, directions and strategies of fresh produce retailers to help growers prepare for future requirements.

Findings/Conclusions

This project has demonstrated that nitrification inhibitors can effectively reduce nitrous oxide (N2O) emissions in vegetable crop production.

In Victoria, stabilised fertilisers containing nitrification inhibitors (e.g. ENTEC, Perlka®) reduced N2O emissions by up to 60 per cent. Importantly, stabilised fertilisers were shown to be cost effective as a result of improved nitrogen-use efficiency and yield in the vegetable crops trialled. In broccoli, the stabilised fertiliser gave yield increases of between 8 to 59 per cent above the standard fertiliser (no inhibitor).

Stabilised fertilisers were also found to bring about a small reduction in the carbon footprint of farms in Victoria due to improved nitrogen-use efficiency and a subsequent reduction in the number of fertiliser applications required. Trial results from Victoria indicated that at least one fertiliser application could be dropped without a reduction in yield. It was estimated that this saved more than $500/ha. Reduced fertiliser application rates for crop production also led to further reductions in N2O emissions.

Results from the trials in Queensland showed that nitrification inhibitors are able to significantly reduce N2O emissions under a range of crops.

The potential of a nitrification inhibitor to reduce N2O emissions was heavily dependent on the inhibitor/fertiliser combination, soil type, crop grown, and whether organic amendments were also added to the production system.

The application of manure produced up to 20 times more N2O than inorganic fertilisers. Trials conducted in Victoria demonstrated that nitrification inhibitors applied to manure can reduce the average N2O emission flux by up to 60 per cent when the manure is incorporated into soil, and up to 16 per cent when the manure is left on the surface.

Chicken manures treated with nitrification inhibitors led to substantial increases in yield and profitability compared to the standard grower practice.

Related projects funded under Round 1 of Filling the Research Gap
N/A

Publications
A peer-reviewed paper is currently being finalised for submission. Facts sheets have been produced and are being reviewed by the Department of Agriculture, Fisheries and Forestry. The fact sheets will be available on a website currently being developed.

Further publications detailing the results of this research are in preparation and will be available.

8.4.2 Demonstrating the minimisation of methane and nitrous oxide emissions from food processing by-products by implementing best-practice management of organic residues

Lead organisation

Gelita Australia

Consortium member organisations

New South Wales Sugar Cooperative

d'Arenberg Wines

SITA Environmental Solutions

Objectives

- Determine greenhouse gas (GHG) emissions methane [CH4] and nitrous oxide [N2O]) from food processing residues with different characteristics (moisture, nitrogen, carbon, bulk density) when stockpiled or composted in turned windrows or aerated piles.
- Demonstrate and promote the minimisation of methane and nitrous oxide emissions by implementing best-practice management of organic food processing residues.
- Determine agronomic and environmental (GHG emissions) effects of applying raw and composted mill mud to land.

Location

Beaudesert and Ipswich, Queensland

Broadwater, New South Wales

McLaren Vale, South Australia

Key activities

- The project measured the GHG emissions from stockpiling and composting of organic residues generated during wine making, sugar milling, gelatine manufacturing, fruit and vegetable processing and beef packaging (abattoirs). All materials were composted in turned windrows and aerated piles, and GHG emissions were measured during 4- to 13-week monitoring periods.
- A simplified life cycle assessment was used to compare the overall environmental performance of compost made from turned windrows or aerated piles.
- The effect on GHG emissions from using raw and composted mill mud as a soil amendment on both loam and clay soils was assessed in field and laboratory incubation trials.

Findings/Conclusions

A valid comparison between composting and stockpiling needs to account for the entire period needed for each material to reach the same level of stability, and/or the point at which it can be safely and beneficially used for land management purposes.
Some methane emission factors determined with flux chambers exceeded the likely future Australian default emission factor for composting (16 kg CO_2-e/t wet input), while nitrous oxide emissions were low, did not exceed the expected future default value for nitrous oxide (30 kg CO_2-e/t wet input) and ensured also that combined values (CH_4 + N_2O) did not exceed likely future default emission factors. However, measurements with a large gas-capturing tent (flow-through wind tunnel) suggested that flux chamber measurements might underestimate emissions.

Use of a handheld methane detector showed promise for estimating methane emissions. Hence, it might be an operational tool for managing composting operations and reducing GHG emissions as methane represented more than 90 per cent of GHG emissions in most cases.

Stockpiled mill mud and grape marc showed low CH_4 + N_2O emissions, while CH_4 + N_2O emissions from stockpiled paunch and wastewater sludge were high. Emissions per tonne of wet feedstock as carbon dioxide equivalent (CO_2-e) were:

- Stockpiled mill mud: CH_4 0.05 kg and N_2O 0.0 kg (11 weeks).
- Stockpiled grape marc (fresh/old): CH_4 0.07/1.31 kg and N_2O 0.3/0.01 kg (13 weeks).
- Stockpiled paunch: CH_4 11.04 kg and N_2O 1.16 kg (10 weeks).
- Stockpiled wastewater sludge: CH_4 19.98 kg and N_2O 7.16 kg (8 weeks).

As stockpiled mill mud showed low GHG emissions, composting did not yield emission reductions. However, use of composted mill mud increased dry matter yield of silage corn significantly over yields achieved with raw mill mud. Both composted mill mud and raw mill mud have the capacity to increase methane emissions and reduce nitrous oxide emissions when applied to soil, but effects vary with soil type and moisture levels.

Use of aerated piles rather than turned windrows for composting reduced emissions markedly when composting paunch (62 per cent) and gelatine manufacturing residues. However, the use of aerated piles rather than turned windrows increased emissions when mill mud and corn residues were composted. Stockpiling of partially composted material (4 to 6 weeks) resulted in significant methane emissions over a 150-day storage period.

Composting of wastewater sludge from gelatine manufacturing (mixed with other materials) can reduce GHG emissions significantly compared to stockpiling, while that was not demonstrated for paunch in the given time frame.

Elevated GHG emissions from composting are primarily due to inappropriate composting conditions and process management. The best way of minimising GHG emissions from composting of food processing residues is to establish operational standards that represent 'good composting practices'. They not only help in minimising GHG emissions but they also ensure appropriate feedstock mixes, low odour and leachate, swift decomposition and high quality compost products.

Related projects funded under Round 1 of Filling the Research Gap

- Trialling compost and biochar amendments to North Queensland tropical agricultural soils—James Cook University. Funding of $1,000,000 ex GST.
- Assessing the carbon sequestration potential of organic soil amendments—CSIRO. Funding of $802,797 ex GST.

8.4.3 Soil organic carbon balances in Tasmanian agricultural systems

Lead organisation Tasmanian Institute of Agriculture

Consortium member organisations

N/A

Objectives

- Determine current stocks of soil organic carbon in different soil types on agricultural land used for pasture and cropping.
- Contribute data about soil organic carbon in Tasmania to the national Soil Carbon Research Program (SCRP) project in order to calibrate a more economical and efficient method of measuring soil organic carbon using mid infrared (MIR) spectroscopy.

Location Major agricultural zones of Tasmania

Key activities

There were two components of this study.

Component one involved investigating organic carbon levels in a range of soil types throughout the State. The samples came from four key soil groups: dark, cracking clay soils (Vertosols), brown, well structured soils (Dermosols), reddish brown, iron oxide rich soils (Ferrosols) and strong texture contrast soils (Chromosols/Sodosols/ Kurosols). For each soil order/group the samples were further split into two land uses, cropping and pasture. For each of these land uses, 10-year land management records such as tillage, fertiliser application, crop type, periods of fallow etc were collected to determine impacts on soil carbon levels. Environmental data such as total and timing of rainfall, temperature, altitude and aspect were included in the monitoring.

Component two involved 25 long-term (13 years) field sites on red Ferrosols in northern Tasmania, which were re-sampled. This sampling contributed to a long-term study initiated by TIA-UTAS in 1997 and re-sampled in 2005 and 2010. The purpose of this study was to determine not only the change in total organic carbon (TOC) levels in pasture and cropping sites but also which carbon pools (either particulate organic carbon and/or humic carbon) are most affected by land use.

Findings/Conclusions

Soil order, rainfall and land use were all strong explanatory variables for differences in TOC, total nitrogen (TN) and bulk density (BD) in Tasmania. Cropping sites had 29–36 per cent less carbon in surface soils than pasture sites, and they also had 2–16 per cent greater bulk densities. The difference between cropping and pasture was most pronounced in the top 0.1 m. Clay rich soils (Ferrosols and Vertosols) contained the greatest carbon stocks.

Land management effects on soil carbon were minor when compared to soil order, rainfall and land use. The number of years cropped and the number of years of conventional tillage had the most effect on soil carbon, i.e. both decreased soil carbon.

The long-term field trial component of the project, conducted on Ferrosols in the north of Tasmania showed that:

- Total organic carbon decreased with increasing years of cultivation. However, between 1997 and 2010, soil carbon levels did not decrease, nor did the ratio between carbon pools change, suggesting that, after many previous years of agricultural management, equilibrium may have been reached.
- Sites that had been used predominantly for pasture had higher organic carbon levels than cropped sites.
- Carbon associated with two soil particle size fractions (particulate organic matter and humus), which play different roles in the soil, was uniformly affected by land use.

Related projects funded under Round 1 of Filling the Research Gap

- Researching the effectiveness of farm management practices in eastern Australia to increase soil carbon—Department of Primary Industries, Victoria. Funding of $2,782,312 ex GST.

Publications

1. Parry-Jones, J 2010, ‘The effect of agricultural land use on the soil carbon fractions of Red Ferrosols in North West Tasmania’, Honours thesis, School of Agricultural Science, University of Tasmania.

2. Parry-Jones, J, Oliver, G, White, E, Doyle, R, Cotching, B & Sparrow, L 2011, ‘The effect of agricultural land use on the soil carbon fractions of Red Ferrosols in North West Tasmania’, poster presented at the Climate Change Research Program for Primary Industries Conference, Melbourne, 15-17 February.

3. Scandrett, J, Oliver, G, Doyle, R & White, E 2010, ‘Agricultural land use and soil carbon in Tasmania’, poster presented at the 19th World Congress of Soil Science, Brisbane, 1-6 August.

4. Sparrow, L, Cotching, W, Parry-Jones, J, Oliver, G, White, E & Doyle, R 2011, ‘Changes in carbon and soil fertility in agricultural soils in Tasmania, Australia’, paper presented at the 12th International Symposium on Soil and Plant Analysis, Crete, June.

8.4.4 Mitigation of indirect greenhouse gases in intensive agricultural production systems with the use of inhibitors

Status

Current project under the Filling the Research Gaps Program

Background

Expanding on PICCC's earlier enhanced efficiency fertiliser study, this project will examine the use of nitrogen fertilisers amended with urease and nitrification inhibitors to mitigate indirect nitrous oxide emissions through ammonia volatilisation and nitrate leaching in high nitrogen input systems.

Up to 48% of applied urea is lost through ammonia volatilisation, and studies conducted in Australia have shown that urease inhibitors may reduce this loss enough to make their use economically viable. High nitrogen input systems such as dairy and vegetable farms have the greatest potential for reduction of ammonia from applied nitrogen fertilisers.

Researchers are aiming to provide verification data to increase the confidence in modelling ammonia volatilisation and nitrate leaching in conventional and inhibitor fertiliser treatments.

Collaborations with research teams at DPI Victoria and Queensland University of Technology studying nitrogen emissions from temperate and sub-tropical pastures and vegetable systems will allow measurement of inhibitor fertiliser effects on nitrous oxide loss and plant productivity.

Project outline

Researchers will measure changes in ammonia volatilisation and nitrate production (using labelled fertiliser) resulting from the application of:

an urease inhibitor (Agrotain) - used to reduce ammonia emissions;
a nitrification inhibitor (3,4-dimethylpyrazole phosphate [DMPP]) used to reduce nitrous oxide emissions but which can increase ammonia volatilisation;
manures, which are increasingly being applied in vegetable production and are potentially a large source of ammonia volatilisation.

Objectives

Quantify mitigation of ammonia volatilisation from nitrogen fertilisers in intensive agricultural production systems (dairy, vegetables) resulting from use of inhibitors.
Obtain a nitrogen mass balance through the use of 15N-labelled fertilisers and through collaborative field sites run by DPI Victoria and Queensland University of Technology.

Provide data to improve the capability of nitrogen models to simulate ammonia volatilisation.

Micrometeorological techniques will be used to measure ammonia volatilisation. The data on the potential mitigation of ammonia volatilisation by inhibitors, and nitrogen mass balance are essential for establishing methodologies to reduce indirect nitrous oxide emission.

8.4.5 Relocation of intensive crop production systems to northern Australia: Costs and opportunities

Lead Organisation

Queensland Department of Agriculture, Fisheries and Forestry (formerly Queensland Department of Employment, Economic Development and Innovation)

Consortium member organisations

University of Southern Queensland

Objectives

- Use crop, farm and regional modelling to investigate the projected effect of climate change and water policy on the relocation of tomato, cotton and rice systems to the Burdekin.
- Analyse options for processing tomatoes, cotton and rice in northern Australia and provide relevant local and regional information with regards to the increased risks and the opportunities arising from climate change.
- Provide advice on effective government policy that would support the sustainable growth of Australian primary industries by:
  1. increasing the preparedness of farmers from vulnerable regions to mitigate impacts; and
  2. identifying opportunities from expected changes in climate.

Location

Field trials: Burdekin region at Bowen (Queensland)

Regions of interest: Darling Downs (Queensland), Riverina (New South Wales) and Shepparton (Victoria)

Key activities

This project used modelling to analyse possible scenarios.

Processing tomatoes case study:

Climatic analyses and the Decision Support System for Agrotechnology (DSSAT) biophysical model were used to compare future risks to tomato production in northern Victoria and northern Queensland. The length of the production season and levels of tomato growth and production were analysed.

Cotton case study:

Biophysical and economic models (CGE model) were used to explore the impact of climate change on cotton yields and profits in southern Queensland and the Burdekin. This project used the Agricultural Production Systems Simulator (APSIM) cotton model OzCot and collected industry data (e.g. production, water use and alternative cropping systems).

Rice case study:

The Tasman Global computable general equilibrium (CGE) model was used to analyse three possible scenarios of relocating rice production from the Riverina to the Burdekin:

1. Rice grown using the fallow period between sugarcane plantings.
2. Rice displacing sugar cane.
3. Rice grown on additional land.

Findings/Conclusions

To adapt to changes in climate and reduced availability of irrigation water, businesses and growers in southern Australia, northern New South Wales and southern Queensland may consider relocating their businesses to northern Australia. Some results from this project showed that if industries are to remain in their existing location/s the following things may occur:

- Rice production may remain more profitable than in northern Queensland as yields in the north will be lower.
- Projected increased temperatures and lower rainfall in southern Queensland may cause declines in cotton production.
- Processing tomato production may be affected because there may be a risk of decreased season length or a break in the season.
- Irrigated cropping industries may need to, or continue to, diversify under climate change as there will most likely be lower water availability.

If industries are to relocate to northern Queensland the following things may need to occur:

- Based on limited agronomic and financial data, rice production in the Burdekin area could be profitable depending on land and water values.
- Rice production may be less profitable than in the existing locations because of lower yields, however, access to water is more secure in the north.
- Rice and cotton are more likely to be grown as complementary crops between sugarcane plantings rather than be the dominant crop because of the higher value of sugar cane.
- Significant investment in processing infrastructure will need to occur.

Overall, this project provides evidence to indicate that movement of processing tomatoes, rice and cotton industries to northern Australia is unlikely to occur rapidly or easily.

Some barriers to moving to northern Queensland include lack of suitable varieties, lack of infrastructure, transport costs, pest and diseases, local reactions to land use change and difficulty attracting new farmers. Also support in terms of infrastructure for processing the product e.g. milling and ginning are critical, but it is also important not to overlook the need for research into agronomic practices that assist in reducing risk to the grower.

Related projects funded under Round 1 of Filling the Research Gap
N/A

Publications

1. Mushtaq, S, Cockfield, G, White, N & Jakeman, G 2012, ‘Climate and environmental risk management through structural adjustment and regional relocation: a case of rice industry in Australia’, 1st National Symposium and Workshop on Environmental Science, University of the Philippines, Quezon City, Manilla, 7-8 May.
2. Mushtaq, S, Cockfield, G, White, N, & Jakeman, G 2012, ‘Plausible futures for regional development and structural adjustment under climate change: A case of the rice industry in Australia’, Practical responses to climate change National Conference, Canberra, May.

8.5 Appendix V. Details of the Relevant Action on the Ground Projects

8.5.1 Best management practices of carbon management on Northern Rivers farms – Northern Rivers Catchment Management Authority

Funding up to: $548,000 ex GST.

The project is trialling and demonstrating multiple practices in the Northern Rivers area of New South Wales, across a suite of farming systems – dairy, beef and horticulture – to increase soil carbon sequestration and reduce on–farm greenhouse gas emissions.

8.5.2 Increased nitrogen use efficiency by cropping farmers in South Victoria and Tasmania – Southern Farming Systems Limited

Funding up to: $540,909 ex GST.

The project will trial and demonstrate practices to reduce nitrous oxide emissions by improved fertiliser management for cropping systems in the high rainfall zones of Victoria and Tasmania.

8.5.3 Horticulture: taking action to capture carbon and reduce nitrous oxide emissions – Applied Horticulture Research Pty Ltd

Funding up to: $394,000 ex GST.

The project is trialling minimum tillage practices, including controlled traffic and use of mulches, to reduce nitrous oxide emissions and increase sequestration of soil carbon during the production of vegetable crops in New South Wales.

8.5.4 Improving soil fertiliser irrigation management for South East Queensland Ginger Production – Queensland Government Department of Agriculture, Fisheries and Forestry

Funding up to: $482,436 ex GST.

The project is trialling and demonstrating improved nitrous fertiliser management practices in combination with legume cover crops to reduce nitrous oxide emissions and increase sequestration of soil carbon in association with cultivation of ginger in South East Queensland.

8.5.5 Nitrous oxide emissions from irrigated cropping – Victorian Irrigated Cropping Council Incorporated

Funding up to: $187,500 ex GST.

The project is trialling and demonstrating practices to reduce nitrous oxide emissions by improved management of nitrous fertiliser applications in association with irrigated cropping in the Northern Victorian and Southern New South Wales irrigation districts.

8.5.6 Improved fertiliser and soil management in South East Queensland intensive horticulture – Queensland Government Department of Agriculture, Fisheries and Forestry

Funding up to: $517,273 ex GST.

The project is trialling and demonstrating reduced tillage practices, use of legume fallow crops and soil organic amendments to reduce nitrous oxide emissions and increase sequestration of soil carbon in association with the production of strawberries and pineapples in Queensland.

8.6 Appendix VI. Details of the three components of the Extension and Outreach program

8.6.1 Component 1: Information, tools and extension activities

The purpose of Component 1 is to develop information and tools to increase awareness and build capacity and capabilities of farmers, land managers and key influencers in emissions management and the CFI. It is intended that the information and tools developed in Component 1 will contribute to the resources available to farmers and land managers and also to any extension providers, including those engaged through Components 2 and 3.

Component 1 activities are expected to be innovative and to be delivered in the earlier stages of the Extension and Outreach Program. They will fill recognised gaps and/or build on existing carbon farming extension products or activities, focusing on the initial information needs of farmers and land managers. They may also use existing organisational structures to minimise lead time.

Priorities for Component 1: Information, tools and extension activities

1.1 Information and awareness to encourage farmers and land managers to become involved in managing greenhouse gas emissions and the CFI, focussing on:

- Opportunities and benefits from reducing emissions and integrating emissions management into day-to-day business decisions.
- Opportunities and benefits of participating in the CFI.

1.2 Activities and products to increase farmers', land managers' and key influencers' understanding of scientifically-proven emissions reduction and carbon sequestration technologies and practices, and participation in the CFI.

1.3 Develop practical tools for delivering information specific to the requirements of the Extension and Outreach Program.

Project activities to address Component 1 priorities may include but are not limited to:

- Producing and publishing booklets, pamphlets, newsletters, DVDs and web and email-based products.
- Producing decision support tools and calculators.
- Hosting workshops, seminars, conferences, tours of demonstration sites and networking events.
- Convening webinars and maintaining a social media presence on opportunities for farmers and land managers to engage.

- Convening forums to encourage rural communities to share knowledge and discuss approaches to respond to greenhouse gas emissions.
- Maintaining, expanding or creating new communication delivery channels—for example carbon farming web portals, social media and professional networks that increase awareness and build capacity and capabilities of farmers, land managers and key influencers in emissions management and the CFI.

The funding for this component is nominally up to $5 million with most of the activities completed by June 2015.

8.6.2 Component 2: Extension providers and service delivery

The purpose of Component 2 is to provide information on greenhouse gas emissions management and participation in the CFI that is accurate, scientifically sound, clear, consistent and current. This will be delivered through long-term extension services and communication between extension providers and farmers, land managers and their key influencers. An essential part of Component 2 will be one-to-one extension services.

Priorities for Component 2: Extension providers and service delivery

- Up-skill and build resources and manpower at local and regional levels to deliver scientifically-sound information on emissions management and opportunities to participate in the CFI.
- Deliver extension services to farmers and land managers using multiple communication approaches.
- Up-skill key influencers to enable them to further extend key knowledge to farmers and land managers.
- Create an on-going legacy whereby farmers and land managers can access information and support after the project has ended.

It is anticipated that extension providers will:

- Become industry and/or regional experts for farmers and land managers on the CFI and land sector emissions reduction and carbon sequestration practices. This includes:
    - understanding the CFI legislation and staying up-to-date with the associated regulations.
    - having a broad knowledge of all and new CFI offset methodologies, particularly those relevant to their industry or region.
    - interpreting research and development results and using/promoting demonstration sites (particularly from the Climate Change Research,

Filling the Research Gap, Action on the Ground, and Biochar Capacity Building programs).
    - knowing the CFI application and reporting processes and how crediting works.
    - being aware of and building connections with regional or industry experts, carbon service providers (e.g. aggregators and carbon traders) and other extension providers.
- Increase the level of awareness, understanding and adoption among farmers and land managers about what they can do to reduce greenhouse gas emissions and respond to climate risks and opportunities. This includes:
    - supporting farmers and land managers to integrate emissions management and the CFI into whole-of-farm management, including integrating these activities with sustainable agricultural practices, production efficiency, resource-use efficiency, financial planning and biodiversity protection.
    - using traditional and novel delivery mechanisms to extend information, knowledge and experience to farmers, land managers, key influencers and the broader community about emissions management and the CFI.
    - tailoring and delivering information, communications products and decision support tools to provide support to their region or industry.
    - encouraging participation in the CFI in their industry or region.
- Engage with key influencers within their industry or region and share information and knowledge with them so that they in turn operate as 'extension multipliers' to provide clear and accurate extension services to their clients.

Within a project under Component 2, there may be an initial emphasis on up-skilling extension providers, establishing mechanisms to augment existing extension capabilities or activities, and raising the profile of the project. However, it is expected that activities will move swiftly to the main phase of service delivery, which is the transfer of information by extension providers to farmers, land managers and key influencers.

Project activities to address Component 2 priorities may include but are not limited to:

- Multiple communication approaches to deliver technical information and support to farmers, land managers and key influencers including on-farm one-to-one contact, responding to inquiries, workshops, written materials, attending field days and web/social media activities.
- Creating relevant technical information, materials and tools for farmers, land managers and key influencers to use directly, as well as for extension providers to use with their clients.
- Regional events and forums to encourage face-to-face sharing of knowledge and experiences.

- Creating or using delivery channels for producing and distributing information to ensure it gets to the right people at the right time.
- Engaging with industries and regions in current research and demonstration projects (in particular those under the Filling the Research Gap, Action on the Ground, and Biochar Capacity Building programs).
- Activities to maintain and build the expertise of extension providers.
- National and regional coordination and provision of oversight to ensure that the messages and services are consistent across industry sectors and regions.

Funding for this component is nominally up to $30 million in grants over the course of the program. It is anticipated that Component 2 activities will become self-sustaining and will be able to continue without ongoing Commonwealth investment after the Extension and Outreach Program has ended.

8.6.3 Component 3: Targeted industry and regional initiatives

The purpose of Component 3 is to support activities that deliver specific advice or assistance for a defined industry sector or region. Activities may also provide short-term support of isolated issues or opportunities; for example around a specific methodology(ies), the latest research results, CFI processes, benefit-cost and risk analyses or case studies.

Projects are expected to be relatively short-term, but high impact.

Component 3 projects should contribute to the overall range of extension services that are available, such as those provided through Component 2, and may use alternative and complementary delivery mechanisms. Component 3 projects may also address identified information and/or extension services gaps.

Priorities for Component 3: Targeted industry and regional initiatives

3.1 Specific targeted industry and regional initiatives on emissions management and the CFI.

3.2 Add value to the activities and services being delivered one-to-one across a defined industry or region.

Project activities to address the priorities of Component 3 may include but are not limited to:

- Producing or contributing to specific industry or regional publications, newsletters and magazines.
- Regional updates, workshops, seminars and social media activities.
- Creating targeted industry or regional technical information and tools for farmers and land managers.
- Engaging with research and demonstration projects (in particular those under the Filling the Research Gap, Action on the Ground, and Biochar Capacity Building programs) and communication research outcomes.

Funding for this component is nominally up to $13 million in grants over the course of the program.