ALMOND
BOARD OF
AUSTRALIA

# Renewable Energy Production
## FROM ALMOND WASTE

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# Executive Summary

The almond industry is rapidly growing its output at a time where the Australian economy is becoming increasingly "carbon" constrained. This means that input prices related to energy and pumping costs are rising and consumer expectations about sustainability are changing. Agriculture is well placed though to take advantage of opportunities under the Clean Energy Future Plan in relation to renewable energy and possibly energy efficiency and carbon farming.

The objectives of this project were to:

- establish current energy demand and carbon footprint (from Scope 1 and 2 emissions)[1] across almond industry producers, processors and packers;
- assess technological options for energy production; and
- conduct a preliminary economic analysis of the commercial viability of energy production.

These objectives were met through a combination of site visits to farms, hullers and shellers and processors from across the industry to enable energy mapping and improved understanding of general operations, energy demand and carbon footprint analysis, review of available energy production technologies suitable to a woody waste such as hull and shell, economic analysis, review of relevant energy and climate change policies and funding programs, and scoping of future directions.

## Energy demand analysis

The on-farm growing component of almond production contributes a high component of the electrical energy demand, on a kWh/T kernel basis. In particular this can be attributed to the high electricity demand of irrigation pumps.

When demand for electricity is high in summer months for the on-farm component (due to irrigation) and during the harvest period for the hulling & shelling, peak electricity use contributes to a large component of electricity cost as these operations have a high day shift component.

Equipment efficiency, in use and selection, can contribute to reducing overall energy use. Further investigations on a site-by-site basis should be considered as this factor will influence the size and operational use of any renewable energy equipment selected.

The greatest energy related risk to the industry is to the on-farm component of production if future electricity pricing tariffs are scaled as a disincentive for electricity use during peak demand times.

Renewable energy presents opportunities for the industry to consider how it might recover waste for resources through shared arrangements between activities such as hulling & shelling, on farm and processing peak electricity demand.

## Carbon footprint analysis

As a consequence of the high electricity use for pumping on farm, Scope 2 emissions (measured as carbon dioxide equivalents ($CO_2e$)/T kernel) contribute a substantial part of the total Scope 1 and 2 carbon footprint. Nitrous oxide emissions (Scope 1) are also a large contributor and are a product of the use of nitrogen based synthetic fertilizers. For hullers and shellers, electricity use contributes the major component of the total carbon footprint.

Overall, mean Scope 1 and Scope 2 emissions of approximately 4.0 T $CO_2e$ are emitted per tonne of kernel produced ready for market. The cost to offset Scope 1 and 2 emissions associated with growing and processing activities would be in the range of 9-10 cents per kilogram of almond kernels, based on production of 50,000 tonne of kernel. The inclusion of Scope 3 emissions would increase the footprint and require a rigorous life cycle assessment at considerable cost. The marketing benefits of this would need to be determined.

## Technological options

Technology is available to convert waste almond hull and shell into electrical and heat energy. There are various options including combustion, pyrolysis and gasification. This study focussed most of its analysis on the use of gasification systems to produce electricity and heat. Being a woody waste, suppliers of gasification systems are confident that almond hull and shell could be used as a feedstock for energy production although there were no commercially operating examples cited. As such, some testing may be required before any purchase of equipment is committed to.

Based on data collected from suppliers in Europe, US, India, China and South Africa the electricity demand for hulling and shelling operations could typically be met with a fraction of the waste they produce. Depending on the energy efficiency of the hulling and shelling

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[1] Scope 1 emissions are the release of greenhouse gases into the atmosphere as a direct result of an activity, or series of activities (e.g. combustion of transport fuel) and Scope 2 emissions are the release of greenhouse gases into the atmosphere as a direct result of one or more activities that generate electricity, heating, cooling or steam. Source: http://www.climatechange.gov.au/government/initiatives/national-greenhouse-energy-reporting/publication-of-data/understanding-nger-data.aspx

process and the ability for the gasification system to convert biomass into power, most hullers and shellers would use less than 20% of available waste to meet their electricity demand and some with less than 10%. In addition to electricity, combined heat and power units produce similar kWh of heat energy. This could be important for almond hullers and shellers and processors given that LPG contributes a major component of energy bills.

The size of the system installed is influenced by the business case, as outlined below in the findings of the economic analysis, but other factors such as the size of available systems are also important. Whereas in the past only larger gasification systems appear to have been commercially viable, recent developments have seen the commercial operation of systems with capacities in the range of 25 kW, 50 kW and 100 kW. These may be more suitable to the small to medium sized hullers and shellers in the almond industry. The Dixon Ridge walnut farm gasification plant (USA) is a good example of application of this scale equipment in a similar industry. Counter to the attractiveness of producing power for onsite use is consideration of ongoing operation resourcing and whether businesses within the almond industry want to also become energy producers, which may be seen as a diversion away from their core business.

A key consideration in what type of energy production system is selected will be the value placed on the by-products. For example, pyrolysis produces biochar but less energy when compared with gasification. However, this may be desirable if the almond industry places a high value on the use of biochar as a soil ameliorant. Activated charcoal can fetch a high price with reliable demand which is another use for the biochar product.

## Economic analysis

The financial benefit of three renewable energy options were compared to the current base case where almond hulls are sold as stock feed. The three options considered the installation of a biomass gasification plant at each hulling and shelling facility based on the following scenarios:

- Option 1 - The average plant size is 100 kW to meet average electricity demand at hulling and shelling facilities. The remaining hull and shell are sold as stock feed.
- Option 2 - The average plant size is 550 kW to meet peak electricity demand at hulling and shelling facilities. The remaining hull and shell are sold as stock feed.
- Option 3 - The average plant size is 1,923 kW to use all waste hull and shell, with none sold as stock feed.

Based on 50% funding through the Clean Tech Investment Program it was determined that:

- Option 1 provides a positive Benefit Cost Ratio (BCR) compared to the base case, where for every $1 spent on the plant there was a return of $1.28.
- Option 2 provides a negative BCR compared to the base case, where for every $1 spent there is a return of only $0.47.
- Option 3 provides a negative BCR compared to the base case, where for every $1 spent there is a return of only $0.44.

For Options 2 and 3 the high capital cost cannot be off-set by the future electricity savings or anticipated feed in tariffs. Operation and maintenance of a large system also impacts the degree of benefit.

The analysis also considered the sensitivity of the results to many factors. It shows that Option 1 supports future investment in energy efficiency upgrades as the future electricity reductions that would result would further improve the positive benefit. The opposite is true for Options 2 and 3 if energy efficiency improvements are made in the future, further reducing the BCR.

The energy efficiency of each individual site is significant. Therefore for small operations or very efficient operations, where their average demand is offset by a plant that is smaller than the 100 kW plant assessed in Option 1, their BCR would increase, potentially to $2.31. This demonstrates the importance of improving efficiency, then off-setting the residual average energy demand.

Also of note is the energy use profile of each operation. If energy is consumed at a more constant rate with smaller peaks, then the amount of electricity consumed above the 100kW plant size would be a smaller percentage compared to a more peaky energy use profile; even though both have the same average energy use and therefore the same sized plant. This higher proportion of electricity purchase will therefore reduce the BCR for the more peaky operation and could even tip Option 1 into the negative net benefit scenario. This again highlights the importance of energy efficiency improvements but also good monitoring and measuring of energy use to allow operations to fit within the capacity of plant as much as possible.

## Impact of existing and emerging climate change policies

The most relevant policy to future considerations of renewable energy production for the Almond Industry lies within the Federal Government's Clean Energy Future Plan. This is clearly placing upward pressure on input prices through the carbon price. Fortunately for the industry, the Clean Energy Future Plan also outlines various funding opportunities that can help with improving energy efficiency or renewable energy production.

If energy production is to be pursued consideration needs to be given to whether members of the industry want to move directly to detailed site specific feasibility studies and installation of equipment or whether a more cautious approach is adopted involving further analysis of technology options. Both are likely to attract funding given the current array of policies and grant programs, however consideration would need to be given to which grants are sought given that some are more focussed on assisting with installation of proven technology whereas others favour investment in continued research and development. *The level of emissions from the industry should be put in context and noted that they are relatively small when compared to the larger liable entities within Australia.*

## Future directions

This study indicates that there is a case for using waste hull and shell to produce energy, but only under certain conditions. This means that an energy solution must be tailored to each site, giving due consideration to site specific factors like energy efficiency, energy demand profile, and the value placed on energy production by-products. The next stages could include:

1. Adoption – Move to a detailed site specific feasibility study and rapidly proceed toward installation.
2. Combustion, pyrolysis or gasification? – Conduct physical trials to better understand the energy that can be generated from combustion, pyrolysis or gasification and the characteristics of by-products such as biochar and ash.
3. Integrated energy supply and demand project – Identify sites where energy systems could be used to meet onsite plus other local demand. This could be suitable in Renmark where the AlmondCo facility is on the edge of town or at Laragon where energy could be produced to support irrigation pumping of the surrounding orchards. Detailed economic analysis and supply considerations would need to be assessed on a case by case basis.
4. Composting and carbon farming – Better understand the potential benefits of composting from a carbon farming perspective, such as increased soil carbon levels and reduced application of nitrogen based fertilisers. This would also consider the potential benefits of adding energy by-products such as biochar or ash to the farm.

There are options to combine some of the above projects such as 2 and 4.

# 1. Introduction

## 1.1. Growth of the almond industry

The Australian almond industry is one of Australia's most rapidly growing horticultural sectors, producing high value tree nuts for domestic and international markets. Domestic almond production is set to more than double in the next 6 years, increasing the output of waste hull and shell from approximately 93,333 tonnes to over 200,000 tonnes by 2016 (Table 1).

Almond waste currently has limited economic value in Australia with alternate uses offering low prices and variable demand. The primary use for almond hull and shell in Australia is for cattle feed. While this use is popular in the United States where feedlots are close to almond hullers and sellers reducing or negating transport costs, in Australia feedlots are often a significant distance from hullers and shellers meaning that revenue earned from sale of hull and shells can be low. More importantly is the variability of demand for hull and shell. Demand can be especially low during years when other preferred feed sources (e.g. grain) are cost competitive leaving hullers and shellers with little demand for their product. This results in stockpiles of waste accumulating at hulling and shelling facilities. Not only does this occupy space on site it can become a nuisance where piles of waste spontaneously combust.

*Table 1. Estimated almond kernel, hull and shell production and the value of nitrogen and potassium in the hull and shell only, 2011-2016 Australian harvests. Source: Almond Board of Australia.*

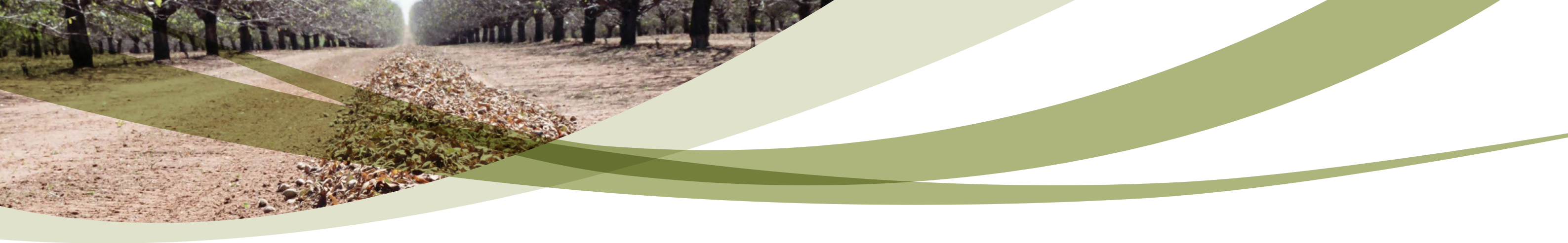
| Harvest | Kernel Production (tonnes) | Hull & Shell Production (tonnes) | Nitrogen & Potassium Fertiliser Cost (Hull & Shell) |
|---|---|---|---|
| 2011 | 40,000 | 93,333 | $8,761,200 |
| 2012 | 67,495 | 157,488 | $14,783,430 |
| 2013 | 75,714 | 176,666 | $16,583,637 |
| 2014 | 81,329 | 189,768 | $17,813,491 |
| 2015 | 84,426 | 196,994 | $18,491,827 |
| 2016 | 85,823 | 200,254 | $18,797,812 |
| 2017 | 86,257 | 201,266 | $18,892,871 |

## 1.2. Changing market conditions and policy environment

The almond industry produces a crop that is experiencing increasing demand from overseas and domestic markets. However, future growth of the industry will occur in an economy that will be increasingly carbon constrained as all industry sectors are exposed to higher power prices or encouraged or required to use less energy in the provision of goods and services.

Electricity prices have already risen because of increasing network and distribution charges and all power produced from fossil fuels will increase in price because of the impact of the carbon price. There are also flow-on impacts of rising energy costs for the almond industry. For example, the cost of irrigation has risen because of increased pumping costs as a consequence of higher electricity charges. Nitrogen based fertiliser production is also energy intensive and forecast to experience price rises.

While for agriculture rising input prices as a consequence of the carbon price pose a financial threat, an opportunity also exists for agriculture within the mitigation actions identified under the Clean Energy Future Plan through renewable energy production, improved energy efficiency and changed land management under the Carbon Farming Initiative. For the almond industry, renewable energy could be produced using waste hull and shell as a feedstock, processing equipment could be modified or changed or its operation improved to increase energy efficiency and management practices on farm could be changed to sequester carbon or reduce emissions and generate carbon offsets under the Carbon Farming Initiative. While few of these practices are established within the industry, the funding support from Federal and State Governments makes exploration of the suitability of these activities more attractive than it has been in the past.



## 1.3. Objectives and outcomes

In rural regions of Australia the agricultural sector presents an opportunity to consider management of bio-wastes as sources of alternative energy and possibly carbon offsets. Investigating the links between waste and energy demands within agricultural production systems will help determine opportunities for industry and regional collaboration in carbon and energy management.

The objectives of this project are to:

1. establish current energy demand across almond industry producers, processors and packers;
2. assess technological options for energy production, including multi-use options that may enhance attractiveness of bioenergy; and
3. conduct a preliminary economic analysis of the commercial viability of energy production.

In meeting these objectives, this report delivers the following outcomes:

- Energy demand analysis, based on an assessment of Scope 1, direct emissions (e.g. combustion of transport fuel) generated in the growing, harvesting, processing and packing of almonds and Scope 2, indirect emissions (e.g. electricity) generated in the growing, harvesting, processing and packing of almonds;
- Advice on the work required to conduct a full scale Scope 3 analysis of all indirect emissions other than those covered by scope 2;
- Assessment of technological options for renewable energy production;
- Estimates of the potential for horticultural waste material to be used for renewable energy as an offset for the carbon footprint of the selected sites;
- Preliminary economic analysis of the commercial viability of energy production using almond waste;
- Analysis of potential business risks and opportunities associated with existing and emerging climate change policies given the results of the Scope 1 and 2 analysis;

Recommendations are presented to help direct future potential investment in renewable energy production using almond waste.

# 2. Methodology

## 2.1. Energy demand analysis

The project team visited farms, hullers and shellers and processing facilities to establish the energy demand across the supply chain for the industry (Table 2). Farms were selected to provide an example of a small farm, moderate sized farm and large farm. While farm managers were met for all sites described, not all farms were visited nor was data available from all farms during the timeframes of this project.

All hullers and shellers for the industry were visited during the term of the project. Extensive site analysis was conducted for all but one facility, which remained under construction at the time of this report's completion. Most of the principal processors were visited during the project.

*Table 2. Site visit locations and types.*

| Name | Location | Type |
|---|---|---|
| CMV Farms | Lindsay Point, Victoria | Farm |
| Laragon | Lindsay Point, Victoria | Huller/sheller |
| Nut Producers Australia | Loxton, South Australia | Processer |
| Larilla | New Residence, South Australia | Farm |
| AlmondCo | Lyrup, South Australia | Huller/sheller |
| AlmondCo | Renmark, South Australia | Processer |
| Costa Farms | Angle Vale, South Australia | Huller/sheller and processor |
| Costa Farms | Swan Reach, South Australia | Farm |
| Select Harvests | Robinvale, Victoria | Farm |
| Select Harvests | Robinvale, Victoria | Huller/sheller |
| Olam | Mildura, Victoria | Farm |
| Olam | Carwarp, Victoria | Huller/sheller and processor |

Data collected for the financial year 2011/12 included monthly and quarterly energy bills (electricity, LPG, Diesel and Unleaded Petrol (ULP)) and where possible interval data from electrical smart meters.

A series of process maps were developed to ensure that energy demand within each of the three processes were understood and that energy use within in the various processes at each location and within facilities could be related to energy consumption patterns.

Energy consumption data was collated into a central spreadsheet and considered in realtion to other relevant factors such as hectares (ha) grown, total tonnes (T) of almonds produced and processed, T's of almond kernel grown and processed and total waste produced (T of hulls and shells).

Electricity use data was reviewed for each site to consider how energy was used in relation to seasonality of the almond industry and daily peak and off-peak tariffs. This data was used when considering and assessing potential renewable energy demand and plant sizing.

Data was consolidated and is reported across the industry on the basis of Tonnes (T) kernel, as this a standard benchmark used by growers, hullers and shellers and processors. For each site visit location, where data was available, data was collated to review kWh(e) and diesel and ULP (L) to compare the range of these values per T of kernel. Means and median values were then compared. It was considered this approach provided commercial confidentiallity for each of the sites visited and an opportunity for participants to review their own data at a later stage against these industry data sets.

## 2.2 Carbon footprint analysis

Energy use data (electrical, LPG, Diesel and ULP) was considered with respect to Scope 1 and 2 carbon emissions and emissions factors applied in each case consistent with those reported by the department of climate change and energy efficiency[2] under the National Greenhouse Accounts Factors – 2012.

The methodology applied to calculation of Scope 1 and 2 carbon footprints was designed to be consistent with internationally recognised carbon footprint protocols, in particular with the British standard known as PAS2050.

In each of the three almond production phases (growing, hulling and shelling, processing), and the facilities visited, carbon emssions were calculated and then similarly to the energy demand analysis, a range mean and median determined and compared to T of kernel produced or processed in each case.

This enabled an industry Sope 1 and 2 carbon foorprint approach to be considered on a broad scale by mutiplying the range data mean by the current projected total industry production (T kernel) to gain an insight in to the approximate Scope 1 and 2 almond industry carbon footprint.

Scope 3 carbon emissions were not considered as a part of this study.

## 2.3 Renewable energy technological analysis

An assessment of available technologies for producing renewable energy from almond waste material was conducted via an extensive literature and internet search of combustion, gasification and pyrolysis equipment from around the world, including both previous investigations into this technology and equipment manufacturer's reports and websites. This enabled best available technologies to be considered to input into the economic modelling analysis.

## 2.4 Economic modelling

EconSearch Pty Ltd was contracted by Mark Siebentritt and Associates to conduct a financial analysis of the Renewable Energy Production from Almond Waste project.

### 2.4.1 Purpose and scope of cost benefit analysis

The main objective of this component of the project was to undertake a cost benefit analysis (CBA) to determine the net financial benefit of renewable production from almond waste. Three options were identified. These options were compared against a base case scenario. The base case and options are described in Table 3. These scenarios have been developed using a hypothetical example of a facility producing 20,000 tonnes of hull and shell per annum.

*Table 3. Alternative energy supply options of a facility producing 20,000 tonnes of hull and shell per annum for the cost benefit analysis.*

| Option | Description |
|---|---|
| Base Case | Maintain existing system of disposal of almond hull and shell waste, i.e. by selling it as stockfeed. |
| Option 1 | Install a (100 kW) biomass gasification system to generate electricity to meet average hulling/shelling process demand. The remainder of the hull and shell waste sold as stockfeed. |
| Option 2 | Install a (550 kW) biomass gasification system to generate electricity to meet peak hulling/shelling process demand. The remainder of the hull and shell waste sold as stockfeed. |
| Option 3 | Install a (1,923 kW) biomass gasification system to generate electricity to use all hulling and shelling waste. No hull and shell waste sold as stockfeed. |

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[2] http://www.climatechange.gov.au/publications/greenhouse-acctg/national-greenhouse-factors.aspx

### 2.4.2 Method of analysis

The cost benefit analysis conducted for this project conforms to South Australian and Commonwealth government guidelines for conducting evaluations of public sector projects (Department of Treasury and Finance (2007) and Department of Finance and Administration (2006)).

The starting point for the financial analysis was to develop the 'base case' scenario, that is, the benchmark against which the option was compared. For the purpose of this analysis the 'base case' was defined as the maintenance of the existing sources of energy, namely grid electricity and bottled LPG gas, and the selling of hull and shell to stockfeed facilities at $23/tonne.

Given that costs and benefits were specified in real terms (i.e. constant 2012 dollars), future values were converted to present values by applying a discount rate of 8 per cent for the economic analysis. A sensitivity analysis was conducted using discount rates of 6 and 10 per cent.

The economic analysis was conducted over a 20 year time period and results were expressed in terms of net benefits, that is, the incremental benefits and costs of the option relative to those generated by the 'base case' scenario. The evaluation criteria employed for these analyses were as follows.

- Net present value (NPV) – discounted[3] project benefits less discounted project costs. Under this decision rule an option was considered to be potentially viable if the NPV was greater than zero. The NPV for option *i* has been calculated as an incremental NPV, using the standard formulation:

  $\text{NPV}_i$ = (PV (option$_i$ benefits – 'base case' benefits) – (PV (option$_i$ costs– 'base case' costs))

- Benefit-cost ratio (BCR) – the ratio of the present value of benefits to the present value of costs. Under this decision rule each option (*i*) was considered to be potentially viable if the BCR was greater than one. The ratio was expressed as:

  $\text{BCR}_i$ = PV (option$_i$ benefits – 'base case' benefits) / PV (option$_i$ costs– 'base case' costs)

- Internal rate of return (IRR) – the discount rate at which the NPV of a project is equal to zero. Under this decision rule an option was considered to be potentially viable if the IRR was greater than the benchmark discount rate (i.e. 8 per cent).

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[3] Discounting refers to the process of adjusting future benefits and costs to their equivalent present-day values (Sinden and Thampapillai 1995).

# 3. Energy Demand Analysis

Energy demand for production of almonds varies substantially across the cycle of almond growing, hulling and shelling and processing enterprises, depending on methods, equipment, seasonality and product requirements.

The main sources of energy are electrical, liquid petroleum gas (LPG), diesel fuel and unleaded petrol (ULP).

To better understand energy demand in the industry the study looked in detail at energy use across a range of business sizes and locations involved in:

- growing (farm),
- hulling and shelling and
- processing (treatment and packaging).

Process flow diagrams were prepared to enable energy flows to be understood within each aspect of production relevant to farm, hulling and shelling and processing businesses.

Setting these boundaries was important to ensure consistency of comparison and clarity around carbon footprint assessments. This is covered further in the next section, carbon footprint analysis.

The following sections present a summary of the energy use data for each of the farm, hulling & shelling and processing phases. In each case a range of data has been presented and the mean and median for that range. Site specific data has purposely not been presented to ensure confidentiality.

The data is presented in most cases using the categories identified in Table 4, as this is considered the most useful for comparative purposes, both for the industry and for the further analysis with respect to possible renewable energy technologies.

*Table 4. Benchmarking categories*

| Energy use category | Units |
|---|---|
| Electrical energy | kWh/ha |
| Electrical energy | kWh/T (kernel) |
| LPG | L/T (kernel) |
| LPG | L/T (k,h&s*) |
| Diesel fuel | L/ha |
| Diesel fuel | L/T (kernel) |
| ULP fuel | L/ha |
| ULP fuel | L/T (kernel) |

** k,h&s = Total weight kernel, hull & shell*

## 3.1 On-farm energy demand

Energy use on farm is principally electricity used for operating water pumps. In addition diesel and unleaded fuel are used for operating farm-based machinery. There is additional electricity use for activities like workshops, elevators and lighting but this is relative small in comparison to the energy required for irrigation pumps.

Consumption of electricity is very seasonal, influenced by weather and tree requirements. Typically, the major irrigation period is from October to March. Because of the intense, often daily requirements of irrigation, there is a reasonably even spread of electricity use between peak (day) and off-peak (night) consumption, particularly in the hottest months at the peak of the irrigation season.

As electricity prices continue to rise, it will be useful for the industry to better understand the detailed energy demand on farm. Use of smart meters and external metering equipment will assist this knowledge gap.

Electricity use data was collected and compared between a range of almond orchard sizes, including small and large growers. Table 5 below indicates the range of kWh's used per hectare and per Tonne (T) of almonds grown.

*Table 5. Electrical energy demand for almond orchards (2010/11).*

| Electricity | Range | Mean | Median |
|---|---|---|---|
| kWh/ha | 1574-4668 | 3519.4 | 3917.5 |
| kWh/T (kernel) | 630-3890 | 1943.2 | 1626.4 |

Similarly fuel use was considered including both diesel and unleaded petrol (ULP). Table 6 indicates the number of litres of fuel used per hectare of almonds grown and litres (L) used per tonne (T) of kernel produced. Activities using fuel include general tractor work, seeding, slashing, spraying, harvesting activities (specific machinery) and general light vehicle on farm and support use.

*Table 6. Fuel demand for almond orchards (2010/11).*

| Diesel | Range | Mean | Median |
|---|---|---|---|
| L/ha | 107-360 | 185.0 | 136.3 |
| L/T (kernel) | 43-300 | 113.6 | 55.6 |
| **ULP** | **Range** | **Mean** | **Median** |
| L/ha | 26-188 | 62.4 | 21.9 |
| L/T (kernel) | 7-77 | 28.4 | 14.5 |

**Almond Growing - Energy use process flow**

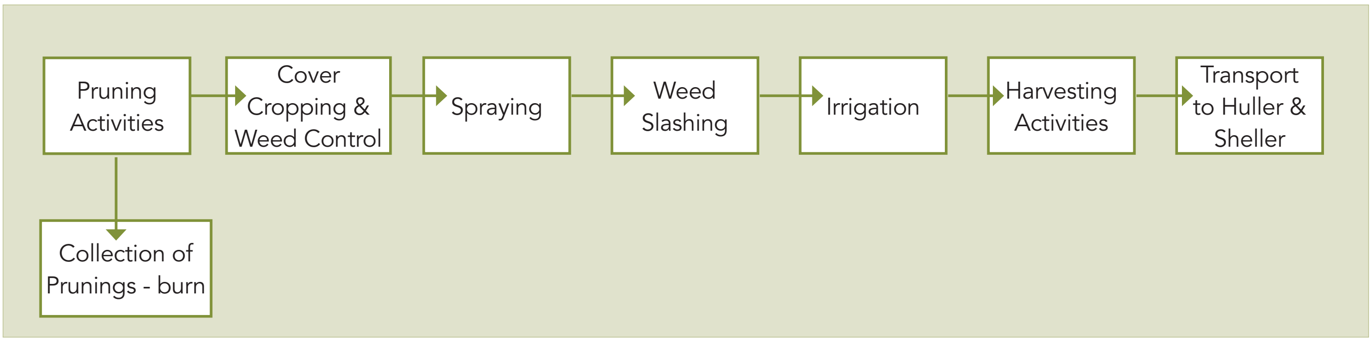

*Figure 1. Flow diagram of almond growing process. Activities which involve energy use (electricity, diesel or unleaded fuel).*

## 3.2 Hullers and sheller's energy demand

Energy use at hulling and shelling facilities is principally electricity for operation of a range of electrical motors engaged in various parts of the hulling and shelling process including:

- Pre-cleaning
- Shelling
- Hulling
- Sorting
- Grading
- Dust Extraction

LPG is also used for operation of forklifts and drying of produce in facilities set up for this activity.

Peak activity for hulling and shelling occurs from February to July, during and immediately after the harvest period which occurs from February to March. Electricity use during this time can be 24/7 depending on demand flows from farm and to processors.

Additional site energy use can be in the form of diesel and ULP for site machinery such as front end loaders, vehicles and other small combustion engine machinery.

*Table 7. Electrical energy demand for almond hulling and shelling (2010/11).*

| Electricity | Range | Mean | Median |
|---|---|---|---|
| kWh/T (kernel) | 58-176 | 110.7 | 99.0 |
| kWh/T (K,hull & shell) | 16-58 | 34.0 | 27.6 |
| **LPG** | **Range** | **Mean** | **Median** |
| L/T (kernel) | 2-14 | 6.7 | 4.1 |
| L/T (K, hull & shell) | 0.5-3.7 | 1.9 | 1.4 |

Data analysis from electrical interval metering was reviewed where available. Whilst energy tariff rates are contracted at quite low rates in some cases (5-10 cents/kWh), additional network supply tariffs are realising substantial total costs across the board.

This is particularly relevant to peak and off-peak use of energy where hulling and shelling activities result in a significant load during peak hours and when hulling and shelling is restricted to peak hours due to constraints such as limits to operating hours in peri-urban areas and availability and cost of labour.

However, when compared to the electrical energy use for farm based activities (farm – range 630-3890 kWh/T (k)) the range of 58-176 kWh/T (k) for hulling and shelling is somewhat lower and less significant in terms of the total energy footprint.

The relevance of load use profiles is critical to the economic analysis for renewable energy options and discussed in more detail in following chapters.

**Almond Hulling & Shelling - Energy use process flow**

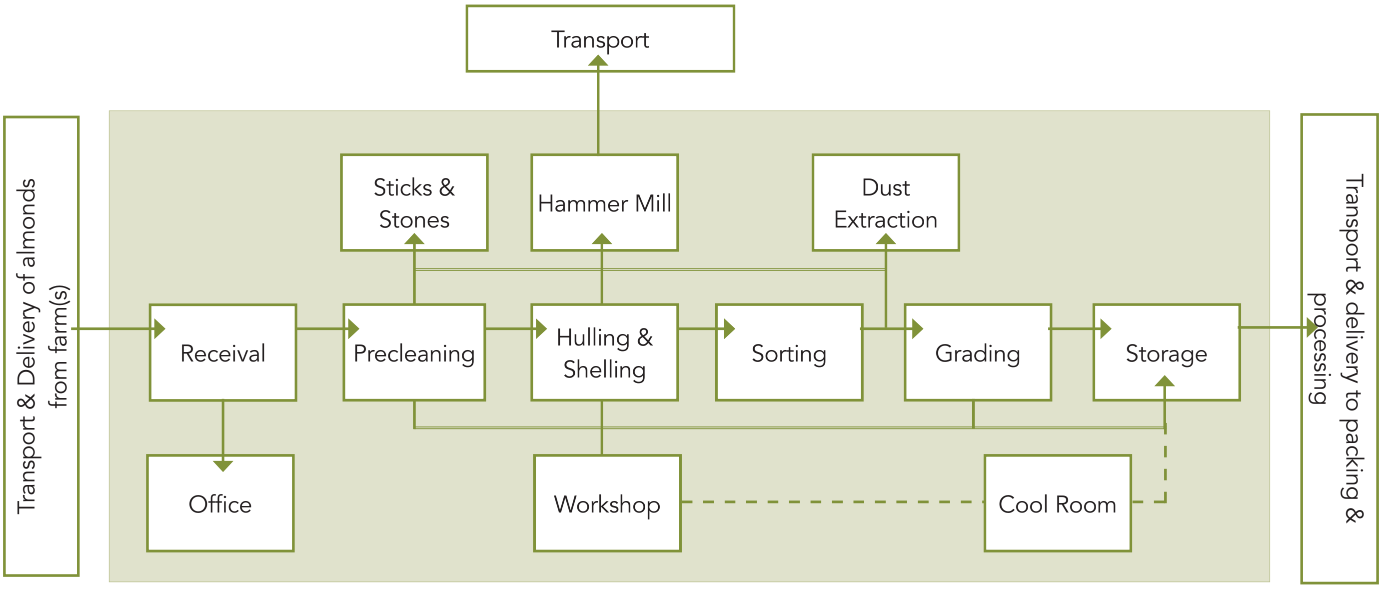

*Figure 2. Flow diagram of almond hulling & shelling process. Activities which involve energy use (electricity, diesel or unleaded fuel).*

## 3.3 Processors energy demand

Almond processing facilities have a range of energy using activities that require a mix of electrical and LPG sources to power activities such as sorting, blanching, mealing, roasting, pasteurization, packaging, lighting and cool room storage.

Whilst these activities are year round to ensure constant market supply, some periods of more intense activity are associated with harvest times when numerous work shifts are run to ensure reduced risk of damage to almonds from weather and pests.

A wide range of electrical motors and compressors power numerous activities such as sorting, grading, blanching, mealing, cooling, packaging and storage.

Because not all facilities undertake the same activities and data was not available for all processing facilities the range for electricity consumption presented was quite narrow in an effort to compare similar activities. Likewise with LPG consumption, not all facilities undertake the same activities using LPG so there was limited ability to define a mean and median value for kWh/T processed.

Never the less, the assessment did present sufficient data for a general range of electricity use for almond processing (87-99 kWh/T kernel) to enable comparison to the growing (630-3890 kWh/T kernel) and hulling and shelling (58-176 kWh/T kernel) phases.

*Table 8. Electricity and Gas (LPG) demand for almond processing (2010/11).*

| Electricity | Range | Mean | Median |
|---|---|---|---|
| kWh/T (kernel) | 87-99 | 92.7 | 92.7 |
| LPG | Range | Mean | Median |
| L/T (kernel) | 13-49 | X | X |

**Almond Processing - Energy use process flow**

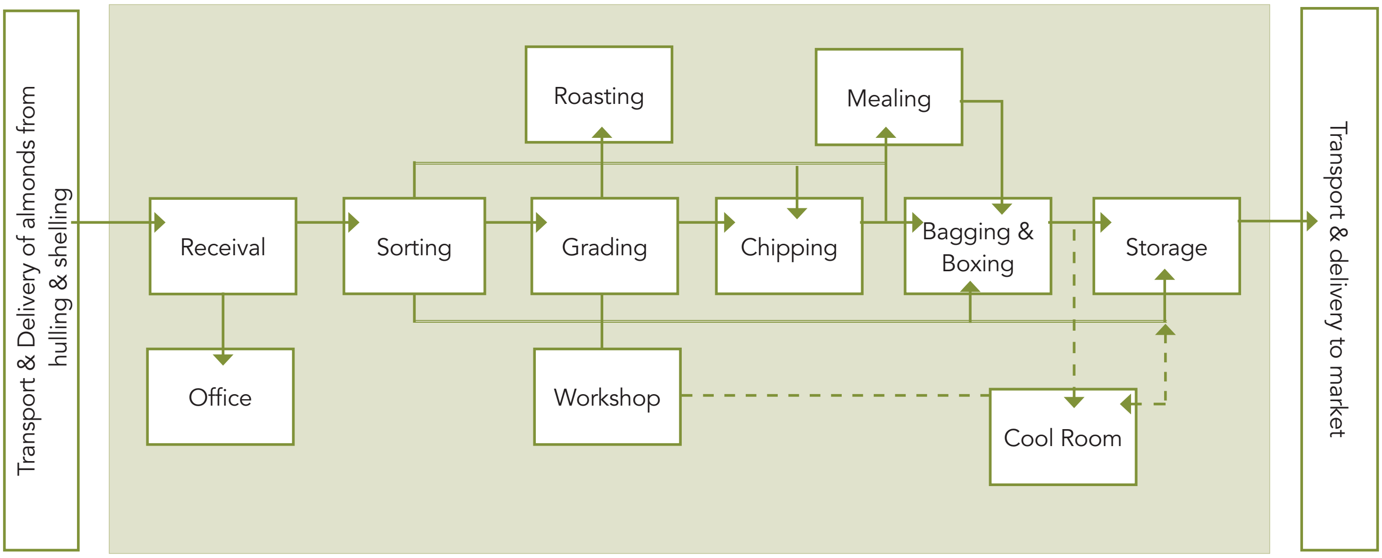

*Figure 3. Flow diagram of almond processing. Activities which involve energy use (electricity, diesel or unleaded fuel)*

## 3.4 Discussion

The key feature of the energy demand analysis is the significant electrical energy requirement to pump water for irrigation. This can be seen in Table 9.

*Table 9. Summary of electricity demand for each phase of almond production.*

| Activity | kWh/T kernel |
|---|---|
| Growing (Farm) | 630-3890 |
| Hulling & Shelling | 58-176 |
| Processing | 87-99 |

This data suggests there is an increased risk to the industry at farm gate should electricity prices continue to increase, particularly if irrigation requirement and the use of peak use tariffs increases as a consequence of climate change and drier conditions.

Other aspects apparent during the analysis were the need for a strong focus on energy efficient practices and equipment. Variability in energy consumption at the farm and hulling and shelling level were as a consequence of variable practices and equipment.

The activities of dust management and hammer milling (hulling and shelling) and cooling (storage) were notably high energy consuming activities.

It was also noted that gas (LPG) pricing is becoming as significant a cost as electricity, with LPG costs greater than electricity in some cases.

Energy efficiency gains in the industry should be considered. This may include selecting appropriate equipment for the task and matching this with efficient work practices, including consideration for timing of use (peak v off-peak electricity). This can have the combined effect of energy and cost reduction.

It is noted however that due to the intense activities of summer irrigation, harvesting and hulling and shelling this is not always possible, due to the demands of 24/7 operations.

These factors become paramount when considering renewable energy options, as described in the economic analysis sections of this report.

Provision of renewable energy to off-set high farm based energy demand could reduce overall almond production costs. Renewable energy may also provide energy reduction strategies for other high electricity cost activities such as processing. Matching energy demand and renewable energy production will be site specific and should be reviewed in detail for each facility.

# 4 Carbon Footprint Analysis

The energy use attributable to each phase of the almond production cycle, growing (farm), hulling and shelling and processing, has been determined. This energy use can be easily assessed to determine a basic carbon footprint for each of the three key almond industry activities.

Collectively this carbon footprint assessment provides some insight into the carbon footprint of the industry as a whole.

The carbon footprint analysis provided in the report should be viewed as indicative as we have not reviewed data for the entire industry i.e. a selection of farms were visited, some processing facilities are yet to come on line and not all data was available for all sites.

The Department of Climate Change and Energy Efficiency (DCCEE, 2012) refers to a **Carbon footprint** as:

> *"a measure of the carbon dioxide equivalent emissions attributable to an activity, commonly used at an individual, household, organisation or product level"*

It is important however to clearly identify the boundaries and scope of the footprint in each case.

For the purpose of this study the boundaries for determining the level of carbon footprints and the scope were set as follows.

## 4.1 Boundary considerations

**Growing (Farm):** All activities occurring on farm that use electricity, burn fuel (i.e. diesel, ULP or LPG) and use nitrogen based fertiliser for the purpose of growing and transporting almond products for further processing.

**Hulling and Shelling**: All activities occurring at a hulling and shelling facility that use electricity or burn fuel (i.e. diesel or ULP) for the purpose of extracting raw almond kernel from the whole almond fruit for further processing.

**Processing:** All activities occurring at a processing facility (including packaging) that use electricity or burn fuel (i.e. diesel or ULP) for the purpose of processing and packaging almonds and almond products for distribution to market.

The carbon footprint assessment was focused on Scope 1 and Scope 2 emissions.

Scope 1 emissions are defined[4] as:

> *the release of greenhouse gases into the atmosphere as a direct result of an activity, or series of activities (including ancillary activities) that constitute the facility.*
>
> *Examples of these would be:*
>
> - *manufacturing processes, such as gas emitted while making cement*
> - *transportation of materials, products, waste and people, such as a transport company burning diesel oil in its trucks*
> - *fugitive emissions, such as methane emissions from coal mines.*

Scope 2 emissions are defined[5] as:

> *the release of greenhouse gases into the atmosphere as a direct result of one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but do not form part of the facility. It is important to recognise that scope 2 emissions from one facility are part of the scope 1 emissions from another facility. For example, a power station burns coal to power its generators and in turn create electricity. Burning the coal causes greenhouse emissions to be emitted. These gases are attributed to the power station as scope 1 emissions. If the electricity is then transmitted to a car factory and used there to power its machinery and lighting, the gases emitted as a result of generating the electricity are then attributed to the factory as scope 2 emissions.*

Typical Scope 1 and Scope 2 activities associated with each part of the almond production cycle are shown in Table 10.

The boundary of the carbon footprint assessments did not include the additional transport, distribution, staff travel, third party activities, air travel, staff travel to and from work and transport of product to market as these were all considered typical Scope 3 emissions.

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[4] Department of Climate Change and Energy Efficiency http://www.climatechange.gov.au/government/initiatives/national-greenhouse-energy-reporting/publication-of-data/understanding-nger-data.aspx

[5] Department of Climate Change and Energy Efficiency http://www.climatechange.gov.au/government/initiatives/national-greenhouse-energy-reporting/publication-of-data/understanding-nger-data.aspx

## 4.2 Scope

The scope of the carbon footprint analysis included Scope 1 (Direct) and Scope 2 (Indirect) emissions only for each of the activities and facilities described above as growing (farm), hulling and shelling and processing (including packaging), and relate only to the facilities visited where sufficient data was available to report Scope 1 and 2 emissions.

The methodology outlined above is designed to be consistent with internationally recognised carbon footprint protocols, in particular the British standard known as PAS2050.

It was not possible to undertake a full carbon footprint analysis in the context of this project, due to the complex and time consuming nature of life cycle assessment. This is discussed further in Section 4.5.

Site data assessment and energy demand analysis has occurred from farm gate to the point of distribution from the processing facility. From the data collated at each site it was possible to calculate a range of carbon emissions data relevant to each phase of almond production and relate this in general terms to the tonnes of carbon dioxide equivalent emissions ($CO_2e$) per tonne (T) of almonds.

It is important to recognise this assessment has not included Scope 3 emissions which, based on knowledge from other industries such as the wine grape, manufacturing and textile industries, is likely to be a significant contribution in the life cycle assessment, in some cases as much as 60%.

## 4.3 Assessment of scope 1 and scope 2 emissions

The typical activities associated with each phase of almond production and the relationship to Scope 1 and 2 emissions are outlined in the tables below. For each phase data was collected from businesses in the form of litres or kWh consumed for the financial year 2011/12. Emissions factors were then applied in each case as published under the National Greenhouse Accounts Factors – 2012 (DCCEE, 2012) to determine tonnes (T) of Carbon Dioxide equivalents $TCO_2e$.

**Growing (Farm Based) Activities**

| Scope 1 Activities | Scope 2 Activities |
|---|---|
| Use of Diesel Fuel<br>Use of ULP Fuel<br>○ Farm based machinery<br>○ Vehicles<br>○ Tractors<br>○ Harvesting equipment<br>Nitrogen based synthetic fertilisers | Use of electricity<br>○ Electric motor – pumps<br>○ Lighting<br>○ Workshop equipment<br>○ Office air-conditioners |

**Hulling & Shelling Activities**

| Scope 1 Activities | Scope 2 Activities |
|---|---|
| Use of Diesel Fuel<br>Use of ULP Fuel<br>Use of LPG<br>○ Drying<br>○ Forklifts | Use of electricity<br>○ Electric motor<br>○ Lighting<br>○ Dust extraction<br>○ Cracking, sorting, grading |

**Processing Activities**

| Scope 1 Activities | Scope 2 Activities |
|---|---|
| Use of Diesel Fuel<br>Use of LPG<br>○ Forklifts<br>○ Boilers<br>○ Roasting | Use of electricity<br>○ Electric motors<br>○ Lighting<br>○ Dust extraction<br>○ Heating/cooling |

### 4.3.1 Results

The range and total of Scope 1 and Scope 2 emissions for each phase of almond production are summarised in Table 10 below.

*Table 10. Scope 1 and 2 carbon emission range for the phases of almond growing, 2011/12.*

| Activity | Scope 1 emission (T) CO2e/T kernel | Scope 2 emission (T) CO2e/T kernel | Total Scope 1 & 2 (T) CO2e/T kernel |
|---|---|---|---|
| Growing | Range | Range | Range |
| | 0.75-1.72 | 0.45-2.80 | 1.20-4.33 |
| Hulling & Shelling | | | |
| | 0.01-0.02 | 0.04-0.13 | 0.06-0.14 |
| Processing | | | |
| | 0.02-0.07 | 0.06-0.08 | 0.08-0.15 |
| Total | | | |
| | 0.78-1.81 | 0.55-3.01 | 1.34-4.62 |

Analysis of the data indicated that up to 80% of the Scope 1 farm based emissions are a consequence of nitrogen based synthetic fertilisers and subsequent $N_2O$ (Nitrous Oxide) emissions (nitrous oxide based compounds have a 300 times greater warming potential than $CO_2$).

Electricity (Scope 2) used for irrigation pumping can account for 40% to 60% of the total Scope 1 and 2 carbon footprint.

Hulling and Shelling contributes a relatively small component to the total footprint but electricity use contributes a large proportion of that activities footprint.

The assessment indicated the mean Scope 1 and Scope 2 total carbon emissions were approximately 4.0 T $CO_2$e per T of kernel produced ready for market.

## 4.4 Off-setting scope 1 and scope 2 emissions

Based on the 2012 Australian almond harvest of 50,000 kernel tonnes and using the 4.0 T $CO_2$e figure above, the industry has emissions totalling approximately 200,000 T $CO_2$e.

The cost to off-set these annual Scope 1 and Scope 2 carbon emissions, based on a carbon cost of $23/T, is approximately $4,600,000 or 9 to 10 cents per kg of almond kernels.

The price could increase or decrease each year depending on the size of the annual almond harvest, the market rate for Australian Carbon Credit Units (ACCU) or international carbon credits.

## 4.5 Implications for a full analysis including scope 3 emissions

Scope 3[6] emissions are defined as:

> *greenhouse gas emissions that are not reported under the National Greenhouse and Energy Reporting (NGER) scheme. These include greenhouse gas emissions (other than scope 2 emissions) that are generated in the wider economy as a result of activities at a facility but are physically produced by another facility. An example of this is the employees of a facility flying on a commercial airline for business.*

Other examples of Scope 3 emissions include the energy used by ancillary businesses that support the business being assessed, such as insurance and tax agents, the emissions associated with other input materials such as computing equipment and paper and end of life waste issues and transportation packaging materials. Therefore, to conduct a detailed full scale carbon footprint for the almond industry, including Scope 3 analysis, a detailed study scope and boundaries would need to be set. Typically this would include defining the product for a detailed life cycle assessment (LCA) i.e. packaged raw almonds.

Once the scope and boundary of the study are set then more detailed input/output analysis can occur.

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[6] Department of Climate Change and Energy Efficiency: http://www.climatechange.gov.au/government/initiatives/national-greenhouse-energy-reporting/publication-of-data/understanding-nger-data.aspx

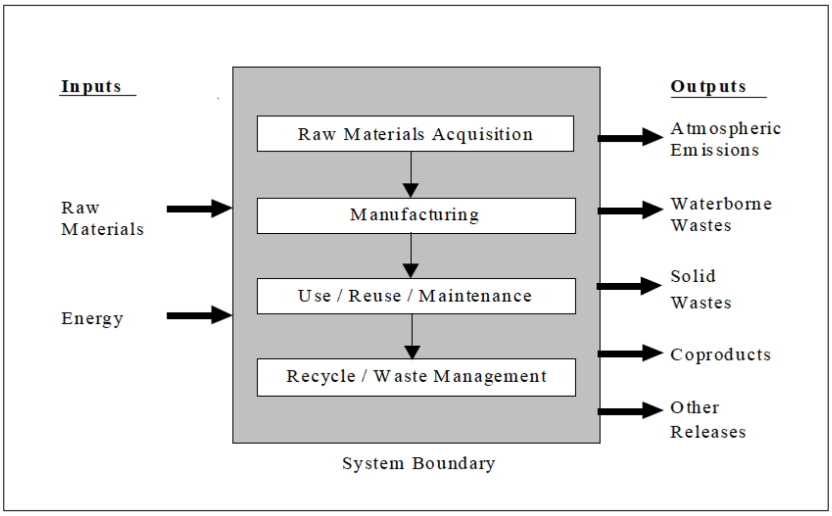

*Figure 4. Stages of a Life Cycle Assessment (Source, US EPA 1993)*

A framework for an LCA study is required and this usually follows protocols as defined by international convention (ISO):

1. *Goal Definition and Scoping* - Define and describe the product, process or activity. Establish the context in which the assessment is to be made and identify the boundaries and environmental effects to be reviewed for the assessment.
2. *Inventory Analysis* - Identify and quantify energy, water and materials usage and environmental releases (e.g. air emissions, solid waste disposal, waste water discharges).
3. *Impact Assessment* - Assess the potential human and ecological effects of energy, water, and material usage and the environmental releases identified in the inventory analysis.
4. *Interpretation* - Evaluate the results of the inventory analysis and impact assessment to select the preferred product, process or service with a clear understanding of the uncertainty and the assumptions used to generate the results.

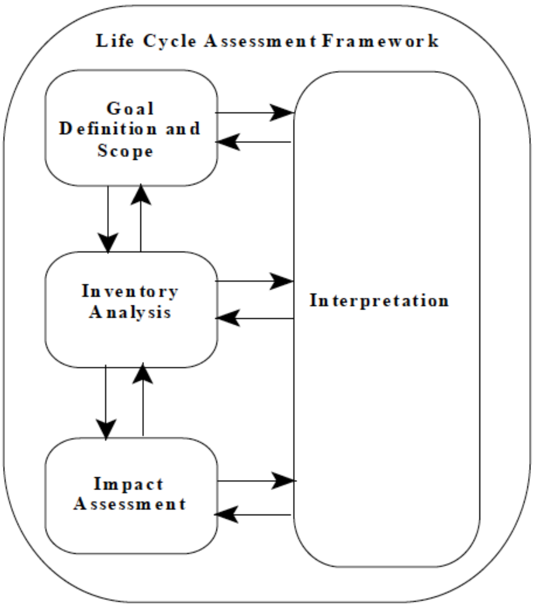

*Figure 5. Phases of an LCA (Source: ISO, 1997)*

This detailed LCA will inevitably lead to a better understanding of the contributing materials, impacts and sustainability challenges of the product. This becomes a valuable consideration of the environmental, economic and social consequences of manufacturing, consuming and managing the product sustainably.

LCA can be very expensive to conduct, but clearly defining the product, scope and boundaries will allow a more accurate assessment of cost and benefit (i.e. value).

# 5 Energy Production Potential

## 5.1 Technological options for renewable energy production

Renewable energy comes from natural, inexhaustible resources such as wind, solar, geothermal, tides and waves. Bioenergy is renewable energy that is produced from living things or biological sources and is considered renewable because the feedstock is replenishable.

Feedstock for bioenergy production is varied and includes: wheat and sugar beet for ethanol production; tallow and abattoir waste; agricultural wastes like prunings, grape marc, rice and wheat husks, nut shell, excess fruit; manures from piggeries, dairies and poultry production; wood, wood waste and thinnings from forestry or energy plantings; and oil from palm oil plantations.

New technologies for renewable energy production are rapidly emerging in response to the rising price of fossil fuel based energy, growing awareness of the impacts of climate change and implementation of polices related to reducing $CO_2$ emissions and other greenhouse gases. A common form of bioenergy in Australia are cogeneration systems at sugar mills that burn bagasse (the fibrous material remaining after processing sugar cane), producing heat and electricity using steam turbine generators. These systems vary in size from 1 MW to 50 MW with a number being connected to the grid.

Almond hull and shell is a woody waste. It has a calorific content of 16-18 kJ/kg (Chen *et al.* 2010), which is comparable with the energy content levels of other lignocellulosic biomass. It has a low moisture content which was recorded as low as 3% by Gómez *et al.* (2010). Moisture content may clearly increase if waste hull and shell are left in an exposed site after processing.

### Converting almond hull and shell into energy

Bioenergy technologies fall into two main categories, first generation and second generation biofuels. First generation biofuels come from common food crops like sugar beet, grains and oil seeds to produce ethanol and biodiesel. They also include processing of wastes like manures through anaerobic digestion to produce biogas. However, second generation biofuel processes are better equipped to process the ligno-cellulosic material found in woody wastes. This can be done through (a) biochemical pathways, which employ enzymes and microorganisms to convert cellulose and hemicelluloses to sugars that are fermented to produce ethanol and (b) thermo-chemical pathways to produce synthesis gas (Sims *et al.* 2008). Of the thermo-chemical pathways, gasification is perhaps the most common and is considered further here.

Gasification converts fossil (e.g. coal) or renewable material (e.g. wood) containing carbon into producer gas (also called syngas) at high temperatures. The gas is then used in a gas engine or gas turbine to produce heat and electricity. Four types of reactors exist: updraft or countercurrent gasifiers; downdraft or co-current gasifiers; cross-draft gasifiers; and fluidised-bed gasifiers (Quaak *et al.* 1999).

Combustion is another process that uses thermo-chemical pathways (i.e. chemical changes that occur when heat is applied to a material, in this case biomass, in the absence of oxygen); however, in contrast to gasification, it produces hot flue gases that can be used directly for baking and drying or indirectly with heat exchangers such as boilers for the production of steam or hot water. This can in turn be used to generate electricity using a steam cycle. Combustion is a well established approach and is the technology used for generating energy for Suncoast Gold Macadamias (Box 1).

**Box 1. Suncoast Gold Macadamias Biomass Cogeneration Facility.**

AGL's Biomass Cogeneration Facility in Queensland is claimed to be the world's first and only macadamia shell powered cogeneration project and aims to convert 5,000 tonnes of shell waste into a biofuel to generate renewable energy. The shell husks from the macadamia nuts are burnt in a 6 MW steam boiler, with steam used to dry the nuts and also to power a 1.4 MW steam turbine and generate renewable energy for the site and export to the grid. The plant produces ~5,500 MWh of renewable electricity each year, reduces landfill waste, creates renewable energy and reduces greenhouse gas emissions by more than 5,100 tonnes of CO2 per annum.

Quaak *et al.* (1999) provide a useful discussion on the relative merits of combustion versus gasification technologies. Their key conclusions were that:

- Combustion systems based on steam cycles are technically mature and commercially available. Even the most advanced concepts are technically proven.
- The steam cycle used for combustion systems is a proven technology used in most large-scale thermal power plants. However, on a smaller scale (< 5 MWe) the cycle tends to be complicated and comparatively inconvenient. Steam cycles <1 MWe tend to be expensive.

- Gasification systems are commercially available. However, small-scale applications need much supervision and suffer from frequent interruptions. Development of gasification systems is directed toward increasing their performance and reliability.
- Advanced integrated gasification and combined heat and power concepts are promising but still not demonstrated.
- It cannot be concluded that one concept is more attractive than the other. Rather, feasibility studies must be performed in each case to determine which system is most suitable

Since this report was published in 1999 there has been further development and demonstration of gasification systems. They have also been demonstrated to work using similar feedstocks to almond hull and shell e.g. walnut shells (see Box 2) and responses from gasification suppliers indicate that almond hull and shell would be a suitable feedstock. As such, this study has focussed further data collection on gasification systems. This should not be taken to imply that combustion would not prove to be a suitable technology for the almond industry. The choice of gasification or combustion would need to be assessed on a case by case basis should entities within the almond industry proceed to a detailed feasibility study.

**Box 2. Dixon Ridge Farms – Gasifying walnut shells for heat and electricity**[7]

Dixon Ridge Farms is based in California and grows, processes and sells organic walnuts. In the past, most of the walnut shell was sold to a nearby large commercial biomass plant. In 2007, the farm set a goal of being energy self-sufficient and carbon negative. The farm sought an on-site energy production solution that would use the shell as an on-site feedstock for generation of power, heat and eventually synthetic diesel fuel. The farm worked with Community Power Corporation (CPC) to install a BioMax® 50 System that could convert the walnut shell into electricity and heat. The BioMax® 50 System produces ~4,400 ft3 of syngas from approximately 100 pounds (45 kg) of shell/hour. The syngas operates an engine generator that produces up to 50 kW of electricity. During the harvest season, some of the syngas is diverted to four modified axial fan dryers to displace propane (LPG) and dry the walnut crop.

The farm recently added a second BioMax® System increasing its renewable electric energy production by 100 kW. The BioMax® 100 System was delivered to the farm in September 2012, and is being prepared for commercial operation. The BioMax 50 and 100 Systems at the farm will work in tandem to provide both electric and syngas to the farm's walnut processing facilities. The syngas is directed to crop drying equipment, rather than the electric generation equipment, for about two (2) months each year. The syngas displaces propane in the drying process, reducing costs significantly. The Dixon Ridge BioMax® 50 was installed in 2008 and has operated for more than 32,000 hours. The owner of Dixon Ridge has said that: "We estimate that the walnut shell that we would normally sell for $20/ton are worth $150/ton when gasified and used to offset our on-site heat and electricity costs."

http://www.gocpc.com/dixon-ridge-success-story.html
http://www.dixonridgefarms.com/accolades.html

A further point of note is the difference between pyrolysis and gasification. Technically speaking, pyrolysis is one step in the gasification process and involves thermal de-composition of feedstock in the absence of oxygen into pyrolysis oil, syngas and solid char. In gasification, the majority of the hydrocarbons are instead broken down into syngas and ash. Pyrolysis would be a better choice where there is specific value ascribed to the pyrolysis oil or char.

There is increasing interest in the use of char, also called biochar, as a soil ameliorant because of its reported ability to improve soil productivity through improved water and nutrient retention. The stability of the carbon in the form of biochar is also attractive because it may provide a way of sequestering carbon in the soil and generating carbon offsets under the Carbon Farming Initiative.

The use of biochar in almond orchards would require some testing because of the need to ground harvest almond fruit after they are shaken from the trees. This could involve trialling methods that would incorporate the biochar below the soil surface (e.g. discing as used for no-till farming). Pyrolysis could also be used to generate activated carbon, which according to Chen at al. (2010) is experiencing increasing global demand of 5.2%. Pyrolysis has not been considered further in this study, but as for combustion systems, it may form part of a detailed feasibility study into renewable energy production if some of the benefits of pyrolysis like biochar are particularly sought after.

## Almond hull and shell as a gasification feedstock?

While gasification is attractive for biomass conversion into an energy source, Quaak *et al.* (1999) suggests there are many reactants and possible reaction pathways meaning the process can be hard to control and operate successfully. Use of almond hull and shell to produce energy via gasification or other means is uncommon around the world so there are few direct comparisons for the Australian almond industry to learn from.

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[7] Adapted with permission from promotional material provided by Community Power Corporation.

Discussions with suppliers demonstrated the lack of experience with using almond hull and shell as a gasification feedstock. There were some enthusiastic suppliers who suggested it would be suitable, subject to further testing. This calls into question the need for pilot projects involving pre-testing of the operation of gasification systems prior to their commissioning. Nevertheless, it can be assumed with confidence that almond hull and shell is suitable, subject to identifying appropriate gasification technology.

## How much waste is required to meet onsite energy demands?

In considering the size of system that may be required it is necessary to consider the average energy demand of an almond hulling and processing facility compared with the power generated by different sized units. Using the data presented in Section 3, we can assume that processing a tonne of hull and shell requires 20 - 90 kWh per tonne of material processed. A site with 10,000 tonnes of hull and shell would therefore consume 500,000 kWh of electricity if a mid point for electrical consumption of 50 kWh per tonne processed is used. This can be compared with the amount of electricity produced if all 10,000 tonnes of hull and shell was gasified, which would be in the range of 5,000,000 to 10,000,000 kWhs.

*Table 11. Key specifications for gasification systems based on a review of information provided by suppliers.*

| Variable | Range | Mean | Median |
|---|---|---|---|
| Conversion of biomass into electricity (kg per kWe) | 0.8 – 1.7 | 1.3 | 1.5 |
| Ratio of heat to electricity produced (kW thermal to kW electrical) | 1.0 – 3.0 | 1.9 | 2.0 |

The exact proportion of material that would need to be gasified to meet on site energy demand will depend on the energy efficiency of the site and the rate of conversion of biomass to energy for a particular system. However, as a guide less than 20% of available feedstock would be required to meet onsite energy demand and in some instances could be less than 10%. These figures should be considered indicative only and would need to be verified on a site by site basis.

## How big does the gasification system need to be?

Traditionally, commercial scale gasification systems have been at least 1 MW in capacity. However, over the past decade there has been increased experience in developing and demonstrating smaller scale systems. These small scale systems can be more attractive for the purpose of meeting onsite energy generation and less likely to be of interest in feeding power back into the grid because of the higher cost per kW than larger systems.

The difference between the size of system that is required to meet energy demands compared with the size of system that could be sustained given available hull and shell can be explored using a hypothetical huller and sheller producing 10,000 tonnes of hull and shell per annum. As described earlier, it can be assumed that this would require 500,000 kWh of electricity per annum. This amount of electricity could be met with a 62 kW system operating at 8,000 hours per annum. In contrast, the 10,000 tonnes of hull and shell could satisfy a 600 to 1200 kW capacity system operating at 8,000 hours per annum. The size of system chosen will be largely influenced by the site specific business case which is explored in Section 6. Some considerations though are as follows:

- Energy demand – The optimal sized system needs to consider the site specific energy demand, which is never "smooth' throughout the year. For example, electricity consumption is variable such as between months when processing is or is not occurring, within months when processing loads vary (e.g. 1, 2 or 3 shifts) and within days depending on when shifts begin and end. The selection of a system would need to consider what the maximum periods of power consumption are during times of peak and off peak pricing, and the extent to which the selected system should be large enough to meet this demand in part or full.
- The size of available gasification units - While the example above identified a theoretical 62kW system, a system with this rating does not exist. Smaller gasification systems are more typically modular and this study identified systems that were generally 25, 50 or 100 kW in size. While some suppliers indicate that systems as small as 10kW are available these were not common based on the information reviewed for this study.

This study has identified suppliers of a range of smaller capacity units. Examples of gasification systems provided by Community Power Corporation are presented in Figure 6.

## Electricity and heat

Much of the discussion presented in this section of the report describes production of electricity. Heat can also be produced in significant quantities from gasification systems via combined heat power (CHP) units. This is important for the industry given the energy demand analysis revealed a significant proportion of the energy costs at a number of sites are from purchase of LPG for production of heat. Review of the information provided by suppliers suggests the ratio of heat produced per unit of electricity ranged from 1:1 to 3:1, depending on the type of system installed (Table 11).

## Operation

Of concern to some members of the almond industry is the additional burden that could come with operating a power generation facility. Quaak *et al.* (1999) suggests that the gasifier/engine installation is relatively simple, but operation is difficult and may require regular cleaning and removal of tar from critical parts of the plant. In contrast, operation of combustion systems is said to be straightforward but requires "skilled and motivated operators".

Other issues include diversion of resources and attention away from the core business of hulling and shelling or processing kernels. A number of the units identified during this study are described as being "automatic". This means that the system is self-operating provided a hopper is regularly filled with waste material. This may be feasible given machinery is already used to move almond hull and shell at onsite storage facilities.

*Figure 6. Modular gasification systems supplied by Community Power Corporation.*

## 5.2 Other options for use of hull and shell

There are various other options that have been identified during this project that could be used in conjunction with energy production or to produce other products that increase the value of hull and shell. While they have not been included in the economic analysis, they could merit further consideration and as such an overview is provided below.

### Briquetting

Briquettes can be made from woody waste under high pressure. The resulting briquettes have a variety of markets. They can be co-fired in boilers with coal or used at a small scale for wood burning stoves or fire places. Briquettes sold into suburban markets are often described as eco-briquettes or carbon neutral heat logs and marketed as being made from a renewable resource or involving re-utilisation of waste. Briquetting machines are available from suppliers around the world including from the United Kingdom (e.g. Biotech Green http://www.biogreentech.com/, which makes direct reference to use of almond hull and shells), Italy (e.g. DI PIU', http://www.di-piu.com/), India and China.

Briquettes have a higher density than milled or unmilled hull and shell meaning that transport costs would be lower. This could make transport of feedstock to another site for energy production more attractive.

### Pelletising

Pelletisers take a variety of forms of organic material and convert them into uniformly size pellets. In the case of woody waste, these pellets can be used on their own or co-fired with other feedstocks to produce energy. Wastes palatable to cattle can also be converted into feed pellets.

Pelletising could provide a range of benefits for the almond industry. Pellets have a higher density than milled or unmilled hull and shell meaning that transport costs would be lower. As for briquetting this could make transport of feedstock to another site for energy production more attractive. Alternately, the pelletised hull and shell could be sold direct to cattle feedlots, rather than requiring an intermediary stock feed company to pelletise the material.

### Composting

In its most simple form, hull and shell can be used as a surface mulch. Processing of the hull and shell though can result in compost with improved qualities, as the waste contains relatively high quantities of certain elements, in particular potassium and nitrogen. The introduction of third party material with further nutrient content (e.g. poultry manures) may significantly add to the value of the compost as a soil ameliorant or fertiliser. However, the incorporation of this material has some risks that need to be managed, such as weed seeds, foreign material (e.g. glass, plastic, metal) and food safety (e.g. bacteria, moulds, etc). Hull and shell compost may be more profitable if it can be sold into other sectors such as the domestic gardening market.

Delivery of waste to a commercial composter incurs a gate fee and costs the deliverer approximately $35 per tonne of delivered weight. Commercial composters could alternately undertake contract composting on-site for approximately $18-20 per cubic meter, subject to the necessary EPA approvals being obtained. It has been estimated that a minimum of 20,000 tonnes of compost needs to be produced per annum to justify the capital investment of a composting facility. It is estimated that a facility costing approximately $3,000,000 could produce 100,000 to 150,000 tonnes of compost per year. Compost could be sold for $100 per tonne or $380-$400 per tonne if it is pelletised. The cost of pelletising is approximately $80 per tonne.

### Vermiculture

Vermiculture is the process of using worms to compost organic material which incorporates worm castings in the product. Vermiculture can generate income from two products: blended vermicastings with the unused composted feedstock (known as composite mix) and liquid vermicastings. While testing would be required, the liquid vermicastings would presumably be suitable for use in fertigation systems.

### Anti-oxidants

Chen *et al*. (2010) provides a summary of the potential for almond hull to be used to produce anti-oxidants for the food industry. Antioxidants in almond residues may be extracted with ethanol, methanol and warm water and have potential to become natural food preservation additives and dietary/nutriceutical supplements. Chen at al. (2010) suggests that extraction of phytochemicals from the residues before the residues are converted to energy presents an "excellent business opportunity".

# 6 Economic Analysis of Energy Production from Almond Waste

## 6.1 Data sources and assumptions

### 6.1.1 Data sources

The costs and benefits of the project were measured using a 'with' and 'without' project framework; that is, quantification of the incremental changes associated with the Renewable Energy Production from Almond Waste project compared with the base case scenario. The options assessed were:

- Base Case - Maintain existing system of disposal of almond hull and shell waste, i.e. by selling it as stockfeed.
- Option 1 - Install a (100 kW) biomass gasification system to generate electricity to meet average hulling/shelling process demand. The remainder of the hull and shell waste sold as stockfeed.
- Option 2 - Install a (550 kW) biomass gasification system to generate electricity to meet peak hulling/shelling process demand. The remainder of the hull and shell waste sold as stockfeed.
- Option 3 - Install a (1,923 kW) biomass gasification system to generate electricity to use all hulling and shelling waste. No hull and shell waste sold as stockfeed.

The method, data sources and assumptions used to quantify these values are described below. Consideration was given to those benefits and costs likely to occur over a 20 year time period. Tables in this section contain derived figures based on information provided by Mark Siebentritt & Associates.

The major economic costs and benefits of the project are listed in Tables 12 and 13, respectively. The estimation of each of the items is detailed below and was based on a series of assumptions regarding installation, operating and maintenance costs and benefits.

Sensitivity analyses were undertaken to reflect the uncertainty associated with these assumptions. Further details of these analyses and results are detailed in Section 4 of this report.

*Table 12. Costs of the Renewable Energy Production from Almond Waste project options. The source of the information used to prepare these tables was Mark Siebentritt & Associates.*

| Option | Description of Costs | Bearer of Cost | Valued in Monetary Terms |
|---|---|---|---|
| Base Case | Cost of grid electricity and bottled LPG gas consumed | Almond processor | Yes |
| Option 1 to 3 | Cost of installation of the biomass gasification system | Almond processor | Yes |
| Option 1 to 3 | Replacement costs for assets with useful lives shorter than 20 years (analysis period) | Almond processor | Yes |
| Option 1 to 3 | Cost of maintaining and operating biomass gasification system | Almond processor | Yes |
| Option 1 | Cost of grid electricity and bottled LPG gas consumed | Almond processor | Yes |
| Option 3 | Cost of installation of electricity feed-into-the-grid connection | Almond processor | Yes |
| Option 3 | Cost of maintaining electricity feed-into-the-grid connection | Almond processor | Yes |

*Table 13. Benefits of the Renewable Energy Production from Almond Waste project options. The source of the information used to prepare these tables was Mark Siebentritt & Associates.*

| Option | Description of Benefits | Beneficiary | Valued in Monetary Terms |
|---|---|---|---|
| Base Case | Revenue from sale of almond waste as cattlefeed | Almond processor | Yes |
| Option 1 to 3 | Clean Technology Investment Program Grant | Almond processor | Yes |
| Option 1 to 3 | Residual value of project capital | Almond processor | Yes |
| Option 1 to 3 | Savings from avoided consumption of grid electricity and bottled LPG gas | Almond processor | Yes |
| Option 1 and 2 | Revenue from sale of almond waste as cattlefeed | Almond processor | Yes |
| Option 3 | Revenue from sale of on-site generated electricity into the grid | Almond processor | Yes |

### 6.1.2 Quantifiable costs and benefits

#### Capital costs

The capital costs associated with the Renewable Energy Production from Almond Waste project options are detailed in Table 14.

*Table 14. Estimated installation costs for the Renewable Energy Production from Almond Waste project options.*

| Cost Item ($'000) | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Biomass gasification system | 950 | 5,225 | 18,269 |
| Electricity feed-in grid connection | | | 962 |
| **Total** | **950** | **5,225** | **19,231** |

Details of the asset life and the residual value of the asset beyond the analysis period are provided in Table 15.

*Table 15. Assets of the Renewable Energy Production from Almond Waste project options.*

| Cost Item ($'000) | Purchase Price ($) | Useful Life (yrs) | Residual Value ($) |
|---|---|---|---|
| *Option 1* | | | |
| Biomass gasification system | 950 | 20 | 0 |
| *Option 2* | | | |
| Biomass gasification system | 5,225 | 20 | 0 |
| *Option 3* | | | |
| Biomass gasification system | 18,269 | 20 | 0 |
| Electricity feed-in grid connection | 962 | 20 | 0 |

## Operating and maintenance costs

The amount of grid electricity and bottled LPG gas consumed under each option is detailed in Table 16.

*Table 16. Estimated grid electricity and bottled LPG gas consumed for all options.*

| | Electricity (kW.h/yr) | LPG gas (L/yr) |
|---|---|---|
| Base case | 800,000 | 40,000 |
| Option 1 | 365,883 | 0 |
| Option 2 | 0 | 0 |
| Option 3 | 0 | 0 |

The price for peak electricity was estimated to be 22.8 c/kWh and for off-peak it was estimated to be 8.0 c/kWh. Electricity prices were assumed to rise by 7.9 per cent per year in the first 3 years and 1.4 per cent per year thereafter (SKM and MMA, 2011). The price of LPG gas was estimated to be $1.03/L and was assumed to rise by 1.7 c per year based on historical trends[8]. The costs of maintaining and operating the biomass gasification system and feed-in grid connection are provided in Table 17.

*Table 17. Estimated annual operating and maintenance costs for the biomass gasification system and feed-in grid connection.*

| | BGS ($'000/yr) | Grid connection ($'000/yr) |
|---|---|---|
| Option 1 | 86 | |
| Option 2 | 470 | |
| Option 3 | 1,644 | 2 |

Based on the above information, the estimated annual operating costs for renewable energy production from almond waste is provided in Table 18.

*Table 18. Estimated annual operating costs for the Renewable Energy Production from Almond Waste project*

| | Operating and Maintenance Cost ($'000/annum) | | | | |
|---|---|---|---|---|---|
| | Year 0 | Year 1 | Year 2 | Year 3 | Year 19 |
| *Base case* | | | | | |
| Electricity | 145 | 156 | 169 | 182 | 1,174 |
| Gas | 41 | 42 | 42 | 43 | 54 |
| *Option 1* | | | | | |
| Bioenergy gasification system | 86 | 86 | 86 | 86 | 86 |
| Electricity | 66 | 71 | 77 | 83 | 537 |
| *Option 2* | | | | | |
| Bioenergy gasification system | 470 | 470 | 470 | 470 | 470 |
| *Option 3* | | | | | |
| Bioenergy gasification system | 1,644 | 1,644 | 1,644 | 1,644 | 1,644 |
| Grid connection | 2 | 2 | 2 | 2 | 2 |

## Clean Technology Investment Program Grant

The analysis assumed that a grant from the Clean Technology Investment Program for 50 per cent of the initial capital investment would be secured.

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[8] Department of Commerce, and, Fuel Watch Historical Price, sourced from: http://www.fuelwatch.wa.gov.au/fuelwatch/pages/public/historicalPriceSearch.jspx on 15/11/2012

### Revenue from sale of almond waste as cattlefeed

For the base case, Option 1 and Option 2 it is assumed that almond hull and shell waste not disposed of by other means, is sold as un-milled cattlefeed. The factory-gate price of un-milled cattlefeed was estimated to be $23/tonne. The estimated annual revenue from cattlefeed for the base case and options 1 and 2 is provided in Table 19.

*Table 19. Estimated annual revenue from the sale of cattlefeed the Renewable Energy Production from Almond Waste project*

| | Revenue from sale of cattlefeed ($'000/annum) | | | | |
|---|---|---|---|---|---|
| | Year 0 | Year 1 | Year 2 | Year 3 | Year 19 |
| Base case | 450 | 450 | 450 | 450 | 450 |
| Option 1 | 427 | 427 | 427 | 427 | 427 |
| Option 2 | 321 | 321 | 321 | 321 | 321 |

### Savings from avoided consumption of grid electricity and bottled LPG gas

The biomass gasification system generates heat and electricity, reducing or avoiding the need to use purchased gas or electricity. The estimated annual savings from avoided consumption of grid electricity and bottled LPG gas is provided in Table 20.

*Table 20. Estimated annual savings from avoided consumption of grid electricity and bottled LPG gas.*

| | Savings from avoided purchases of electricity and gas ($'000/annum) | | | | |
|---|---|---|---|---|---|
| | Year 0 | Year 1 | Year 2 | Year 3 | Year 19 |
| *Option 1* | | | | | |
| Electricity | 79 | 85 | 91 | 99 | 637 |
| Gas | 41 | 42 | 42 | 43 | 54 |
| *Option 2* | | | | | |
| Electricity | 145 | 156 | 169 | 182 | 1,174 |
| Gas | 41 | 42 | 42 | 43 | 54 |
| *Option 3* | | | | | |
| Electricity | 145 | 156 | 169 | 182 | 1,174 |
| Gas | 41 | 42 | 42 | 43 | 54 |

### Revenue from sale of on-site generated electricity into the grid

The estimated annual revenue of on-site generated electricity into the grid for Option 3 is provided in Table 21.

*Table 21. Estimated annual revenue from the sale of on-site generated electricity into the grid (Option 3).*

| | Revenue from sale of on-site generated electricity ($'000/annum) | | | | |
|---|---|---|---|---|---|
| | Year 0 | Year 1 | Year 2 | Year 3 | Year 19 |
| Option 3 | 729 | 729 | 729 | 729 | 729 |

## 6.2 Results of the financial analysis

### 6.2.1 Results

The results of the financial analysis have been expressed in terms of two evaluation criterion, the net present value (NPV) and the benefit cost ratio (BCR). The NPV is a measure of the aggregate, annual net benefits (i.e. benefits – costs) of an option over a 20 year period, discounted (i.e. expressed as a present value[9]) using a discount rate of 8 per cent. BCR is the ratio of the present value of benefits to the present value of costs.[10]

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[9] The present value is the value now of a sum of money arising in the future. Money now is worth more than money in the future because it could be invested now to produce a greater sum in the future. The present value of money in the future is calculated by discounting it at a rate of interest equivalent to the rate at which it could be invested (Bannock et al. 1979).

[10] For more detailed explanation of each criterion and the method of analysis see Section 2.2.

*Option 1*

- The net present value of the Renewable Energy Production from Almond Waste project for Option 1 was estimated to be approximately $0.527 million. This indicates that the investment in Option 1 would generate higher net benefits than the base case scenario.
- Consistent with a positive NPV result, the benefit-cost ratio for Option 1 was calculated to be 1.28. This indicates that the incremental benefits of Option 1 are greater than the incremental costs (i.e. for every $1 spent, $1.28 is returned).
- The principal driver of the estimated positive financial outcome is the relatively small capital investment ($0.95 million) required to undertake Option 1.

*Option 2*

- The net present value of the Renewable Energy Production from Almond Waste project for Option 2 was estimated to be approximately -$5.399 million. This indicates that the investment in Option 2 would not generate higher net benefits than the base case scenario.
- Consistent with a negative NPV result, the benefit-cost ratio for Option 2 was calculated to be 0.47. This indicates that the incremental costs of Option 2 are greater than the incremental benefits (i.e. for every $1 spent, $0.47 is returned).
- The principal driver of the estimated negative financial outcome is the relatively large capital investment ($5.225 million) required to undertake Option 2.

*Option 3*

- The net present value of the Renewable Energy Production from Almond Waste project for Option 3 was estimated to be approximately -$20.545 million. This indicates that the investment in Option 3 would not generate higher net benefits than the base case scenario.
- Consistent with a negative NPV result, the benefit-cost ratio for Option 3 was calculated to be 0.44. This indicates that the incremental costs of Option 3 are greater than the incremental benefits (i.e. for every $1 spent, $0.44 is returned).
- The principal driver of the estimated negative financial outcome is the large capital investment ($19.231 million) required to undertake Option 3. A minimum of an average feed-in tariff rate of 18.3 c/kW.h, rather than the 5c/kW.h used in this analysis, would need to be achieved in order to attain a positive NPV.

### 6.2.2 Sensitivity analysis

The results of the financial analysis were re-estimated using values for key variables that reflect the uncertainty of those variables. The sensitivity analyses included changes in the following:

- discount rate;
- with and without the Clean Technology Investment Program grant;
- size of the biomass gasification system;
- biomass gasification system cost per unit;
- energy efficiency of processing operation;
- proportion of peak and off-peak electricity used;
- price of peak electricity;
- electricity price increase (years 4 to 19);
- proportion of electricity consumed above average demand; and
- feed-in tariff.

The range of values used for each uncertain variable and detailed results of the sensitivity analysis are set out below with some interpretation of the results. Note that the sensitivity analysis was undertaken by assuming that all other variables were held constant at their 'expected' values.

## Discount rate

Costs and benefits are specified in real terms (i.e. constant 2012 dollars) and future values are converted to present values by applying a discount rate of 8%. A sensitivity analysis was conducted using discount rates of 6 and 10 per cent. The results are detailed in Table 22.

*Table 22. Sensitivity of results of the analysis to changes in the discount rate.*

| Discount Rate | Option 1 | | Option 2 | | Option 3 | |
|---|---|---|---|---|---|---|
| | NPV [a] ($'000) | BCR [a] | NPV [a] ($'000) | BCR [a] | NPV [a] ($'000) | BCR [a] |
| 6 per cent | 809 | 1.41 | -5,561 | 0.49 | -21,901 | 0.44 |
| 8 per cent [b] | 527 | 1.28 | -5,399 | 0.47 | -20,545 | 0.44 |
| 10 per cent | 317 | 1.18 | -5,241 | 0.46 | -19,435 | 0.44 |

[a] In 2012 dollars.
[b] Expected value.
Source: EconSearch analysis

The results were shown to be relatively insensitive to changes in the discount rate.

## With and without the Clean Technology Investment Program grant

The CBA included a Clean Technology Investment Program (CTIP) grant for 50 per cent of the initial investment costs. The impact of this grant on the NPV and BCR of the options was tested by removing the grant from the analysis. The results are presented in Table 23.

*Table 23. Sensitivity of results of the analysis to inclusion/exclusion of the CTIP grant*

| Discount Rate | Option 1 | | Option 2 | | Option 3 | |
|---|---|---|---|---|---|---|
| | NPV [a] ($'000) | BCR [a] | NPV [a] ($'000) | BCR [a] | NPV [a] ($'000) | BCR [a] |
| 6 per cent | 809 | 1.41 | -5,561 | 0.49 | -21,901 | 0.44 |
| 8 per cent [b] | 527 | 1.28 | -5,399 | 0.47 | -20,545 | 0.44 |
| 10 per cent | 317 | 1.18 | -5,241 | 0.46 | -19,435 | 0.44 |

[a] In 2012 dollars.
[b] Expected value.
Source: EconSearch analysis

From the sensitivity analysis it can be seen that the CTIP grant had a significant impact on the magnitude of the results of the different options, although it did not affect the overall outcome (i.e. Option 1 maintained a positive NPV and Options 2 and 3 maintained negative NPV's).

## Energy efficiency of processing operation

Due to the differing energy efficiencies observed in this project, there is a range in the power demanded and electricity consumed. A range including the most and least energy efficient operations was tested. The results of this sensitivity analysis are presented in Table 24.

*Table 24. Sensitivity of results of the analysis to energy efficiency of processing operation.*

| Processing operation energy efficiency | Option 1 |  | Option 2 |  | Option 3 |  |
|---|---|---|---|---|---|---|
|  | NPV [a] ($'000) | BCR [a] | NPV [a] ($'000) | BCR [a] | NPV [a] ($'000) | BCR [a] |
| 20 kW.h/t | 506 | 1.55 | -6,938 | 0.32 | -21,872 | 0.40 |
| 40 kW.h/t [b] | 527 | 1.28 | -5,399 | 0.47 | -20,545 | 0.44 |
| 90 kW.h/t | 578 | 1.14 | -1,549 | 0.85 | -17,226 | 0.53 |

[a] In 2012 dollars.
[b] Expected value (kW.h/t processed).
Source: EconSearch analysis

From the sensitivity analysis it can be seen that processing operation energy efficiency has a significant effect on the NPV and BCR for Option 2, and less of an impact on Option 1 and 3.

## Size of the biomass gasification system (BGS)

Due to the differing energy efficiencies observed in this project, there is a range in the power demanded and the overall consumption of electricity. Therefore a range in size of the BGS to meet these energy profiles can be expected for Option 1 and 2. The results of the sensitivity analysis are presented in Table 25 for Option 1 and Table 26 for Option 2.

*Table 25. Sensitivity of results of the analysis to the size of the biomass gasification system, Option 1.*

| Size of BGS | Option 1 |  |
|---|---|---|
|  | NPV [a] ($'000) | BCR [a] |
| 50 kW | 1,218 | 2.31 |
| 100 kW [b] | 527 | 1.28 |
| 225 kW | -1,200 | 0.71 |

[a] In 2012 dollars.
[b] Expected value.
Source: EconSearch analysis

From the sensitivity analysis it can be seen that size of the BGS has a significant effect on the NPV and BCR for Option 1, and can for the least energy efficient operations (i.e. those requiring bigger than expected BGS) turn a positive NPV into a negative NPV.

*Table 26. Sensitivity of results of the analysis to the size of the biomass gasification system, Option 2.*

| Size of BGS | Option 3 | |
|---|---|---|
| | NPV [a]<br>($'000) | BCR [a] |
| 1,563 kW | -15,476 | 0.48 |
| 1,923 kW [b] | -20,545 | 0.44 |
| 2,500 kW | -28,666 | 0.40 |

[a] In 2012 dollars.
[b] Expected value.
Source: EconSearch analysis

From the sensitivity analysis it can be seen that size of the BGS has a significant effect on the NPV and BCR for Option 2, although it did not affect the overall outcome.

For Option 3 the size of the BGS is determined by the conversion rate of biomass to electricity. The range of likely values for the conversion rate of biomass to electricity was found to have limited effect on the results of options 1 to 3, and similarly the range in size of the BGS for Option 3 was found to have little impact on the results of the analysis (see Table 27).

*Table 27. Sensitivity of results of the analysis to the size of the biomass gasification system, Option 3*

| Size of BGS | Option 3 | |
|---|---|---|
| | NPV [a]<br>($'000) | BCR [a] |
| 1,563 kW | -15,476 | 0.48 |
| 1,923 kW [b] | -20,545 | 0.44 |
| 2,500 kW | -28,666 | 0.40 |

[a] In 2012 dollars.
[b] Expected value.
Source: EconSearch analysis

### Biomass gasification system cost per unit

This project found a wide range in prices for BGS cost per kW installed. A sensitivity analysis was undertaken with the full range of prices identified (see Table 28).

*Table 28. Sensitivity of results of the analysis to biomass gasification system cost per unit*

| Unit cost of BGS | Option 1 | | Option 2 | | Option 3 | |
|---|---|---|---|---|---|---|
| | NPV [a]<br>($'000) | BCR [a] | NPV [a]<br>($'000) | BCR [a] | NPV [a]<br>($'000) | BCR [a] |
| $3,000/kW | 1,472 | 3.51 | -199 | 0.94 | -2,366 | 0.81 |
| $9,500/kW [b] | 527 | 1.28 | -5,399 | 0.47 | -20,545 | 0.44 |
| $12,000/kW | 163 | 1.07 | -7,398 | 0.43 | -27,537 | 0.40 |

[a] In 2012 dollars.
[b] Expected value.
Source: EconSearch analysis

From the sensitivity analysis it can be seen that the unit cost for the BGS has a significant effect on the NPV and BCR for all three options, although it did not affect the overall outcome (i.e. Option 1 maintained a positive NPV and Options 2 and 3 maintained negative NPV's).

## Proportion of peak and off-peak electricity used

This project has observed varying proportions in the use of peak to off-peak electricity between different operations. A sensitivity analysis was undertaken with a representative range of peak to off-peak electricity use profiles (see Table 29).

*Table 29. Sensitivity of results of the analysis to proportion of peak and off-peak electricity used.*

| | Option 1 | | Option 2 | | Option 3 | |
|---|---|---|---|---|---|---|
| % peak electricity used | NPV [a] ($'000) | BCR [a] | NPV [a] ($'000) | BCR [a] | NPV [a] ($'000) | BCR [a] |
| 89 per cent | 958 | 1.52 | -4,604 | 0.55 | -19,750 | 0.46 |
| 69 per cent [b] | 527 | 1.28 | -5,399 | 0.47 | -20,545 | 0.44 |
| 48 per cent | 96 | 1.05 | -6,193 | 0.39 | -21,339 | 0.42 |

[a] In 2012 dollars.
[b] Expected value.
Source: EconSearch analysis

From the sensitivity analysis it can be seen that the variation in the proportionate use of peak to off-peak electricity has a significant effect on the NPV and BCR for Option 1, and less of an impact on Option 2 and 3. This can be explained by electricity consumption being proportionately more of the cost structure for Option 1 than for Option 2 and 3. This is because the capital costs for Option 1 are relatively small in comparison to Option 2 and 3. Furthermore, the more peak energy is used the higher the cost of operation and hence the higher the potential is for cost saving.

## Price of peak electricity

This project has observed variation in the price of peak and off-peak electricity between different operations. A sensitivity analysis was undertaken with a representative range of peak and off-peak price profiles. It was found that the range in off-peak electricity prices had limited impact on the results of the analysis. The results of the sensitivity analysis for the price of peak electricity are presented in Table 30.

*Table 30. Sensitivity of results of the analysis to the price of peak electricity.*

| | Option 1 | | Option 2 | | Option 3 | |
|---|---|---|---|---|---|---|
| Price of peak electricity | NPV [a] ($'000) | BCR [a] | NPV [a] ($'000) | BCR [a] | NPV [a] ($'000) | BCR [a] |
| 25.5 c/kW.h | 700 | 1.38 | -5,080 | 0.50 | -20,226 | 0.45 |
| 22.8 c/kW.h [b] | 527 | 1.28 | -5,399 | 0.47 | -20,545 | 0.44 |
| 16.7 c/kW.h | 143 | 1.08 | -6,107 | 0.40 | -21,253 | 0.42 |

[a] In 2012 dollars.
[b] Expected value.
Source: EconSearch analysis

From the sensitivity analysis it can be seen that the variation in the price of peak electricity has a significant effect on the NPV and BCR for Option 1, and less of an impact on Option 2 and 3. This can be explained by electricity consumption being proportionately more of the cost structure for Option 1 than for Option 2 and 3. This is because the capital costs for Option 1 are relatively small in comparison to Option 2 and 3.

## Electricity price increase (years 4 to 19)

This analysis modeled a real increase in the price of electricity of 7.9 per cent in years 1 to 3 and 1.4 per cent thereafter. Sensitivity analysis was undertaken on these figures using a range of 50 per cent either side of the expected amount. The initial price increase (years 1 to 3) was found to have a limited impact on the results and is not reported. The results of the sensitivity analysis for the electricity price increase for years 4 to 19 are presented in Table 31.

*Table 31. Sensitivity of results of the analysis to the electricity price increase (years 4 to 19).*

| Electricity price increase Yr4-Yr19 | Option 1 | | Option 2 | | Option 3 | |
|---|---|---|---|---|---|---|
| | NPV [a] ($'000) | BCR [a] | NPV [a] ($'000) | BCR [a] | NPV [a] ($'000) | BCR [a] |
| 2.1 per cent | 1,345 | 1.72 | -3,892 | 0.62 | -19,038 | 0.48 |
| 1.4 per cent [b] | 527 | 1.28 | -5,399 | 0.47 | -20,545 | 0.44 |
| 0.7 per cent | 100 | 1.05 | -6,185 | 0.39 | -21,331 | 0.42 |

[a] In 2012 dollars.
[b] Expected value.
Source: EconSearch analysis

From the sensitivity analysis it can be seen that the variation in the electricity price increase has a significant effect on the NPV and BCR for Option 1, and less of an impact on Option 2 and 3. This can be explained by electricity consumption being proportionately more of the cost structure for Option 1 than for Option 2 and 3. This is because the capital costs for Option 1 are relatively small in comparison to Option 2 and 3.

## Proportion of electricity consumed above average demand

This parameter is relevant only to Option 1. This project has observed variation in the proportion of electricity consumed above average demand between different operations. All operations use electricity 24 hours per day, whether or not they run a shift (this is due to stand-by demand, refrigeration etc). Those operations that typically run one shift will have a highly skewed demand profile, with comparatively few instances of high demand and comparatively more instances of low demand than an operation that typically runs more shifts. As a result, for operations running one shift, the proportion of electricity consumed above the average demand will be higher than operations that run more shifts. The observed variation in this parameter was tested. The results of the sensitivity analysis are presented in Table 32.

*Table 32. Sensitivity of results of the analysis to the proportion of electricity consumed above average demand.*

| % electricity consumed above 100kW demand | Option 1 | |
|---|---|---|
| | NPV [a] ($'000) | BCR [a] |
| 23 per cent | 1,218 | 2.31 |
| 46 per cent [d] | 527 | 1.28 |
| 68 per cent | -1,200 | 0.71 |

[a] In 2012 dollars.
[b] Expected value.
Source: EconSearch analysis

From the sensitivity analysis it can be seen that the proportion of electricity consumed above the average demand (i.e. 100kW) has a significant effect on the NPV and BCR for Option 1, and can for the fewer shift operations (i.e. those with a higher proportion of electricity consumed above average demand than is expected) turn a positive NPV into a negative NPV.

## Feed-in tariff

This parameter is relevant only to Option 3. Wholesale electricity prices paid to generators who put electricity into the grid varies significantly from day-to-day and hour-to-hour. Conservative values were used in this analysis. For Option 3 the capital costs and the price received for electricity fed into the grid are the key drivers influencing the results. The results of the sensitivity analysis are presented in Table 33.

*Table 33. Sensitivity of results of the analysis to the feed-in tariff.*

|  | Option 3 |  |
|---|---|---|
| Feed-in tariff | NPV [a] ($'000) | BCR [a] |
| 18.3 c/kW.h | 24 | 1.00 |
| 9.0 c/kW.h | -14,359 | 0.61 |
| 5.0 c/kW.h [d] | -20,545 | 0.44 |
| 3.0 c/kW.h | -23,638 | 0.36 |

[a] In 2012 dollars.
[b] Expected value.
Source: EconSearch analysis

From the sensitivity analysis it can be seen that a power purchase agreement where a feed-in tariff of at least 18.3 c/kW.h would be needed for the investment to make positive returns.

# 7 Risks and Opportunities of Climate Change Policy

## 7.1 Implications of climate change policy given scope 1 and scope 2 emissions assessment

The carbon price will have an impact on electricity prices, which in turn has the greatest impact on farm activities. Moving forward in a carbon constrained economy this presents both a risk and an opportunity.

The analysis on energy demand and carbon footprint indicates that individual companies are unlikely to trigger the need for National Greenhouse and Energy Reporting Act requirements unless agriculture was included at some stage in the future, which it is presently not.

Future policy directions regarding agriculture and methodologies for agriculturally based carbon sequestration may enable the almond industry to manage carbon off-sets within its own industry in the future.

Any adoption of renewable energy will clearly reduce the impact of a future carbon footprint, particularly through reducing electricity associated Scope 2 emissions associated with on-farm electricity use.

## 7.2 Opportunities of current policies and funding

There are a variety of policies and funding programs that can help improve the business case for adoption of renewable energy production by the almond industry. Funding programs vary across Federal and State Governments and include the following:

### ARENA and the Emerging Renewables Program

The Australian Renewable Energy Agency (ARENA) is an independent statutory authority with the objectives of improving the competitiveness of renewable energy technologies and increasing the supply of renewable energy in Australia. ARENA oversees the $126 million Emerging Renewables Program which supports the development of renewable energy technologies in Australia across the innovation chain.

The Program is merit-based and provides grants for emerging renewable energy technologies in two funding categories:

- Projects—grants for the development of renewable energy technologies along the technology innovation chain;
- Measures—grants for renewable energy industry capacity building activities, renewable energy industry development activities and preparatory activities for a Project.

### Clean Technology Investment Program[11]

The Clean Technology Investment Program is an $800 million competitive, merit-based grants program to support Australian manufacturers to maintain competitiveness in a carbon constrained economy. The program provides grants for investments in energy efficient capital equipment and low emission technologies, processes and products.

The grant ratio is dependent on the size of the grant and the turnover of the applicant:

| Grant amount | Annual turnover of applicant* | Applicant to grant ratio |
|---|---|---|
| $25,000 – < $500,000 | Less than $100 million | Up to 1:1 |
| $25,000 – < $500,000 | $100 million or more | Up to 2:1 |
| $500,000 – < $10 million | N/A | Up to 2:1 |
| ≥ $10 million | N/A | 3:1** |

* applies to the annual turnover of the applicant in the financial year preceding the lodgement of an eligible application.

** unless otherwise recommended by the Cabinet of the Australian Government.

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[11] http://www.ausindustry.gov.au/programs/CleanTechnology/CleanTechnologyInvestment/Documents/CT-InvestmentCustomerGuidelines.pdf

Grants are provided for projects that generate energy or carbon savings. Projects will have to meet the eligibility requirements of the program and rate highly against the program's merit criteria. Applicants for grants of $1.5 million or more will also need to show how the project will contribute to a competitive, low carbon Australian manufacturing industry and how the project will benefit the broader Australian economy.

Proponents can include activities related to energy efficiency or emissions reduction measures at multiple sites, provided the relevant sites are located within Australia. This could be relevant for projects being conducted by entities with multiple sites.

### Clean Technology - Food and Foundries Investment Program

Special assistance is also being provided to the food processing, metal forging and foundry industries through the Clean Technology Investment Program. These industries are considered to be trade-exposed and have somewhat higher exposure to energy costs than general manufacturing businesses. Through the Food and Foundries Investment Program, the Federal Government will provide grants worth up to $150 million over six years to the food processing industry and up to $50 million over six years to the metal forging and foundry industries. The grants will assist the industries to invest in energy-efficient equipment and low-pollution technologies, processes and products.

### Low Carbon Australia[12]

Low Carbon Australia (LCA) provides financial solutions and advice to Australian business, government and the wider community. Finance is directed at projects that deliver cost-effective carbon and energy savings, and accreditation of carbon neutral products and organisations. LCA manages:

- The Energy Efficiency Program - finance and advice to eligible businesses and the public sector for the retrofit of non-residential buildings and industrial process upgrades; and
- The Carbon Neutral Program - accreditation for organisations that have products or operations certified as carbon neutral under the Australian Government's National Carbon Offset Standard.

Finance options include:

- Loans - Building owners and tenants can apply for either direct or cofinanced loans
- Operating Leases - Off-balance sheet lease financing
- Finance Leases - On-balance sheet lease financing
- On-bill Financing - Finance through an energy utility
- Environmental Upgrade Agreements (EUAs) - A finance agreement between building owners, financiers and local government

### Private financing[13]

There is an increasing range of finance options offered by major financial institutions and other entities to support energy efficiency or low emission energy projects. This is illustrated by the co-finance partners currently working with Low Carbon Australia, which includes Origin Energy, Macquarie Bank and National Australia Bank. For example, LCA and NAB are jointly funding Environmental Upgrade Agreements for commercial buildings. The NAB Environmental Upgrade Funding provides finance from $250,000 to $10 million plus. It is understood that private financing could be used to improve the funding for renewable energy projects for the almond industry.

### Carbon Farming Futures Fund[14]

The Carbon Farming Futures program will invest $429 million to advance emissions reduction technologies and techniques in the land sector. The Department of Agriculture, Fisheries and Forestry is responsible for delivering four components of the Carbon Farming Futures program including:

Filling the Research Gap - $201 million to fund research into new technologies and practices for land managers to reduce emissions and store soil carbon. Also includes a national survey to identify existing land management practices to assist with determination under the CFI.

Action on the Ground - $99 million to assist industry and farming groups test and apply research outcomes in real farming situations.

While the CFF does not fund renewable energy project research and development or installation, it could be important in funding activities that consider the benefits of by-products of the energy production process such as biochar from pyrolysis or ash from gasification to improve soil productivity to reduce the use of nitrogen based fertilisers.

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[12] http://www.lowcarbonaustralia.com.au/media/4871/11.11.15_-_low_carbon_overview.pdf

[13] http://www.lowcarbonaustralia.com.au/business/finance-solutions/co-finance-partners.aspx

[14] http://www.daff.gov.au/climatechange/carbonfarmingfutures

### Regional Development Australia Fund

The Regional Development Australia Fund is designed to support the infrastructure needs of regional Australia. Nearly $1 billion has been allocated to fund capital infrastructure projects which are identified as priorities by local communities. The program is administered by the Department of Regional Australia, Local Government, Arts and Sport.

Rounds Three and Four of the Regional Development Australia Fund (RDAF) opened in October 2012 and expressions of interest are set to close in December 2012. Round Three will provide $50 million for projects in small towns, while Round Four will provide $175 million for strategic infrastructure projects in regional Australia. The current timelines are likely to preclude seeking any funding for projects emanating from this study. Future funding rounds are likely though and this could be considered should proposals not be ready until late 2013.

### Victoria

A summary of funding opportunities available for Bioenergy projects in Victoria is provided at http://bioenergyvictoria.net.au/funding-and-incentives.

This document cites a number of initiatives including the Regional Growth Fund, administered by Regional Development Victoria (RDV). RDV aims to work with business and community sectors and will provide $1 billion over the next eight years. The Regional Growth Fund will support major strategic infrastructure and community-led local initiatives that improve both the competitiveness and liveability of regional and rural Victoria.

### South Australia

Until recently, South Australia had a dedicated Renewable Energy Fund. However, this was abolished by Premier Weatherill in 2011 and renewable energy projects in South Australia now need to focus more on Federal funding opportunities. One possible exception is ZeroWaste SA, which is a South Australian Government organisation dedicated to improving recycling and waste avoidance practices. ZeroWaste SA has a number of funding programs and should be consulted directly on funding opportunities should an implementation ready project be identified.

### Horticulture Australia Limited (HAL)

It is understood that HAL funding may be available for further work on renewable energy production if it qualifies under the research or development criteria. It may be appropriate to see this as an industry contribution and attempt to leverage additional funds from other funding sources to improve the business case for individual projects.

As described above, there are significant funding opportunities currently available for renewable energy projects in Australia. It will be important for the almond industry to first consider what type of projects it wishes to pursue and then determine which grant is most suitable. This will be influenced by the extent to which a project involves further research and development, is based on implementation ready technology, requires consider of co-benefits of energy production and other by-products (e.g. biochar for soil amelioration or analysis of supply and demand matching.

*NB. Renewable energy certificates have not been discussed above. This is because it is unlikely that small-medium sized renewable energy systems for the almond industry would qualify for producing either large-scale generation certificates, because their capacity is too low, or small-scale technology certificates, which are focused on solar water heaters, heat pumps, and small-scale solar panels, wind and hydro systems.*

# 8 Future Directions

This study indicates that there is a case for using waste hull and shell to produce energy, but only under certain conditions. This means that an energy solution must be tailored to each site, giving due consideration to site specific factors like energy efficiency, energy demand profile, and the value placed on energy production by-products.

The next stages are thus:

1. Adoption – Move to a detailed site specific feasibility study and rapidly proceed toward installation.
2. Combustion, pyrolysis or gasification? – Conduct physical trials to better understand the energy that can be generated from combustion, pyrolysis or gasification and the characteristics of by-products such as biochar and ash.
3. Integrated energy supply and demand project – Identify sites where energy systems could be used to meet onsite plus other local demand. This could be suitable in Renmark where the AlmondCo facility is on the edge of town or at Laragon where energy could be produced to support pumping of neighbouring shareholder orchards. Detailed economic analysis and supply considerations would need to be assessed on a case by case basis.
4. Composting and carbon farming – Better understand the potential benefits of composting from a carbon farming perspective, such as increased soil carbon levels and reduced application of nitrogen based fertilisers. This would consider the potential benefits of adding energy by-products such as biochar or ash to the farm.

There are options to combine some of the above projects such as 2 and 4.

# 9 References

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# Appendix 1 - Detailed financial analysis spreadsheet model

*Appendix 1, Table 1 - Financial analysis for Option 1*

| | Present Value | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 16 | Year 17 | Year 18 | Year 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **BASE CASE** | | | | | | | | | | | |
| **Benefits** | | | | | | | | | | | |
| Cattlefeed | 4,771,620 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 |
| **Total Benefits** | **4,771,620** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** |
| | | 0 | 1 | 2 | 3 | 4 | 5 | 16 | 17 | 18 | 19 |
| **Costs** | | | | | | | | | | | |
| Electricity | 3,079,446 | 144,743 | 156,221 | 168,609 | 181,980 | 184,491 | 189,619 | 633,406 | 767,386 | 942,537 | 1,173,640 |
| Gas | 485,487 | 41,000 | 41,680 | 42,360 | 43,040 | 43,720 | 44,400 | 51,880 | 52,560 | 53,240 | 53,920 |
| **Total Costs** | **3,564,933** | **185,743** | **197,901** | **210,969** | **225,020** | **228,211** | **234,019** | **685,286** | **819,946** | **995,777** | **1,227,560** |
| **ALMOND RENEWABLE ENERGY PROJECT (OPTION 1)** | | | | | | | | | | | |
| **Benefits** | | | | | | | | | | | |
| Clean Technology Investment Program Grant | 475,000 | 475,000 | | | | | | | | | |
| Residual value of project capital | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cattlefeed | 4,523,495 | 426,600 | 426,600 | 426,600 | 426,600 | 426,600 | 426,600 | 426,600 | 426,600 | 426,600 | 426,600 |
| **Total Benefits** | **4,998,495** | **901,600** | **426,600** | **426,600** | **426,600** | **426,600** | **426,600** | **426,600** | **426,600** | **426,600** | **426,600** |
| **Costs** | | | | | | | | | | | |
| Capital costs | 950,000 | 950,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Operating and maintenance costs | | | | | | | | | | | |
| Bioenergy gassification system | 906,608 | 85,500 | 85,500 | 85,500 | 85,500 | 85,500 | 85,500 | 85,500 | 85,500 | 85,500 | 85,500 |
| Electricity | 1,408,395 | 66,199 | 71,448 | 77,114 | 83,229 | 84,378 | 86,723 | 289,690 | 350,967 | 431,072 | 536,768 |
| Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Capital replacement costs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Costs** | **3,265,003** | **1,101,699** | **156,948** | **162,614** | **168,729** | **169,878** | **172,223** | **375,190** | **436,467** | **516,572** | **622,268** |
| **Incremental Benefits** | **226,876** | **451,600** | **-23,400** | **-23,400** | **-23,400** | **-23,400** | **-23,400** | **-23,400** | **-23,400** | **-23,400** | **-23,400** |
| **Incremental Costs** | **-299,930** | **915,956** | **-40,953** | **-48,355** | **-56,291** | **-58,334** | **-61,796** | **-310,095** | **-383,480** | **-479,204** | **-605,292** |
| **Net Benefit (NPV)** | **526,806** | **-464,356** | **17,553** | **24,955** | **32,891** | **34,934** | **38,396** | **286,695** | **360,080** | **455,804** | **581,892** |
| **BCR** | **1.28** | | | | | | | | | | |
| **IRR** | **15%** | | | | | | | | | | |
| **Discount Rate** | **8%** | | | | | | | | | | |

a In 2012 dollars. Complete analysis covers 20 years (years 6 to 15 hidden for presentational purposes).

Source: EconSearch analysis

Appendix 1, Table 2 - Financial analysis for Option 2

| | Present Value | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 16 | Year 17 | Year 18 | Year 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **BASE CASE** | | | | | | | | | | | |
| **Benefits** | | | | | | | | | | | |
| Cattlefeed | 4,771,620 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 |
| **Total Benefits** | **4,771,620** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** |
| **Costs** | | | | | | | | | | | |
| Electricity | 3,079,446 | 144,743 | 156,221 | 168,609 | 181,980 | 184,491 | 189,619 | 633,406 | 767,386 | 942,537 | 1,173,640 |
| Gas | 485,487 | 41,000 | 41,680 | 42,360 | 43,040 | 43,720 | 44,400 | 51,880 | 52,560 | 53,240 | 53,920 |
| **Total Costs** | **3,564,933** | **185,743** | **197,901** | **210,969** | **225,020** | **228,211** | **234,019** | **685,286** | **819,946** | **995,777** | **1,227,560** |
| **ALMOND RENEWABLE ENERGY PROJECT (OPTION 2)** | | | | | | | | | | | |
| **Benefits** | | | | | | | | | | | |
| Clean Technology Investment Program Grant | 2,612,500 | 2,612,500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Residual value of project capital | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cattlefeed | 3,406,936 | 321,300 | 321,300 | 321,300 | 321,300 | 321,300 | 321,300 | 321,300 | 321,300 | 321,300 | 321,300 |
| **Total Benefits** | **6,019,436** | **2,933,800** | **321,300** | **321,300** | **321,300** | **321,300** | **321,300** | **321,300** | **321,300** | **321,300** | **321,300** |
| **Costs** | | | | | | | | | | | |
| Capital costs | 5,225,000 | 5,225,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Operating and maintenance costs | | | | | | | | | | | |
| Bioenergy gassification system | 4,986,343 | 470,250 | 470,250 | 470,250 | 470,250 | 470,250 | 470,250 | 470,250 | 470,250 | 470,250 | 470,250 |
| Electricity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Capital replacement costs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Costs** | **10,211,343** | **5,695,250** | **470,250** | **470,250** | **470,250** | **470,250** | **470,250** | **470,250** | **470,250** | **470,250** | **470,250** |
| **Incremental Benefits** | **1,247,817** | **2,483,800** | **-128,700** | **-128,700** | **-128,700** | **-128,700** | **-128,700** | **-128,700** | **-128,700** | **-128,700** | **-128,700** |
| **Incremental Costs** | **6,646,409** | **5,509,507** | **272,349** | **259,281** | **245,230** | **242,039** | **236,231** | **-215,036** | **-349,696** | **-525,527** | **-757,310** |
| **Net Benefit (NPV)** | **-5,398,593** | **-3,025,707** | **-401,049** | **-387,981** | **-373,930** | **-370,739** | **-364,931** | **86,336** | **220,996** | **396,827** | **628,610** |
| **BCR** | **0.47** | | | | | | | | | | |
| **IRR** | **Undefined** | | | | | | | | | | |
| **Discount Rate** | **8%** | | | | | | | | | | |

a In 2012 dollars. Complete analysis covers 20 years (years 6 to 15 hidden for presentational purposes).

Source: EconSearch analysis

Appendix 1, Table 1 - Financial analysis for Option 3a

| | Present Value | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 16 | Year 17 | Year 18 | Year 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **BASE CASE** | | | | | | | | | | | |
| **Benefits** | | | | | | | | | | | |
| Cattlefeed | 4,771,620 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 | 450,000 |
| **Total Benefits** | **4,771,620** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** | **450,000** |
| **Costs** | | | | | | | | | | | |
| Electricity | 3,079,446 | 144,743 | 156,221 | 168,609 | 181,980 | 184,491 | 189,619 | 633,406 | 767,386 | 942,537 | 1,173,640 |
| Gas | 485,487 | 41,000 | 41,680 | 42,360 | 43,040 | 43,720 | 44,400 | 51,880 | 52,560 | 53,240 | 53,920 |
| **Total Costs** | **3,564,933** | **185,743** | **197,901** | **210,969** | **225,020** | **228,211** | **234,019** | **685,286** | **819,946** | **995,777** | **1,227,560** |
| **ALMOND RENEWABLE ENERGY PROJECT (OPTION 3)** | | | | | | | | | | | |
| **Benefits** | | | | | | | | | | | |
| Clean Technology Investment Program Grant | 9,615,385 | 9,615,385 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Residual value of project capital | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Feed-in electricity | 7,732,471 | 729,231 | 729,231 | 729,231 | 729,231 | 729,231 | 729,231 | 729,231 | 729,231 | 729,231 | 729,231 |
| **Total Benefits** | **17,347,855** | **10,344,615** | **729,231** | **729,231** | **729,231** | **729,231** | **729,231** | **729,231** | **729,231** | **729,231** | **729,231** |
| **Costs** | | | | | | | | | | | |
| Capital costs | | | | | | | | | | | |
| Bioenergy gassification system | 18,269,231 | 18,269,231 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grid connection | 961,538 | 961,538 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Operating and maintenance costs | | | | | | | | | | | |
| Bioenergy gassification system | 17,434,764 | 1,644,231 | 1,644,231 | 1,644,231 | 1,644,231 | 1,644,231 | 1,644,231 | 1,644,231 | 1,644,231 | 1,644,231 | 1,644,231 |
| Grid connection | 20,392 | 1,923 | 1,923 | 1,923 | 1,923 | 1,923 | 1,923 | 1,923 | 1,923 | 1,923 | 1,923 |
| Electricity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Capital replacement costs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Costs** | **36,685,925** | **20,876,923** | **1,646,154** | **1,646,154** | **1,646,154** | **1,646,154** | **1,646,154** | **1,646,154** | **1,646,154** | **1,646,154** | **1,646,154** |
| **Incremental Benefits** | **12,576,236** | **9,894,615** | **279,231** | **279,231** | **279,231** | **279,231** | **279,231** | **279,231** | **279,231** | **279,231** | **279,231** |
| **Incremental Costs** | **33,120,992** | **20,691,180** | **1,448,253** | **1,435,184** | **1,421,134** | **1,417,942** | **1,412,135** | **960,868** | **826,208** | **650,377** | **418,594** |
| **Net Benefit (NPV)** | **-20,544,756** | **-10,796,565** | **-1,169,022** | **-1,155,954** | **-1,141,903** | **-1,138,712** | **-1,132,905** | **-681,637** | **-546,977** | **-371,146** | **-139,363** |
| **BCR** | **0.44** | | | | | | | | | | |
| **IRR** | **Undefined** | | | | | | | | | | |
| **Discount Rate** | **8%** | | | | | | | | | | |

a In 2012 dollars. Complete analysis covers 20 years (years 6 to 15 hidden for presentational purposes).

Source: EconSearch analysis