Biogas generation feasibility study

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RMCG

Project Number: VG13049

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Biogas Generation Feasibility Study
VG13049

Final Report

Whiteoak et al.

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Purpose of this report: This report presents the findings of the feasibility analysis of on-farm biogas for Australian vegetable farms. There is significant interest within the vegetable industry in maximising efficiency and productivity across the production process, including maximising value from waste streams. Previous analysis has suggested that generating biogas from on-farm vegetable waste could be a cost-effective option. This study was commissioned to explore in more detail the feasibility of biogas on Australian vegetable farms.

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Media Summary

There is significant interest within the vegetable industry in maximising efficiency and productivity across the production process, including maximising value from waste streams. Previous analysis has suggested that generating biogas from on-farm vegetable waste could be a cost-effective option for vegetable farms.

Biogas is methane and carbon dioxide produced from the bacterial degradation of organic waste. Using anaerobic digestion, the process produces electricity, heat and a residual organic product that can be used on-farm as an organic fertiliser.

This study was commissioned to explore in more detail the feasibility of biogas on Australian vegetable farms. Extensive consultation with industry was undertaken, including a number of case studies. The key findings from this analysis were:

- Feasibility is highly variable
- Potentially feasible for larger operations
- Other factors contribute to feasibility such as crop type, consistency of waste supply and energy use, and the current costs of waste management
- ‘Cluster’ model adds complexity
- Technical feasibility a reflection of cost
- Regulatory burden not excessive
- Digestate use and management will require careful consideration.

The feasibility of biogas on-farm will depend upon the specific context of each operation. However, the following key factors will influence biogas feasibility on-farm:

- **Scale of operation**: the cost-effectiveness of biogas generally increases with scale, an input volume of 25 tonnes per day or more would warrant further consideration of biogas on farm
- **Type of waste**: different organic wastes produce different volumes of biogas per unit[1,2]
- **Electricity value**: retail tariffs vary significantly by type of site and to some extent by jurisdiction
- **Nature of current waste management**: biogas value will be influenced by the costs and revenues associated with a farm’s current waste management practices
- **Consistency in feedstock and electricity use**: in general, consistency in both waste production and electricity use are preferred features to highly variable waste supply and electricity use.

As a matter for immediate attention, the development of a biogas feasibility tool would ensure that the analysis undertaken in this project would be available for use by the industry. To assist in the use of the tool we recommend one-on-one support provided to growers interested in the technology. The exploration of using a ‘cluster’ model with neighbouring farms and/or incorporating additional waste streams (vegetable, other agricultural such as piggeries and poultry) is recommended for further consideration.

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[1] Testing typically costs around $2,000-$3,000 per waste type, and the biogas efficiency of different waste types is often commercial in confidence information.

[2] However, lettuce may be combined with other waste types to produce a high-methane mix.

Technical Summary

There is significant interest within the vegetable industry in maximising efficiency and productivity across the production process, including maximising value from waste streams. Previous analysis has suggested that generating biogas from on-farm vegetable waste could be a cost-effective option for vegetable farms.

Biogas is methane and carbon dioxide produced from the bacterial degradation of organic waste. Using anaerobic digestion, the process produces electricity, heat and a residual organic product that can be used on-farm as an organic fertiliser.

This study was commissioned to explore in more detail the feasibility of biogas on Australian vegetable farms. Extensive consultation with industry was undertaken, including a number of case studies.

One challenge for this assessment is the lack of an existing commercial biogas plant in operation on a vegetable farm in Australia. This limits insights developed from current practice, and requires adaptation of insights from biogas plants in different contexts,[3] or from planned (but not operating) biogas plants on vegetable farms in Australia.

Nevertheless, a number of key findings from this analysis are observable:

- **Feasibility is highly variable**: factors affecting biogas financial feasibility will vary significantly by farm. Establishing an understanding of high level feasibility for any farm will require detailed analysis using farm specific data to provide necessary accuracy of results.
- **Potentially feasible for larger operations**: our analysis suggests that financial feasibility of biogas is a genuine possibility for larger Australian vegetable farms (producing in the order of 10 kt of waste per year or higher, although this threshold size could be lower depending on feedstock or other factors).
- **Other factors contribute to feasibility**: a number of other factors contribute to the feasibility of biogas, including crop type (sweet corn is a high energy crop), consistency of waste supply and energy use, and the current costs of waste management.
- **'Cluster' model adds complexity**: for smaller farms, the potential exists to 'cluster' several neighbouring farms, or for a biogas plant to be established to compile waste from a variety of sources. However, this type of collaboration increases the complexity of arrangements for sharing costs and benefits of biogas. Significant further work would be required to further establish the feasibility of different cluster models.
- **Technical feasibility a reflection of cost**: while a relatively high technology option for waste management, the technical requirements for operating a biogas plant appear to be largely addressed in ongoing service arrangements with biogas service providers, reflected in the cost of this ongoing arrangement. Ongoing management actions of the plant can be expected to be codified in management plans, and of limited burden on farmers.
- **Regulatory burden not excessive**: Regulatory arrangements for biogas are not prohibitive but will require engagement with environmental regulators in project development, as part of the service arrangement with the biogas provider. A risk exists that the infrequency of biogas projects makes environmental regulators and local government wary, which may slow regulatory approvals. However, meeting regulatory requirements on land application can be expected to be codified in a management plan, without significant ongoing attention.

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[3] For example, from biogas plants on piggeries and wastewater treatment plants in Australia, or from vegetable farms overseas. The context of these are likely to be significantly different from vegetable farms in Australia, limiting insights drawn from them.

- **Digestate use and management will require careful consideration**: The value of digestate use will depend upon the cost of current waste management, and the scale of any value currently being generated by its use (for example, as a stock feed). Use of the digestate can provide a potentially significant value as a fertiliser replacement, but it must be aligned with the needs of the operation regarding soil health and fertiliser application, given the precision of fertiliser use in Australian vegetable farms.

As noted above, the feasibility of biogas on-farm will depend upon the specific context of each operation. However, the following key factors will influence biogas feasibility on-farm:

- **Scale of operation**: the cost-effectiveness of biogas generally increases with scale. While other factors will need to be considered, an input volume of 25 tonnes per day or more would warrant further consideration of biogas on farm. Below this volume is less likely to produce a cost-effective investment.
- **Type of waste**: different organic wastes produce different volumes of biogas per unit. The specific biogas efficiency of each waste product would require testing as part of a feasibility assessment,[4] however some general information is available. Sweet corn is considered favourable for biogas, while lettuce is predominantly comprised of water and is considered of low biogas potential.[5]
- **Electricity value**: retail tariffs vary significantly by type of site and to some extent by jurisdiction. The price of electricity will of course influence biogas feasibility, with higher prices increasing the value of electricity generated with biogas. In general, displacing energy imported from the grid will be significantly higher in value than energy sold into the grid, based on the difference between retail tariffs and the wholesale value of electricity.
- **Nature of current waste management**: biogas value will be influenced by the costs and revenues associated with a farm's current waste management practices. Our case studies suggest that current waste management costs are not necessarily significant management concerns, but they do require time and attention. Similarly, biogas digestate use has costs and a small fertiliser replacement value, but the nature of digestate management will depend upon farm needs.[6]
- **Consistency in feedstock and electricity use**: in general, consistency in both waste production and electricity use are preferred features to highly variable waste supply and electricity use. Biogas plants are most cost effective and reliable when run consistently. Therefore feasibility is improved for plants supplied with a consistent volume of input and feeding a consistent source of energy demand. Both of these issues can be overcome (for example, with storage) but at an increased cost.

As a matter for immediate attention, the development of a biogas feasibility tool would ensure that the analysis undertaken in this project would be available for use by the industry. To assist in the use of the tool we recommend one-on-one support provided to growers interested in the technology. The exploration of using a 'cluster' model with neighbouring farms and/or incorporating additional waste streams (vegetable, other agricultural such as piggeries and poultry) is recommended for further consideration.

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[4] Testing typically costs around $2,000-$3,000 per waste type, and the biogas efficiency of different waste types is often commercial in confidence information.

[5] However, lettuce may be combined with other waste types to produce a high-methane mix.

[6] For example, farms with highly specific fertiliser application methods may prefer not to apply digestate to their crop area, preferring to sell the digestate as a 'biofertiliser' product.

1 Introduction

1.1 Project background and context

The Vegetable Industry Strategic Investment Plan 2012-17 (AUSVEG and HAL 2012) identified the loss of half a billion dollars per year in product wasted throughout the supply chain.

This potential value of vegetable product waste combined with the significant component of total farm costs attributable to on-farm energy use[7] has led to an interest in exploring the cost-effectiveness of on-farm electricity generation from vegetable waste, specifically Anaerobic Digestion (AD).

Previously considered uneconomic for vegetable farms, recent indicative analysis suggests that AD may prove viable for larger farms (Rogers et al 2013; Rogers and Montagu 2013). However, the preliminary analysis needs to be taken further, ground-truthed and tested using actual farm data, to provide more definitive guidance that is sensitive to farm size and type. The viability of AD differs markedly based on individual circumstances.

Horticulture Australia Limited (HAL) commissioned this project to provide a more detailed analysis about the viability of on-farm generation of biogas in the vegetable industry.

1.2 Purpose and structure of this report

This report presents the findings of the feasibility analysis of on-farm biogas.

This report is structured as follows:

- **Section 1** provides project background and context
- **Section 2** outlines the project approach
- **Section 3** presents the desktop review of biogas and anaerobic digestion
- **Section 4** outlines the feasibility analysis
- **Section 5** details the case studies undertaken as part of this project
- **Section 6** presents the extension and adoption plan
- **Section 7** provides conclusions and recommendations.

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[7] For example, Tasmanian analysis shows that for irrigated farms, electricity costs comprise 65% of total farm costs (NRM North 2009)

2 Approach

2.1 Overview

The approach for this study involved three key aspects:

1. Desktop review
2. Framework development and feasibility analysis
3. Consultation.

These are described in further detail below.

2.2 Desktop review

A desktop review of available literature and technical information was undertaken in the preliminary stages of the project. The purpose of this desktop review was to gather available data to inform subsequent stages of the project. The following information was reviewed in undertaking the desktop analysis:

- Biogas policy context
- Anaerobic digestion plants and vegetable farms
- Vegetable farm waste
- Vegetable farm energy use
- Projected electricity prices by state
- Regulatory arrangements by state.

2.3 Framework development and feasibility analysis

The feasibility analysis of on-farm anaerobic digestion (AD) was undertaken following the desktop review and preliminary consultation with industry, researchers and growers. The development of the feasibility framework and subsequent modelling of a reference case, including sensitivity analysis of key variables, informed the core feasibility assessment.

The following aspects were analysed in the feasibility analysis:

- Core feasibility assessment including drivers, development of modelling framework, assessment of feasibility for a reference case and conclusions
- Additional viability factors including technical skills, expected regulatory burden, feedstock timing and other viability factors.

2.4 Consultation

2.4.1 Broad engagement

Consultation formed an important part of the approach to this study. Industry, government, research agencies and growers were engaged and consulted with during the project (Table 2-1).

A total of 25 people were consulted with from December 2013 to May 2014.

The consultation was designed to:

- Gain input of industry leaders in financial analysis of renewable energy projects, with specific experience of AD plants
- Produce outputs of direct relevance to vegetable growers in assessing the viability of on-farm AD for their enterprise.

2.4.2 Case studies

The high level assessment of AD feasibility on-farm required a more detailed and thorough analysis of on-farm feasibility that combined expertise of horticultural practices with advanced knowledge of energy economics and regulation. Given the extent to which feasibility can differ based on specific circumstances, four on-farm case studies were developed, involving the following steps:

- Scoping of four case studies in consultation with the Design Team and Grower Partner. This considered the major commodity groups (leafy vegetables [lettuce], root and tuber vegetables [carrot], legumes [beans], brassica vegetables [broccoli] and other vegetables [sweet corn], cucurbit vegetables [pumpkin] and specialty leafy vegetables [celery])
- Field visit to discuss issues with growers and establish site-specific data (e.g. waste volumes, energy use, siting issues)
- Financial and technical feasibility assessment
- Reporting of results in this report.

Table 2-1: Summary of consultation

Type	Position	Organisation	Date
Research	Biogas industry expert	CRC CARE	Dec-13, Mar-14, May-14
Research	Senior Research Fellow (Bioresources and Waste Utilisation)	National Centre for Engineering in Agriculture, University of Southern Queensland	Dec-13
Research	Associate Professor (Agricultural Engineering)	National Centre for Engineering in Agriculture, Faculty of Health, Engineering and Sciences, University of Southern Queensland	Dec-13
Government	Biomass Industry Development	Regional Development Victoria	Dec-13
Government	Previous role in biogas	Department of Environment and Primary Industries	Jan-14
Industry	CEO, biogas industry expert	Utilitas	Jan-14
Research	Visiting Fellow	The University of Adelaide	Jan-14
Research	Anaerobic digestion expert	Active Research	Feb-14
Industry	Industry Services Manager for the Vegetable industry	Horticulture Australia Limited (on behalf of Design Team)	Throughout project
Industry	Vegetable extension officer	Queensland	Mar-14
Industry	Vegetable extension officer	Western Australia	Mar-14
Industry	Industry Development Officer	Vegetables Western Australia	Mar-14
Grower	Grower contact	Butlers	Mar-14
Industry	Biogas industry expert	Red Earth Ag Co, Vegetable Technical Advisory Group, Victoria	Mar-14
Research	Researcher	University of Southern Queensland	Mar-14
Industry	AD provider and biogas industry expert, CEO	Utilitas, Queensland	Mar-14
Industry	AD provider and biogas industry expert	AD Australia Pty Ltd, Western Australia	Mar-14
Industry	AD provider and biogas industry expert	AD Australia Pty Ltd, Western Australia	Mar-14
Grower	General Manager and Operations Manager	Rugby Farms, Queensland (brassica, leafy, sweet corn)	Mar-14
Grower	Manager	Center West Exports, Western Australia (carrots)	Mar-14
Grower	Manager	Western Australia (lettuce), also President Vegetables WA	Mar-14
Grower	Manager	Harvest Moon P/L, Tasmania (carrots, onions, brassicas, swedes, beans)	Mar-14
Industry	Biogas supplier	Australian Harvestore Products Pty Ltd	Apr-14

3 Understanding of Biogas and Anaerobic Digestion

3.1 Policy context

Both international and domestic policy influences the feasibility of biogas on vegetable farms at a high level. High oil prices, tight energy markets and evidence about climate change are among the reasons policy makers around the world are increasing support for the production and use of alternative, renewable energy sources such as biogas.

In Australia, bioenergy production is still a small component of our energy profile. Bioenergy currently provides 0.9 per cent (2400 GWh in 2012) of Australia's electricity generation (mainly from bagasse and landfill gas generation). Bioenergy projections (assuming the right support is in place) are for 10,624 GWh per year by 2020 with biogas contributing 791GWh of that target (Clean Energy Council 2012).

The Australian carbon pricing mechanism (a cap-and-trade emissions trading scheme) was legislated in 2011[8] and commenced in July 2012. Vegetable growers have no direct liabilities under the existing scheme. In 2013, a new policy was introduced comprising the Direct Action Plan (DAP) and Emissions Reduction Fund (ERF, which is to purchase emissions reductions through a reverse auction). Electricity prices are expected to be reduced[9] and a series of incentives will be made available for improving energy efficiency, renewable energy production and/or land sector abatement. There are already accepted emissions reduction methodologies under the current Carbon Farming Initiative (CFI) legislation (DoA 2014), which will continue to apply under the Coalitions ERF (Commonwealth of Australia 2013). None currently apply to vegetable production.

There is evidence that policies and regulations have a strong influence on the viability and timeline for bioenergy projects. A recent study in the almond industry (Almond Board of Australia 2010) demonstrated that the feasibility of renewable energy production from almond waste was limited without higher feed-in tariff rates and/or the added incentive from Government for further technology development or capital investment.

Due to the uncertain future of domestic situations related to renewable energy and the price on carbon, it is difficult to quantify the policies and/or funding programs that could improve the business case for adoption of renewable energy production by the vegetable industry.

The two largest sources of Green House Gas (GHG) emissions from the vegetable industry are electricity used for irrigation and post-harvest farm activities (65% of total emissions), and soils nitrous oxide emissions due to use of N fertilisers (17% of total emissions) (Maraseni et al 2010). The adoption of renewable energy technologies will improve the energy efficiency and waste management and consequently reduce the long-term carbon footprint for an enterprise.

Additional information on the international and domestic policy environment is provided in Appendix 1.

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[8] Under the Federal Government's *Clean Energy Act 2011*

[9] "Lower retail electricity by around 9 per cent and retail gas prices by around 7 per cent than they would otherwise be in 2014-15 with a $25.40 carbon tax." (DoE 2014)

3.2 Anaerobic digestion plants and vegetable farms

3.2.1 Anaerobic digestion (AD)

Anaerobic digestion (AD) is a process by which organic materials in an enclosed vessel are broken down by micro-organisms, in the absence of oxygen. The micro-organisms feed on the organic materials to produce methane and carbon dioxide (biogas) as well as heat. Biogas is a renewable energy source.

The AD process also produces a liquid effluent ('digestate') comprised of water, nutrients and approximately half of the carbon from the feedstock materials. Almost all of the water and nutrients are retained in the process (DeBruyn and Hilborn 2010). Conventional AD has been a "liquid" process, where waste is mixed with water to facilitate digestion, but a "solid" process is also possible.

AD systems typically operate at the farm (or processing plant) scale using on-site waste streams, or at a centralised scale using large volumes of waste from multiple sources.

Any organic material can be used in the AD process. Most frequently high nutrient waste streams such as sewerage and animal wastes are the source. These waste streams have a high disposal cost which can be reduced through the biogas process, contributing to the overall business case for AD.[10]

3.2.2 The AD Process

The process of converting waste vegetable matter into electrical energy involves the following sequence of steps as outlined in Figure 3-1 below:

- Vegetable waste matter (or 'feedstock') is collected, aggregated and transported, if required, to the anaerobic digestion site
- Matter is finely chopped and made into a semi liquid slurry by adding water (Rogers 2013)
- This slurry is fed into a 'digester ', which is typically a tank but can also be a lagoon. Within the digester the feedstock is biodegraded by microbes in the absence of air (this is the process known as anaerobic digestion)
- The biodegradation process creates a methane containing gas known as 'biogas'. There are potential storage solutions available for the biogas. For example, in some configurations the biogas is stored in inflatable rubber bags
- The chemical energy within the biogas is then transformed into electrical energy through a generator. There are various combustion engine types (primarily reciprocating engines and gas turbines) that may be used to generate electricity
- The power generated is then used to offset local electricity imports and/or exported to an electricity grid

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[10] For example, piggery waste disposal can be costly – AD provides the opportunity to produce a saleable potting mix product from the digestate which simultaneously produces revenue and avoids disposal costs.

- The process also generates a mixture of solid and liquid waste known as 'digestate' (Rogers 2013), which may have agricultural applications.

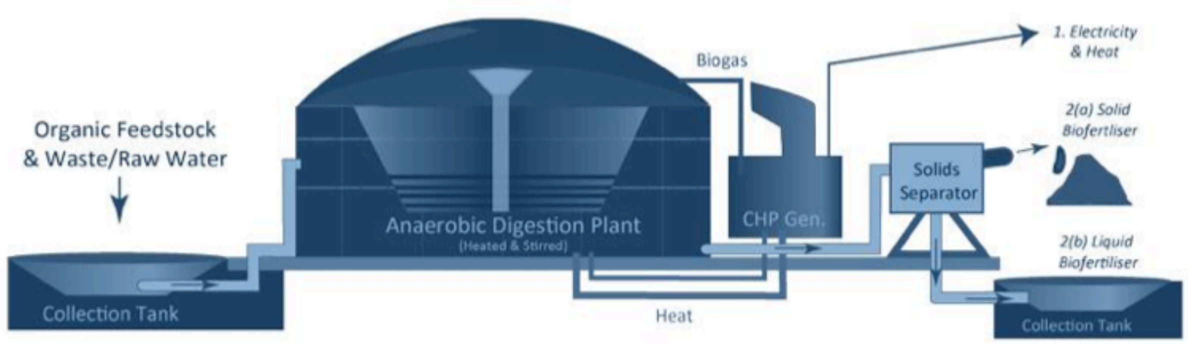

Figure 3-1: AD process (Rogers et al. 2013)

Anaerobic digestion systems are configured to site specific and feedstock specific conditions. The systems vary with respect to operational temperatures, wet or dry operation, stages, retention time and digester design. These characteristics represent just some of the considerations when designing AD systems and many other technical factors exist.

Operating temperature

The bacteria used in anaerobic digesters typically operate at two temperature ranges (EFA 2012**).** These are referred to a Mesophilic (between 20°C and 45°C temperature) and Thermophilic (higher than 50°C temperature). Mesophilic is relatively simpler as it relies on ambient temperature, whereas Thermophilic requires the addition of heat.

Wet or dry systems

In 'wet' AD systems, the input into the digester is comprised of 10–15% Total Solids (TS), therefore, organic wastes with higher proportion of total solids are first diluted with water to obtain a slurry with such a moisture content (Vandevivere et al 2002). Wet configurations allow the use of a classical 'complete mix reactor' and the equipment to handle slurries is relatively cheaper (although requires additional pre-treatment steps and larger reactor volume).

In 'dry' systems, the mass in the digester is kept at a TS proportion of 20–40% (Vandevivere et al 2002). Therefore, only very dry substrates are required to be diluted with water. Relative to wet systems, the equipment can be more expensive because of the physical characteristics of waste. However, the feedstock needs less pre-treatment because fine contaminants cause less operational issues relative to a wet reactor and only coarse contaminants (ca. 40 mm) require removal (Vandevivere et al 2002).

Retention time

The rate of solids and liquids moving through the digester is an important characteristic as it influences the size of the digester. Retention time may be measured as Hydraulic Retention Time (HRT), which is the average time that liquids remain in the digester, or Solids

Retention Time (SRT), which is the rate that solids remain in the digester. HRT and SRT may be measured in days.

3.2.3 Digester design

The three main types of anaerobic digestion reactors include Complete Mix, Plug Flow and Covered Lagoons (EFA 2012)**.**

Complete Mix reactors consist of an insulated and heated tank with a gas tight cover to trap the biogas. Waste heat may be used to heat tank contents thus reducing retention time (Figure 3-2).

Plug Flow reactors have a long rectangular design with an expandable cover to capture the gas. Feedstock is fed in one end of the reactor, which pushes reactor contents along the reactor and causes by-product to exit at the other end. Dry configurations utilise plug flow reactor design due to their high viscosity (Vandevivere et al 2002).

Covered Lagoons are essentially plastic lined holes in the ground with a cover that traps the biogas. While a simple design, Covered Lagoons are relatively inefficient.

More complex variations of these designs are possible and should be considered for site-specific conditions, in particular through multiple stages.

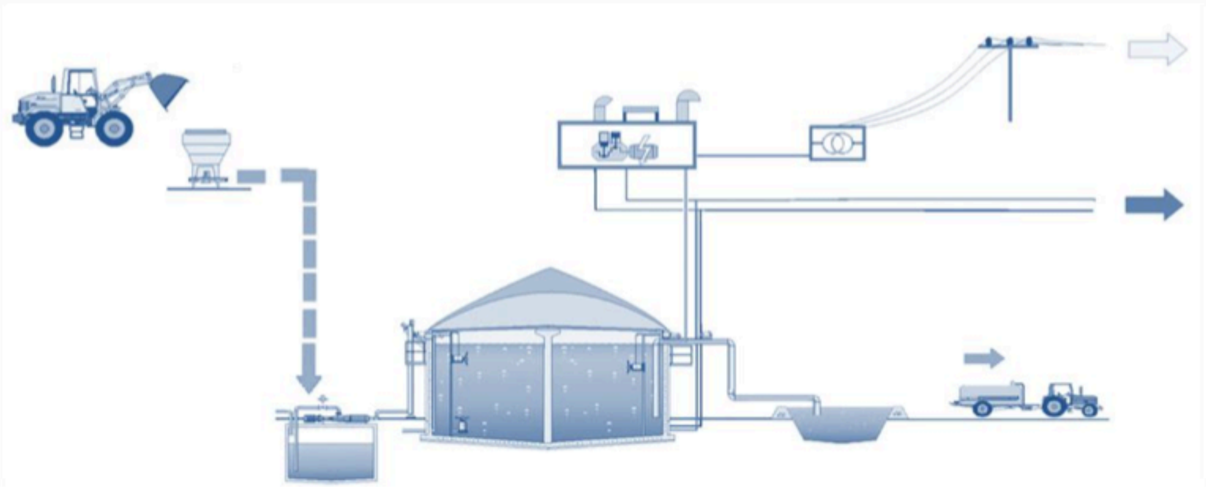

Figure 3-2: Continuously stirred reactor biogas plant (Rogers et al. 2013)

In a one stage system all reactions necessary to produce methane occur in a single reactor (Vandevivere et al 2002), whereas in two or multi-stage systems these reactions occur in multiple reactors. Multi-stage systems can be more effective at producing methane than one-stage systems for certain feedstocks, however, they are more expensive (Vandevivere et al 2002).

Limited generalisations can be made from the literature about appropriate digester configurations for vegetables. Some considerations are apparent, for example, that dry systems are more robust in dealing with waste streams that have fine contaminants. However, given the lack of Australian examples of vegetable waste anaerobic digestion and the sparseness of public domain data on international vegetable waste anaerobic digestion projects, further investigation of appropriate digester types and configurations for vegetable waste is warranted.

Our case study investigations suggested that ‘wet’ systems are being explored on Australian vegetable farms, and that the high cost of spreading whole (unseparated) digestate on-farm is leading providers to explore separation of solid and liquid digestate.

3.2.4 Costs associated with AD

As the configuration of an AD system for a specific site varies based on a number of design elements, it is not possible to obtain a precise estimate of capital and operating cost. However, indicative costs are available in the literature.

The main upfront cost of an AD system lies in the digester, followed by the electrical equipment (Keskar 2013). An indicative capital and operating cost for a 500 kW, 15.2 kt/y continuous anaerobic digestion system suitable for a vegetable grower/processor is $3,173,618 and $97,829 per year respectively (Rogers 2013). There is limited public information relating to AD system costs in Australia.

The international literature highlights similar challenges with obtaining cost information. For example, California Integrated Waste Management Board (2008) recognises these challenges but provides a useful comparison of cost data from two studies and the construction of cost curves (although focussed on Municipal Solid Waste (MSW)). Their analysis showed that data from one study (Tsilemou and Panagiotakopoulos 2006) produced a curve with high R^2 (data fitted the curve well). The cost curves estimates are:

- Capital cost (Million $US 2007) = 1.7171 x Design Capacity (Thousand tons/y) $^{0.5581}$; and
- Operating cost ($/MT) = 315.62 x Design Capacity (Thousand tons/y) $^{-0.618}$

Comparing Rogers (2013) with California Integrated Waste Management Board (2008) produces a wide variance in estimates as shown in Table 3-1.

Table 3-1: Comparison of AD costs

	Rogers (2013)	California IWMB (2008)[11]
kW capacity of electricity generator	500	Not specified
kt/year of waste	15.2	15.2
Capital cost (million $AU 2013)	$3.2	$10.5
Operating cost ($AU 2013/yr)	$97,829	$78,400

It should however be noted that the Rogers (2013) estimates are produced for Australia and vegetable waste processing in particular, whereas California Integrated Waste Management Board (2008) is based on wider geographic coverage and applies to MSW.

As the costs associated with AD are largely unknown, we iteratively refined cost estimates through the projects stages (i.e. desktop review, industry consultation and case study analysis). The Rogers (2013) estimates were a reasonable starting point for costs, however, these were adjusted for economies of scale using scaling factors from the California Integrated Waste Management Board (2008).

Technical challenges associated with AD will frequently translate into higher costs, which will then be described in financial feasibility. For example, if it requires significant skills to run the plant, this will tend to translate into a service agreement, which becomes a cost issue rather than a technical one. Technical challenges include lumpiness of feedstock, variability of energy use and ideal use of digestate (potting mix, liquid spreading, solid spreading).

3.3 Vegetable farm waste

3.3.1 Feedstock sources

For this study, we have considered feedstock for AD sourced from crop wastage that occurs during harvest and processing stages of the supply chain, along with rejected crop returned to farm.

‘Wastage’ technically also occurs pre-harvest – crops affected by pests and disease, and inedible parts of the crop. These volumes are typically left on paddock to be worked back into the soil as green manure. However, Rogers et al (2013) highlights that some of these waste volumes may be useful for other processes such as biofuels, biochar or extraction of compounds, which can be used in manufacturing. It is highly unlikely under current policy settings that this waste can be cost-effectively harvested and incorporated into AD.[12]

Similarly, waste is produced at supply points post-processing, such as unsold retail product and consumer waste. These supply points are beyond the farm gate and are thus outside of scope of the core analysis.

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[11] Converted to Australian 2013 dollars using 2007 exchange rate (OANDA 2014), 2007 Power Purchasing Parity (PPP) adjustment (World Bank 2014) and estimated inflation of 2.5% per year.

[12] Analysis of incorporation of this type of waste would have to consider the ‘lost value’ of incorporated green manure removed for biogas production.

As such, we focus on three main sources of crop waste:

- Low quality product rejected at packing
- Processing waste such as trimmings
- Market-rejected product returned to farm.

Wastage volumes can be expected to differ significantly for each farm, depending upon farm size, crop type, market conditions, management practices and extent and type of processing. However, to explore feasibility, averages and ranges of waste volumes per hectare of area cultivated must be calculated. By assessing average waste volumes per hectare, waste volumes for farms of different sizes can be calculated based on area under production.

Rogers (2013) undertook an analysis of wastage rates for National Vegetable Levy crops for HAL, noting the dearth of previous research in this area. The study was based on a survey of key growers from major crops and regions. Results for key crops are reproduced in Table 3-2. Whilst there is a significant proportion of ‘in-field’ wastage, we are aware of no examples of the use of this waste stream for biogas. Total wastage therefore includes postharvest and processing wastage only. These wastage proportions (averages and ranges) have been used within the analysis to assess the financial feasibility of biogas for different farm settings.

Table 3-2: Proportion of harvested crop wasted by crop type (Rogers et al 2013)

Crop	In-field wastage (%)	Postharvest reject (%)	Processing wastage (%)	Total wastage (%)	Wastage used for
Cabbage (fresh)	0-50	10	-	10	Animal feed, Green manure
Cabbage (processing)	0-50	-	20	20	Animal feed, Green manure
Cauliflower	0-30	10	7	17	Animal feed, Green manure
Broccoli (fresh)	60	10	10	20[13]	Animal feed, Green manure
Broccoli (processed)	60	-	65	65	Animal feed, Green manure
Sweet corn (fresh)	-	5	20	5-25[14]	High value animal feed
Sweet corn (processed)	-	-	32-55	32-55[15]	High value animal feed
Carrots (fresh)	-	33		33	Animal feed
Carrots (processed)	-	10	5	15	Animal feed
Beetroot (fresh)	-	5-10	10	20-25	Animal feed, Green manure
Beetroot (processed)	-	17	26	43	Animal feed, Green manure
Head lettuce (fresh)	0-25	5-25	-	5-25	None[16]
Head lettuce (processed)	-	-	10	10	None[11]
Baby leaf and fancy lettuce	-	-	10-17	10-17[17]	Animal feed, Green manure
Baby leaf vegetables	3-5	7-10	-	7-10	Green manure Animal feed
Capsicums	18	8	-	8	-
Beans		10	-	10	High value stock feed

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[13] Second grade produce (12-30%) of volume is not always saleable, so waste volumes may extend to 50% of harvest under certain circumstances.

[14] 5% wastage for whole fresh corn, 25% wastage for trimmed fresh corn.

[15] 38% wastage for processed cobs, 52% for processed kernals.

[16] There are no real uses for lettuce waste due to its high water content and low nutritional value.

[17] Summer crop (2/3 of total production) has processing waste of 10%, while winter crop (1/3 of total production) has processing waste of 17%.

The analysis also describes a number of current uses of on-farm vegetable waste. Actual practice and value of waste usage will depend heavily on specific circumstances for each farm. For example, the value of vegetable waste as stock feed can vary from zero dollars when given away as a lowest cost disposal option, to as high as $15/t when fed to own stock replacing home grown feed.[18]

In establishing feasibility of on-farm AD, growers will need to understand the value of their current usage:

- Green manure: use of vegetable waste as green manure theoretically has a value reflecting the avoided fertiliser cost of nitrogen and phosphorus retained in the waste. However, in practice the value will depend upon application (evenly spread or applied in bulk to a small, easily accessible area).
- Stock feed (own or sold): the value of stock feed can range from zero dollars (when given away to neighbouring stock farmers) to as much as $15/t when replacing hay or wheat for own stock. Circumstance will dictate this value for each farmer.
- Landfill or other paid disposal cost: it is possible that farmers would pay for waste disposal should alternative options be unavailable. In practice, however, return to land as green manure would be lower cost and would be preferred wherever possible (but not without capital and labour costs). There may be limitations to green manure use, such as in Western Australia where there are restrictions on waste management due to the existence of stable fly.

All of these options involve costs of some kind, and some result in revenue for farmers. The details of these costs and benefits will need to be understood in establishing the feasibility of biogas for each farm.

3.3.2 Production of biogas from substrates

The amount of energy that can be produced through waste vegetable matter varies according to the:

- Mass of waste matter used as feedstock for the process
- Composition of that matter and
- Efficiency of conversion to biogas.

The greater the mass of feedstock that is input into an AD process, the greater the energy that can be produced. Input mass is measured as the weight (tonnes) of either fresh (wet) or dried vegetable waste. For our study, we have considered waste volumes as tonnes of digestible waste produced over a year.

The composition of the matter (referred to as a ‘substrate’ in the context of Anaerobic Digestion) significantly influences the amount of energy produced. Organic matter (or volatile solids) in the substrate is comprised of a combination of Fat/Lipids, Protein and Carbohydrate (Schunner 2010).

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[18] RMCG analysis based on Victorian Department of Primary Industries (2007)

The chemical process of AD involves transforming these molecules (in turn composed of Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N) and Sulphur (S) atoms) and water (H_2O) into:

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Ammonia (NH_3)
- Hydrogen Sulphide (H_2S).

It is the methane in the biogas that contains energy; therefore it is necessary to estimate the amount of methane in biogas produced by a substrate to estimate that substrate's energy potential. The Buswell Equation is often used to estimate the theoretical potential of substrates if their chemical composition is known. However, this provides a theoretical value as the method assumes 100% of the organic material is broken down during digestion (Banks 2011). Application of the Buswell Equation provides the following theoretical biogas production from the three organic components Schunner (2010) (Table 3-3).

Table 3-3: Three organic components in biogas

Representative organic compounds	Biogas (Nm^3/kg)[19]	Methane (%)
Fat/Lipid ($C_{57}H_{104}O_6$)	1.4	70
Protein ($C_5H_7O_2N$)	1.0	50
Carbohydrate ($C_6H_{12}O_6$)	0.8	50

This analysis:

- Assumes 100% of the organic material is biodegraded, whereas in practice this will be less
- Uses representative chemical compositions
- Estimates potential at normal temperature and pressure
- Assumes a representative atomic composition of organic compounds.

While this provides a first principles approach to estimating potential energy yield, clearly assumptions and adjustments for specific AD site conditions are required. Information from credible literature sources are preferred sources for this study.

The Bavarian State Ministry for Nutrition, Agriculture and Forestry (no date) provides data for vegetable substrates derived from literature review or calculated (as theoretical maxima). We have augmented this data with information for sweet corn grain and silage from alternative sources (Table 3-4). Note the significantly higher biogas yield per cubic metre of sweet corn grain and silage than most other vegetable crops.

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[19] At 0°C temperature and 1 atm atmospheric pressure

Table 3-4: Substrate concentration and data source[20]

Substrate	Nm^3/t Fresh Matter	CH_4 [%]	Data source
Acidified oil pumpkin fruit	79.0	55.3	Calculated
Oil pumpkin fruit	50.9	55.8	Calculated
Cauliflower	59.2	56.0	Calculated
Cauliflower leaves fresh	63.5	56.2	Calculated
Vegetable waste	57.0	56.0	Literature
Kohlrabi leaves	50.5	55.7	Calculated
Carrots	73.3	52.0	Calculated
Silverbeet leaves	50.1	56.4	Calculated
Cabbage fresh	64.3	54.7	Calculated
Savoy fresh	60.0	55.2	Calculated
Onions	80.3	65.0	Literature
Onions	103.3	52.3	Calculated
Onion skins	267.8	65.0	Literature
Maize (sweet corn) grain	200-220	-	Literature

Comparing the theoretically calculated and literature derived figures highlights:

- Literature derived values are lower than theoretical calculations suggesting a certain proportion of matter is likely to be biodegraded rather than the entire organic matter; and
- Onion skins, maize grain and maize silage appear to produce significantly higher methane per tonne of throughput than remaining substrates. Based on publicly available data, biogas yields of the remaining vegetable matter substrates do not vary significantly.

A broad range of vegetables do not feature as common feedstocks for biogas projects, with the exception of corn which has significantly higher biogas yields than other vegetables.

In the absence of robust literature on the biogas yield of each levy vegetable crop, we have grouped relevant vegetables into logical groups for the quantitative assessment of feasibility. Groupings are summarised in Table 3-5.

For more precise estimates, substrates may be tested in a laboratory environment and biogas service providers generally provide this testing service.

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[20] All data from The Bavarian State Ministry for Nutrition, Agriculture and Forestry (no date), except for Maize (sweet corn) grain and Maize (sweet corn) silage which were sourced from the UK National Non-Food Crops Centre (no date). This source provides estimates of biogas yields for a number of common non-vegetable feedstocks, but not methane percentage. 'Vegetable waste' methane percentage of 56% was used in analysis for vegetable crops without specific identified methane percentages.

Table 3-5: Substrate groups and biogas concentration used in this analysis

Crop group	Example crops	Nm^3/t FM
Corn	Mix of corn and silage waste	200.0
Leafy vegetables	Asian vegetables, lettuce types, spinach, silverbeet, rocket	35.8
Root and tuber vegetables	Carrot, parsnip, beetroot	52.3
Legumes	Beans, peas, other legumes	57.0
Protected cropping	Solanaceous vegetables such as tomatoes, capsicums, eggplant	57.0
Brassica vegetables	Broccoli, cabbage, cauliflower, brussel sprouts, kohlrabi, swedes, turnips and some Asian vegetables	45.9
Cucurbit vegetables	Pumpkin, cucumber, zucchini	56.4
Specialty leaf vegetables	Celery, parsley	35.8
Other vegetables		57.0

3.4 Vegetable farm energy use

3.4.1 Energy use on farm

There are four major forms of energy use on farms. These include:

- General electricity
- Irrigation and pumping
- Fuel for vehicles and machinery
- Heating and cooling.

Electricity for water harvesting and pumping, and for running processing facilities are the two major forms of energy that can be displaced with electricity generated through anaerobic digestion (AD) of vegetable waste. For a vegetable farm without processing facilities, irrigation appears to contribute to the majority of electricity use. Chen et al (2009) note in their study on evaluating on-farm energy performance that in some cases nearly 80% of operational energy was expended on water harvesting and irrigation. For farms with processing facilities, the proportion accounted for by irrigation will depend on the energy use by that facility.

Energy use varies significantly from farm to farm and generalisations are not easy or useful. However data from two studies provide a useful basis to estimate the likely scale of electricity use on farm. These include:

- Chen et al (2009), which provides estimates of electricity use for pumping (water harvesting and irrigation) and other uses (cleaning and on-site refrigeration) on a range of representative Queensland farms; and
- ABARES (2012), which provides economic data (including electricity cost) for Australian vegetable growing farms.

Data was also sought on the electricity used by processing facilities. This is minimal information available, however, a presentation from Rugby Farm (2013) (a vegetable growing operation with growing regions across Queensland) provides data on the relativities between growing area (hectares), irrigation electricity costs (dollars) and packing facility electricity costs (dollars).

The concurrent HAL project, economic evaluation of farm energy audits and benchmarking of energy use on vegetable farms (VG13054), has provided additional important energy data for this project.

3.4.2 Modelled energy use

The Chen et al (2009) data was used in the model as an estimate for the average water harvesting and irrigation electricity consumption across farms. This combined with the ABARES (2012) data provided information on how this might vary by crops (e.g. some crops may require more energy to irrigate). The Chen et al (2009) data was also used in the model as an estimate for 'other' electricity use (i.e. cleaning and on-site refrigeration) whilst the Ausgrid website was used to estimate the average electricity consumption at the farmhouse.

To estimate the processing facility energy, Rugby Farm (2013) figures were used. Since the type of processing facilities and their energy use will vary significantly by business, the model allows for electricity use at a processing facility to be specified. For the central case, a hypothetical processing facility of 1,000 MWh per year has been assumed. While this is a relatively arbitrary assumption, it should be noted that energy use is not a driver of profitability of AD but more of a precondition. Since the value of retail electricity is much higher than the wholesale electricity value (and much more practical to capture), the analysis assumes that the site must have a certain amount of minimum electricity demand for AD to be considered (enough to be able to use effectively all of the energy produced by AD).

Based on these estimates of electricity use, the following settings (Table 3-6) have been used for the central case in the model.

Table 3-6: Indicative energy use for modelling purposes

Parameter	Unit	Value
Farmhouse electricity demand	kWh/year	5,840
Other electricity demand	kWh/ha/year	143
Water harvesting and irrigation electricity demand		Varies by crop
Leafy vegetables	kWh/ha	1,746
Root and tuber vegetables	kWh/ha	1,259
Legumes	kWh/ha	517
Protected cropping	kWh/ha	720
Brassica vegetables	kWh/ha	780
Cucurbit vegetables	kWh/ha	735
Specialty leafy vegetables	kWh/ha	1,746
Other vegetables	kWh/ha	869
Processing facility		
Default hypothetical processing facility demand	MWh/y	1,000

3.4.3 Profile of energy production and use

As the value of electricity varies significantly by time of day and type of load it is important to make reasonable assumptions about:

- How much of the energy produced by AD will be used to offset electricity used by the processing facility and how much is used to offset electricity used on the farm
- How much of this offsetting is during peak times (and therefore saving at a higher rate) and how much is during off-peak times
- For the processing facility, which is assumed to pay both demand and energy charges, what is the maximum demand of that facility and can this be reduced.

For the central case, the following assumptions about a hypothetical business are made.

Table 3-7: Assumptions about a hypothetical business

Parameter	Unit	Value
Processing facility average Monthly Max Demand	kW	250
Processing facility energy consumption	MWh/year	1,000
Processing facility % demand reduction per % energy reduction	Percent	100%
% of total energy produced used to offset		
Farm and irrigation energy use during peak times	Percent	10%
Farm and irrigation energy use during offpeak times	Percent	40%
Processing facility energy use during peak times	Percent	40%
Processing facility energy use during offpeak times	Percent	10%

3.4.4 Value of energy produced

Energy is produced through the AD system by combusting the methane containing biogas and generating electricity. This energy provides value to farmers because it can be a source of revenue and/or a source of cost savings by offsetting energy currently used on farm. The energy value can be broken down into the following items:

- **Electricity:** a generator transforms the potential energy within the biogas into electricity. Some or all of this electricity can be used to meet part of the farm's power requirements and in doing this it reduces the amount of electricity that needs to be drawn from the grid, thus reducing a growers power bill (referred to as the retail value of electricity). Any electricity produced that is over and above the power needs at the time may also be put back into the power grid to provide farmers with a source of revenue (negotiated with their power suppliers), however at a much lower value (referred to as the wholesale value of electricity). As these exports provide a much lower value it is ideal if all energy produced is used to offset own power demand;
- **Large-scale Generation Certificates (LGCs):** Formerly known as Renewable Energy Credits (RECS), LGCs are generated for each Megawatt-hour unit (MWh) of electricity produced by eligible renewable generators. Once accredited with the Clean Energy Regulator (CER), biogas systems can generate LGCs for each MWh. These LGCs can then be sold through an LGC broker or to a power supplier; and
- **Heat and Carbon dioxide:** Hot steam is a by-product of the AD system and its value depends on whether this can be used on farm and for what purpose. Some of this heat is redirected back into the digester to offset its own energy needs. Heat and carbon dioxide may be used in greenhouses but this has not been a focus of the study since the cost of AD systems makes them prohibitive for smaller scale applications.

3.4.5 Value of electricity

This review has focused on the retail value of electricity as this is more relevant and material to vegetable farm AD systems than wholesale value of providing electricity to the grid (five times more valuable than wholesale electricity). Additionally, exporting wholesale electricity requires additional infrastructure, processes and contracting requirements, which is likely to outweigh any benefits delivered.

It is therefore recommended that vegetable farms size AD systems so that most of the energy produced may be used locally on farm or through associated facilities. The following characteristics are preferable.

- Continuous power demand throughout the day and night (as far as possible) is ideal. It helps to recover the high upfront costs of AD systems by utilising the equipment as much as possible (referred to as high utilisation or Capacity Factor (CF)). Secondly, excessive switching on and off of the generator or constant increasing or decreasing of its power output leads to greater wear and tear (and therefore maintenance costs); and
- A storage solution for the biogas so that it can be built up at times that it is not needed and used when required. A possible solution is inflatable rubber bags that store the biogas and deflate when it is required (Keskar, J, personal communication).

The value of retail electricity is the amount that it can reduce a grower's power bill. This varies according to:

- Jurisdiction: retail electricity prices vary across each state and territory and reflect the costs of supplying power in those regions; and
- Tariff: a tariff is the set of charges that an electricity consumer is billed for. It is structured into tariff components and the structure as well as the price of each component can vary by electricity user. The components can comprise:
  - Energy charges: this is a charge per unit of energy consumed (typically measured in cents per kilowatt hours(kWh)) changing with the time of day or season;
  - Fixed service fee or supply charges: an amount that is charged irrespective of the amount of energy used, typically as cents per day per electricity metre; and
  - Maximum demand charges: this charge reflects the fact that a large proportion of the cost of supplying power relates to the amount of power that may be required at any one time (referred to as demand or capacity and measured in kilowatts (kW)). Typically, demand charges apply to large electricity consumers (greater than 100 MWh a year) and are therefore likely to apply to the focus group of this study.

More information on prices associated with electricity by jurisdiction is summarised in Appendix 2.

Forecasts of future energy value

AEMC (2013) provides short-term forecasts for residential retail electricity prices (2011/12 to 2014/15) in all Australian jurisdictions. These forecasts were prepared at a time when it was likely that the carbon price legislation would remain in place. Since then, the government has stated that it will repeal the carbon price likely to be effective from 2014/15 onwards. Therefore the AEMC forecasts have been adjusted to 'back out' the effect of the carbon price, using carbon price impact data from Wild et al (2012) and DIICSRT (2013).

Beyond 2014/15 there is limited recent data on forecasts. However, it is likely that there will be continued upwards pressure on the delivered price of electricity due to the impact of rising gas prices (as a result of the LNG industry linking Australian gas prices to higher international prices), a likely reintroduction of a carbon price and continued installation of Solar PV (which increases grid electricity prices as it reduces the utilisation of the grid). Counteracting these forces somewhat will be the likely continued government vigilance on containing unnecessary electricity price increases. Due to the combination of these factors a nominal annual increase of 4% has been assumed over the long run.

3.5 Regulatory arrangements

There are two main areas of regulatory concern for biogas operations on-farm:

- Flaring standards and regulations, concerning the burning of gas produced from AD
- Environmental standards and regulations, which will be concerned largely with any application of digestate to land.

Flaring standards and regulation will in practice be addressed within the system design for any proven technology, so will not be a direct concern to any grower. In contrast, environmental standards and regulations will directly concern business operators, specifically where digestate is applied to land.

In practice, a works approval can be expected to be required prior to construction of the facility, which will contain a licence condition around demonstration that the AD plant will not pose an unacceptable environmental risk. Development of an Environmental Improvement Plan outlining how digestate use will meet this condition would therefore be required. This may be an additional cost.

Each state and territory has its own legislation covering the safe operation and environmental performance of gas burning appliances, including biogas systems. A summary of the relevant standards and regulations associated with biogas flaring and management of waste by-products (i.e. digestate) is provided in Appendix 3. These include:

- Australian Standards that apply to all gas burning appliances (Australian RIRDC 2008)
- Flaring regulations and responsible authorities (Australian Pork and Prime Consulting International (Australia) Pty Ltd 2013).

These standards and regulations represent the minimum requirements to be attained for any gas burning appliance to receive certification. For proven biogas systems, these standards and regulations are likely to be addressed during manufacturing and installation. Therefore, they are unlikely to be a constraint for farmers purchasing on-farm biogas systems.

Environmental standards and regulations apply to biogas operations for all elements of the environment – air, land, water and groundwater. This is no different from any other potential contaminating commercial enterprises.

The relevant regulations, responsible authorities and key trigger limits are provided in Appendix 3.

For most states some kind of works approval is required for on farm biomass plants, irrespective of whether or not the material being processed is generated onsite or sourced offsite. Under the approvals process the owner/operator is required to demonstrate that biogas generation and combustion does not pose an unacceptable risk to the environment. Ongoing monitoring obligations that ensure biogas schemes continue to attain best practice compliance are likely to be provided as a licence condition.

4 Feasibility Analysis

4.1 Core feasibility assessment

The assessment of financial feasibility was undertaken by developing a financial model and applying that model to various example situations. The key output of this analysis was the expected profitability of on-farm AD.

The model was designed after establishing an understanding of key analytical factors. These included drivers of feasibility, the development of the modelling framework, and assessment of feasibility for a reference case.

4.1.1 Drivers of feasibility

Through the completion of the desktop review and consultation phases it was apparent that farm businesses would need four major factors in place for AD to be feasible including scale, crop type, logistics and energy use.

1. Scale

Both the literature and AD experts support the notion that greater scale (i.e. size of AD equipment) improves profitability. This is because the upfront costs reduce with increased size on a per unit basis ($ per tonnes/year of waste throughput).

2. Crop type

Type of crop can significantly affect the cost effectiveness of on-farm biogas through two main drivers:

- Different crops are associated with varying methane production per tonne of throughput
- Proportion of crop wastage is expected to differ by crop type (this flows through to ‘scale’).

Based on available literature, corn appears to be a high biogas-producing crop, and leafy vegetables such as lettuce are low biogas producers per tonne.

3. Logistics

This relates both to timing and cost:

- Timing – as far as possible waste production should be continuous (ideally year round) and stable (not fluctuate too much within the year). This is because the upfront cost of AD can only be recovered if the equipment is utilised constantly throughout the year. If the equipment is sized for peak waste production and is underutilised during a large proportion of the year due to no waste throughput, this significantly affects both profitability and performance of the system. Some storage is possible to ‘smooth’ out waste volumes but storage capacity is limited (waste can only be stored for some time without comprising its energy potential and, once turned into biogas, the gas can only typically be stored for a day or two)

- Cost – the digestate should ideally have a high fertiliser-replacement value (ability to displace farm's purchases of fertiliser), a low cost to spread and the input waste vegetables should not have a high opportunity cost (e.g. if the waste can already be sold for a revenue stream to a neighbouring farm as animal feed then diverting it for AD negates this existing revenue).

4. Energy use

Since the ability to use the AD electricity output to offset the farm's own energy costs is by far of the highest value (compared to exporting the electricity to the grid), the farm's energy use should be sufficiently high (if measured in terms of annual MWh) and match closely with the output of the AD. Electricity is even more costly (practically prohibitively costly) to store and so it must be matched instantaneously with farm demand. Unlike the scale and to some extent logistics factors, where it is the case that the bigger (for scale) or cheaper (for logistics) the better, with energy use it is a case of either the farm operation has the right profile of energy use, or it does not. This is because the high costs of connecting generated electricity to the grid, and the low revenue earned from feeding into the grid, mean that electricity generated in excess of own-farm demand is essentially valueless.

It is apparent that by and large, one factor cannot sufficiently compensate for the other. That is, a farm operation that has favourable scale (produced a large amount of waste) can not make up for a situation where logistics surrounding digestate production and use would be too costly (or impractical) or where there is a lack of energy demand (or that demand can not be matched up with likely AD output). Essentially all four of these conditions are necessary for AD to be feasible. This is depicted in Figure 4-1.

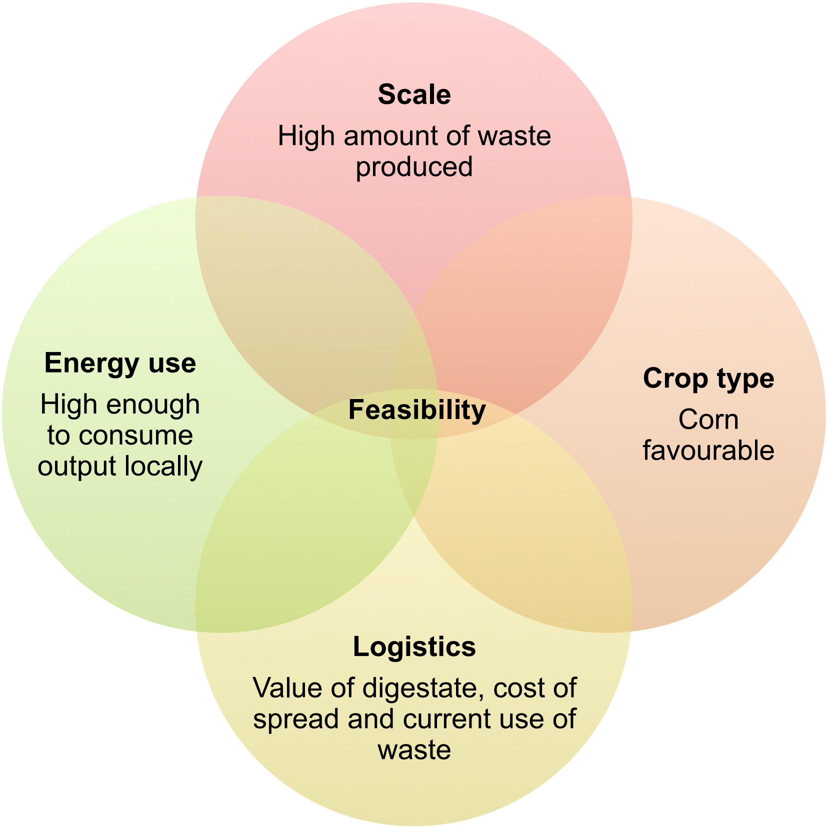

Figure 4-1: Four core drivers of feasibility

4.1.2 Modelling framework

The modelling approach needed to ensure that it could adequately address these four drivers and how they interact.

The feasibility model is comprised of model inputs, calculations and model outputs. There are two types of model inputs:

1. Assumptions: a set of assumptions relating to the cost and benefits of AD was one of the primary outputs of the desktop review and consultation phase. These were then entered as inputs into the model and did not have site-specific values (values would apply to all cases)
2. Case parameters: these are inputs relating to the specific farm operation (mainly relating to crops and energy use) and therefore specified for each individual case.

The main categories of assumptions, case parameters and model outputs are summarised in Figure 4-2.

DCF: A discounted cash-flow (DCF) approach was used to estimate the profitability of on farm AD for vegetable growers. A DCF framework models the annual revenues[21] ('top line'), costs and profit ('bottom line') of an AD project. For the modelling, twenty years' worth of cash-flows was included.

NPV: The annual bottom line is then totalled to produce what is referred to as a Net Present Value (NPV). In an NPV calculation, future year's profits (or losses) are 'discounted'. Discounting takes account of the fact that a dollar earned today is worth more than a dollar earned next year, since that same dollar can then be invested for one year at the going rate. If the going savings rate is 7%, for example, then that dollar is worth 7% more than a dollar a year from now. A general rule of thumb is that a project with a positive NPV should be invested in and one with a negative NPV should not.

IRR: Another metric produced is what is known as an Internal Rate of Return (IRR) which can be thought of as a rate of return on the initial investment over the time horizon (twenty years in this case). With IRR's, the rule of thumb is that a project should be invested in as long as the IRR is higher than the interest rate that would be charged on a loan used to fund the project.

Furthermore, a simple measure of profitability (known as a simple payback) was also produced. This is the number of years it takes to earn enough profits equal to or higher than the initial investment (without accounting for discounting).

The framework also required adequate sensitivity analysis to account for uncertainty (and variability) in factors.

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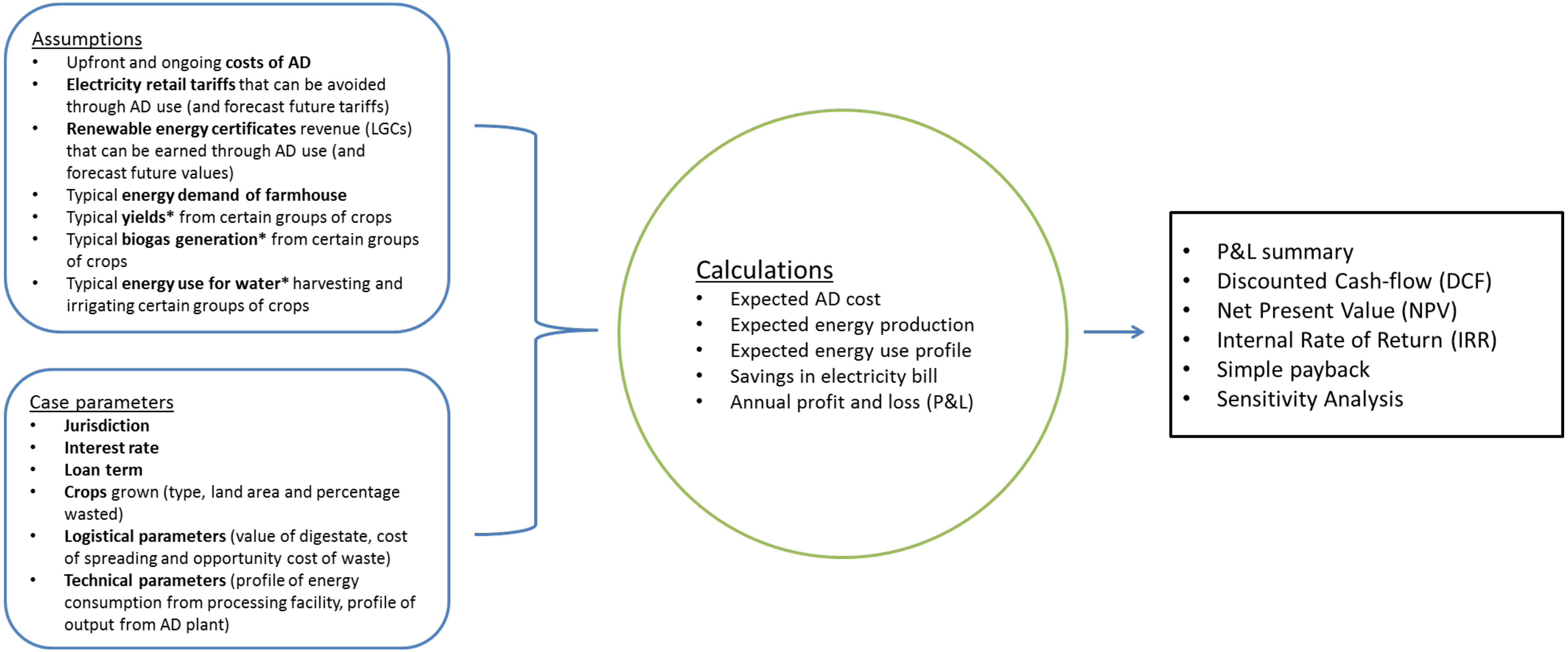
[21] Strictly speaking a DCF should only account for revenues (costs) only when cash is actually received (spent) rather than when it is invoiced (billed). However, for this study it was assumed that the timing of cash transactions matched when revenues/costs are earned/incurred (assuming this all happens at the end of each year). This is a simplifying assumption that is normally used and is a reasonable representation in this case.



Assumptions

- Upfront and ongoing **costs of AD**
- **Electricity retail tariffs** that can be avoided through AD use (and forecast future tariffs)
- **Renewable energy certificates** revenue (LGCs) that can be earned through AD use (and forecast future values)
- Typical **energy demand of farmhouse**
- Typical **yields*** from certain groups of crops
- Typical **biogas generation*** from certain groups of crops
- Typical **energy use for water*** harvesting and irrigating certain groups of crops

Case parameters

- **Jurisdiction**
- **Interest rate**
- **Loan term**
- **Crops** grown (type, land area and percentage wasted)
- **Logistical parameters** (value of digestate, cost of spreading and opportunity cost of waste)
- **Technical parameters** (profile of energy consumption from processing facility, profile of output from AD plant)

Calculations

- Expected AD cost
- Expected energy production
- Expected energy use profile
- Savings in electricity bill
- Annual profit and loss (P&L)

- P&L summary
- Discounted Cash-flow (DCF)
- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Simple payback
- Sensitivity Analysis

Figure 4-2: Main categories of assumptions, case parameters and model outputs[22]

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[22] Note: Crops have been organised into groups and each group assigned an expected yield (t/Ha), biogas generation (GJ/t) and energy use for water (kWh/Ha). These are broad generalisation and will not precisely match actual farm conditions. To cater for farm specific conditions, the model allows/will allow 'overrides' that take in more specific values for actual cases.

4.1.3 Reference case

Prior to conducting actual case studies, a ‘reference’ case was developed in order to validate hypothesised drivers and ensure the proper functioning of the model. The reference case was not intended to represent an actual farm but rather a plausible set of farm conditions appropriate for AD.

The selection of farm conditions was done before undertaking the modelling and assessing profitability. Rather than modifying assumptions until AD was expected to be profitable, a ‘threshold’ analysis (i.e. assessment of how much more favourable would conditions need to be for the example to be profitable) was undertaken.

A summary of key assumptions in the reference case is presented in the following tables (Table 4-1, Table 4-2 and Table 4-3). The reference case is intended to represent a hypothetical site, which may not have any close parallels in Australia. The jurisdiction for the reference site was Queensland.

Table 4-1: Production profile

Crop types	Land area (ha)	Waste (%)
Root and tuber vegetables	800	10%
Cucurbit vegetables	800	10%

Table 4-2: Logistical and technical parameters

Parameter	Value
Logistical parameters	
Digestate value ($/tFM[23])	10
Spreading cost ($/tFM)	0
Waste opportunity cost ($/tFM)	0
Technical parameters	
Processing facility	
Average Monthly Max Demand (kW)	250
Energy consumption (MWh/y)	1,000
AD production and use on farm	
% of demand reduced for every % of energy reduced	100%
Capacity factor of AD	75%
Farm energy offset using AD output	
Farm and irrigation energy use during peak times	10%
Farm and irrigation energy use during offpeak times	40%
Processing facility energy use during peak times	40%
Processing facility energy use during offpeak times	10%

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[23] tFM = tonnes of fresh (wet) vegetable waste

Table 4-3: Other parameters

Assumed financing of AD	Source / value
Funding	Business loan
Loan term	20 years
Interest rate	7%

Findings for the reference case

The reference case was estimated to be unprofitable for AD. The hypothetical AD project was estimated to have:

- An upfront cost of $1.68m
- An estimated NPV of -$234,485
- IRR of 5.3%
- Simple payback of 14 years.

The annual financial projections are provided in Appendix 4.

The results suggest that such a project is not expected to be financially profitable. In interpreting the results it is important to reiterate that this does not represent an actual site, nor can it be concluded that no sites would be profitable. It does however suggest that potential sites would have conditions that are more favourable than the reference case to be profitable.

Threshold analysis

The construction of a reference case allowed validation of hypothesised drivers. This was done through a ‘threshold analysis’ where a model parameter is varied until the desired outcome is achieved. For example, if for a particular size of operation, AD is expected to be unprofitable, then threshold analysis allows an estimation of what size would be required (keeping all other circumstances the same) before AD could be expected to be profitable.

The results of the threshold analysis are presented in Appendix 4.

The results of the threshold analysis confirmed that scale and logistics are important drivers of profitability. In particular:

- An operation with 25% more land area (1,500 Ha), 25% higher crop yield (50 t/Ha) or 13% of crop wasted (instead of 10%) is estimated to be profitable
- Adjusting capital and operating costs within the range indicated above (-10% to +30% of estimated capital and operating costs) do not affect whether the project is expected to be profitable or not
- An operation with a net value of logistics (the digestate value net of spreading costs and waste opportunity cost) 50% higher (i.e. $15 per tonne of fresh matter instead of $10 per tonne of fresh matter) than the reference case is expected to be profitable.

The pre-condition of a consistent and high energy use could not be precisely validated through modelling of this nature. Specifically, an annual cash-flow model which uses annual totals of energy use during peak and off peak times (rather than looking at how energy use varies from hour to hour) does not have the necessary level of resolution. However, metrics were produced to provide a 'sense-check' of whether such an operation has the appropriate energy use profile. Figure 4-3 compares expected energy use (demand) during peak and off-peak times and expected energy production from AD (generation) during those same times.

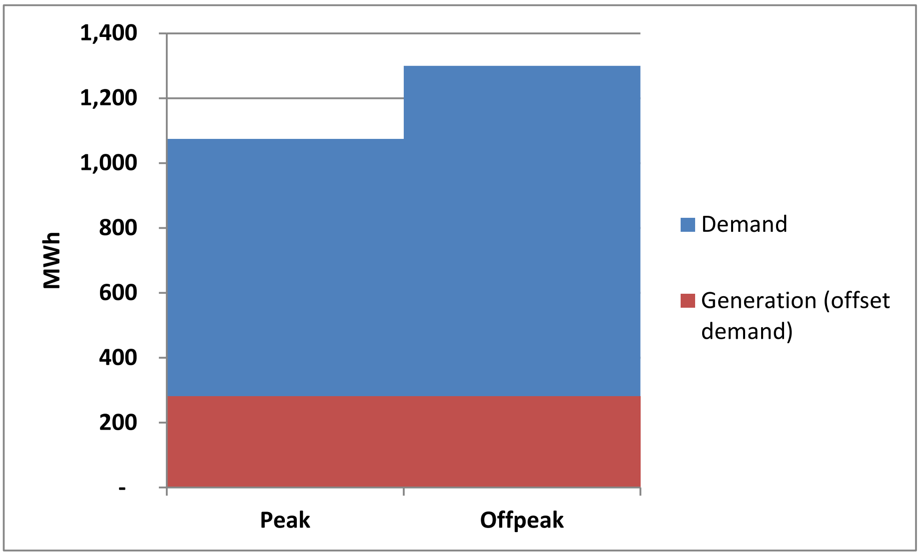

Figure 4-3: Comparison between expected energy demand and generation

The measures of total demand and generation during peak/offpeak periods show that there is (on face value) a high level of demand compared to generation. This does not necessarily guarantee that all generation can be used to offset demand during all hours of the year, which in turn depends on how both generation and demand fluctuate and how well they coincide. Therefore, in considering the appropriateness of AD on specific sites, analysis should be undertaken to confirm this coincidence.

Conclusions

Although the reference case represents a hypothetical scenario it can be safely concluded from the results that AD may not be suitable on every (or indeed the majority) of farm operations. That is, the hurdle of meeting the preconditions necessary for AD (appropriate scale, crop type, logistics and energy use) is set reasonably high.

This informed our case study selection in that specific sites that meet these challenges to profitability or overcome them in some way were sought.

4.2 Additional viability factors

There are a number of additional viability factors associated with AD that will influence vegetable growers decision-making and their willingness to explore AD. In practice, these additional viability factors are typically addressed within project development and service provision. As a result they form part of project costs, and are addressed in the site-specific financial feasibility assessment.

4.2.1 Management of AD plant

In most cases the technical skills in the design, construction, feasibility, operation and management of AD plants is a service offered by AD suppliers. These include, but are not limited to, suppliers listed through the Australian Biogas Group (no date):

- Active Research
- Aquatec-Maxcon
- BEKON
- Biogas Australia Pty Ltd
- Clarke Energy Biogas Cogeneration
- GHD
- Hurll Nu-way Pty Ltd
- Natural Systems Limited
- Ron Mendelsohn
- Utilitas
- Vogelsang Pty Ltd
- AD Australia Pty Ltd.

In general, the technology and infrastructure is imported by these service providers and construction and operation is offered locally. The AD system can be scaled according to grower needs, but some elements of AD management require technical expertise that may not be retained by vegetable growers. These skills are outlined in Table 4-4.

The AD process is a biological process that has been likened to the breaking down of foods in a stomach – ensuring balance is important to maximising efficiency and avoiding negative outcomes. For example, too much nitrogen kills the microbes in the digestor. Ongoing testing of substrate for input into the digester is one key part of the AD process that requires ongoing management needing specific technical skills, and is typically done under an arrangement with an AD supplier.

Table 4-4: Skill requirements for managing AD plants

Area	Skill
System design and construction	▪ Investigate suitable location for biogas digester with respect to current buildings and existing farm infrastructure ▪ Evaluate type and quantity of vegetable waste and logistical issues associated with maintaining a constant supply to feed digester ▪ Scale the design of a suitable system to enable consumption waste supply and the generation of a useful amount of biogas to meet farm needs ▪ Determine engineering requirements of the digester ▪ Determine the possibility of using waste heat and gas for further energy generation, such as electricity.
Financial feasibility	▪ Calculate construction and operational costs ▪ Calculate average biogas and/or electricity production on an annual basis ▪ Evaluate farm energy needs on an annual basis ▪ Undertake analysis of energy production costs and farm energy needs to determine net benefit to the farm business using standard financial analysis methods.
Operation and management	**Planning, timing and regulatory compliance** ▪ Determine daily, weekly, monthly and annual management routines ▪ Construct weekly, monthly and annual maintenance schedules ▪ Investigate the local and regional planning laws and other laws or regulations surrounding the operation of an on-farm biogas digester. **Biological analysis and monitoring** ▪ Substrate and raw materials management ▪ Quality management: recurring inspections, commissioning and repairs ▪ Complete biological support, including the acquisition of fermentation auxiliaries ▪ Property management ▪ Monitoring process biology ▪ Cost security through contractual relationships ▪ Calculations for adjustments when changing the ingredients (BT Biogas no date) ▪ Ongoing testing of digestate may be part of ongoing quality management, which will require specialist expertise. Beyond this, digestate management processes will be established in project design and the Environmental Management Plan, which will not require advanced ongoing technical skills to follow.

Feedstock management issues include managing variable volumes of feedstock (waste volumes may arrive at varying rates) and timing. This can either be addressed through short-term storage of excess waste, or sizing of infrastructure to allow for variable input.

Feedstock timing needs to be considered in the context of seasonal waste production in the main vegetable producing regions of Australia. Where large seasonal variations exist in waste volumes, the digester either needs to be sized for the largest seasonal use and thus operating below maximum capacity in other seasons, or sized smaller for the remaining seasons with some excess waste volumes in high waste seasons.

Transport and supply of feedstock plays an important role in the operation of a biogas plant. This includes ensuring:

- Continuous supply of feedstock
- Suitable quality
- Consistent quantity.

Managing these issues is easier if the feedstock is produced on-farm. However, this will be more difficult if additional off-farm feedstock (co-substrates) produced by neighbouring farms, industries or households is used. This includes checking, accounting and verifying the co-substrate as well as the associated transportation logistics and costs.

Regulatory obligations and legal and administrative costs are also important to consider for feedstock types classified as wastes (Al Seadi et al 2008). Contamination management (including soil and plastic) may be another feedstock management issue. Pre-processing of waste (maceration to appropriate size) is another issue, which can be addressed where required with machinery.

Once feedstock management processes are established, ongoing technical requirements can be expected to be minimal.

The set of equipment that turns biogas into electricity (referred to as the ‘gen-set’) requires some level of expertise to operate and maintain. The actual engine may be a variety of technology types but most likely to be either a reciprocating engine or a gas turbine generator. Growers are likely to have the skills to operate and address minor maintenance issues with reciprocating engines (given similarity to reciprocating engines in some other farm equipment) but possibly less so with gas turbines. Gen-set providers do often provide maintenance plans (to address technical issues and regular maintenance) and in some cases remote monitoring and operation of gen-sets. Maintenance and warranty is normally contingent on agreed biogas quality specifications.

4.2.2 Digestate management

Digestate is a residual product of the AD process, consisting of residual indigestible material and dead microorganisms. The primary agricultural potential for digestate is as a fertiliser substitute (Lukehurst et al 2010). The fertiliser value of the digestate will depend upon the nutrients present in the feedstock, and will thus differ for each plant and even for each digestate batch. It can be expected that digestate from AD containing some proportion of animal wastes will contain higher loads of phosphorus than that purely from vegetable waste, and as such may be a higher value fertiliser substitute.

Digestate can be used in ‘whole’ (unseparated) form, which is predominantly liquid, or it can be mechanically separated into solid and liquid forms. Whole digestate is highly liquid (typically between 95 to 98 per cent liquid), and can be applied to land using a variety of liquid spreading machinery including trailing hose, trailing shoe, injection and splash plate (Arthurson 2009).[24] These are relatively expensive application methods, given the relatively low concentrations of mineral load in digestate compared to standard liquid fertilisers.

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[24] It may be possible to apply whole digestate through the irrigation system, however clogging of the solid component may prevent this.

The capital and operating costs of applying whole digestate of a value less than $15 per kilolitre would seem infeasible. Separation of digestate into solid and liquid forms seems more cost-effective, as liquid can be added to the irrigation network, and the solid can be stockpiled for spreading as per a solid manure. Mechanical separation will add to the capital and operating costs of the plant, and will separate some of the mineral content of the digestate between solid and liquid components.

An alternative to separation is the use of heat-based drying technology that retains the mineral load in the resulting concentrated product. The concentrated product can be pelletised for easy spreading or potential sale should a market exist.[25] However, studies have found that the drying process can reduce some mineral loads. Some advantages of separation or drying include:

- The ability to cost-effectively store the dry fraction and/or pump the liquid fraction through an irrigation system
- Reduced liquid storage costs
- The potential to sell the end product into agriculture markets or the retail nursery market
- Increased efficiency of nitrogen uptake from the liquid
- Reduced application costs by reducing the volume of digestate per nutrient load.

Nutrient load of the digestate is equivalent to that of the feedstock as nutrients and minerals are not removed during the AD process (Marinari et al 2000). One of the identified benefits of digestate compared to the application to land of raw manure or vegetable waste as ‘green manure’ is that through the AD process, most organically bound nutrients, in particular nitrogen, are mineralised and become easily available for plant take-up (Al Seadi et al 2008).

Some studies have found that pathogens including fungal diseases that affect crops are killed or irreversibly inhibited during the AD process, due to the temperature and digestive process, providing an additional benefit of digestate use over raw and green manure (Haraldsson 2008; Zetterstrom 2008).

At a high level, the financial impact of digestate management on financial feasibility can be described in four steps:

1. Net financial impact of ceasing alternative waste management approach: plus
2. Additional costs of digestate treatment/storage; plus
3. Cost of digestate application; less
4. Value of digestate use (e.g. fertiliser value).

These four attributes, when combined, produce the formula for financial impact of the digestate use.

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[25] Examples exist of the commercial sale of dried digestate from piggery wastes as a ‘potting mix’, sold into the retail nursery market.

4.2.3 Regulatory burden

Producing a system that meets regulatory compliance will be primarily the responsibility of the AD supplier, with some input from the grower, especially around application of digestate to land. Regulatory compliance will be a function of system design and construction, and management plan, which would be subject to regulatory approval. In the case where the grower decides to forgo a service arrangement with an AD service supplier, they would need to address these regulatory concerns themselves. This could be a more time intensive and higher risk option. Section 3.5 provides regulations relating to plant design and gas flaring and the application of digestate to land.

Specific regulatory arrangements differ by jurisdiction, but addressing these can form part of the service provided by AD suppliers. Without an existing biogas plant in operation on an Australian vegetable farm, difficulties associated with regulatory burdens in practice are as yet unknown.

4.2.4 Commercial arrangements

Three main types of commercial arrangements exist for biogas on-farm, of which two are more likely options for commercial farms. These include build, own, operate (BOO) and build and operate. The third arrangement is build only.

Build, own, operate (BOO)

A BOO arrangement occurs where the grower engages a company to build the AD plant, which that company then owns and operates. The grower then engages with the company as an energy provider, with a long-term contract at an agreed rate.

As the AD supplier retains ownership and operations management of the facility, the need for the grower's technical knowledge of the AD process is minimised. Processes are established for feedstock quantity and quality, input management and digestate use, and remaining AD services are provided by the AD supplier as part of the arrangement.

This type of arrangement provides the grower with a more stable and known energy price over the contract, and the AD provider has a predictable rate of return over the lifetime of the contract. The grower pays a fixed price for the energy produced so they are hedging their energy price risk. However, this could have a downside if the market price of energy is actually lower than the agreed rate. In this case the grower may have been better off buying their energy off the market, rather than the AD supplier.

Greater project risk is borne by the AD supplier as they finance the project, but the AD supplier also retains any project profits. The AD supplier bears the following risks:

- Project design, construction and operation risk e.g. equipment failure and compensation to the grower for having to buy energy off the market or some other penalty payment
- Commercial risk if the vegetable farm is forced to cease production or close.

This type of arrangement is more likely for large AD projects, given the challenges associated with project financing and management.

There are some key considerations in assessing risk for commercial arrangements under the BOO model, these include:

- Change in crop type
- Variation in feedstock quality, quantity and timing
- Reduction in waste volume due to improved production efficiency
- Reduced scale due to external factors such as market pressure
- Change in farm ownership or closure.

Build and operate

The other main type of commercial arrangement that is likely for AD on vegetable farms is a standard commercial arrangement in which the grower finances the project, and commissions an AD supplier to build the plant. The AD supplier is then engaged to provide operations consulting services on an ongoing basis.

This type of arrangement involves greater up-front cost (whether on balance sheet or wholly/partly bank debt financed) to the grower, but allows the grower to benefit directly from the reduced cost of energy. By purchasing operating services, technical skills in AD management are not required by the grower.

This type of arrangement is suitable for smaller operations as well as large ones, as it is not typically of a scale to require external equity investment.

Build only

The third type of commercial arrangement is one that is managed, owned and operated by the grower as part of farm operations. In this arrangement, the AD supplier is commissioned to build the plant, but ongoing operations are managed by the grower.

This approach requires significant technical skills by the grower, or the ability to purchase assistance on an ‘as-needs’ basis. Given the scale of financial investment required to develop an AD project on-farm, and the expertise for AD management required for ongoing operations, this type of arrangement appears less likely than the previous two.

4.2.5 Cluster model

As a general rule, the cost-effectiveness of AD improves with increasing scale – the larger the scale, the lower the unit cost of electricity generation and digestate management. Our analysis of available data suggests that cost-effectiveness of AD on a single vegetable farm is more likely to be financially viable for very large farms (producing 6,000 tonnes of waste per year, although this is an approximate guide only and would vary according to crops, farm practices and other circumstances).

However, alternative models exist to benefit from scale across several farms (multiple vegetable farms, other farm types, or potentially from non-farm waste streams such as food waste). While no examples currently exist in practice that we are aware of, two types of ‘clustered’ models present as options:

1. Two or more neighbouring farms, combining waste volumes and sharing benefits amongst themselves
2. Larger, regional clusters that could potentially incorporate a variety of different waste streams (vegetable, other agricultural such as piggeries or poultry farms, food waste).

Operations at this scale might require full time management by a dedicated AD service provider, and would need detailed management arrangements for digestate use given the scale.

However, a number of additional challenges exist when establishing shared AD assets among a ‘cluster’ of farms, specifically:

- Establishing commercial arrangements for the sharing of costs and benefits (including electricity, heat, carbon dioxide and digestate)
- The wholesale rate that such an asset would earn for energy produced is often much less compared to a single-farm operation where an individual grower enjoys a high retail rate saving (issues relating to electricity value from the cluster model are elaborated on in the next section)
- Potentially greater regulatory burden when receiving off-farm waste streams than when using own-farm volumes.

The opportunities and challenges of the cluster model approach require further investigation.

A further consideration of the cluster model is the value of electricity under different scenarios. In a clustered approach either:

- Waste volumes are pooled and electricity produced is used to offset a single farm’s electricity costs, or otherwise shared among participating farms ‘behind the meter’.[26] The fundamental costs and benefits are similar to that of a single farm model but the sharing of those costs and benefits would need to be agreed; or
- Electricity produced from the pooled waste volumes is too large and must be exported to the grid.

In the latter case, the value of electricity is fundamentally different. Specifically, electricity exported to the grid is valued at the ‘wholesale’ price rather than the ‘retail’ price (the retail price is the price a grower would avoid paying on their retail bill). Average retail prices are much higher (approximately 4 to 5 times) than average wholesale prices. Wholesale prices are also unpredictable and vary from half-hour to half-hour depending on trading in the market.

A summary of key differences between single-farm electricity use (offset of local electricity) and export value is provided in Table 4-5.

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[26] If the biogas plant is centrally located between several farms, the gas could be distributed through pipes to each farm and used on-site by each farm, or electricity generated could be similarly delivered to each farm.

Table 4-5: Summary of differences between local electricity use and exports

	Offset local electricity use	Export electricity to grid
Average benefit (c/kWh)	Predictable, based on rate normally charged by retailer.	Variable and less predictable, much lower on average if AD is run consistently but can be higher if output from AD is flexible to coincide with time periods of higher value
Process to monetize energy value	Automatic, retail bills will be lower as local energy use is reduced (offset).	Negotiate and sell price to local retailer or trade on the electricity market.
Process to monetize potential value of 'grid support'	Not possible under this model.	Negotiate with Distribution Network Service Provider (DNSP).
Overall transaction and equipment costs	Electrical wiring and equipment that allows energy to be used on-site.	Electricity market registration fees and additional metering and associated equipment (e.g. transformers, wiring etc.) to operate as an exporting generator. May be required to pay costs of reinforcing network to support export of electricity.
Generally suitable for	Single farm and on-site electricity use is large enough to be offset by AD electricity generation.	Much larger scale (e.g. multiple large farms etc.) such that the benefit of reduced unit costs (due to economies of scale) and/or potentially higher average price/grid support value make up for the additional transaction and equipment costs and loss of retail value.

5 Case Studies

5.1 Case study 1: sweet corn, brassica and leafy in Queensland

5.1.1 Overview

A large vegetable farm based in Gatton in the Lockyer Valley of Queensland grows and packs a range of vegetables for both domestic and international markets. The operation has over 4000 hectares in multiple sites across southern and northern Queensland. The largest site is situated in Gatton, which also houses their main processing and packing operations.

The farm involves a continuous operation producing sweet corn, fresh beans, broccoli, lettuce, cauliflower, wombok, baby corn and watermelon. With sites in different growing regions (and climates), they are better able to meet year round demands from different markets.

This analysis focuses on costs and waste volumes associated with their main processing site only (Figure 5-1).

Figure 5-1: Sweet corn waste at case study 1 farm

5.1.2 On-farm context and drivers for biogas

Energy use

The site is a high electricity user, with total monthly costs exceeding $30,000 over the past year. Electricity use is characterised by relatively high and flat demand, a trend of growing use over time (reflecting growing operations) and electricity use during peak times (summer months) being around 50 per cent higher compared to non-summer months. Overall electricity use during peak times exceeds off-peak use by around 10-20 per cent.

Electricity costs are largely associated with cool room energy use, which is continuous but higher during peak (daylight) periods and especially so during the summer months.

Being a large energy user, the site's retail electricity tariff is relatively low. However, the operation faces an increasing network charge reflecting the operation's maximum demand at any given time. As the operation grows, this component of their electricity cost increases as a proportion of total cost. Biogas may be a useful way to reduce this maximum demand and thus electricity costs.

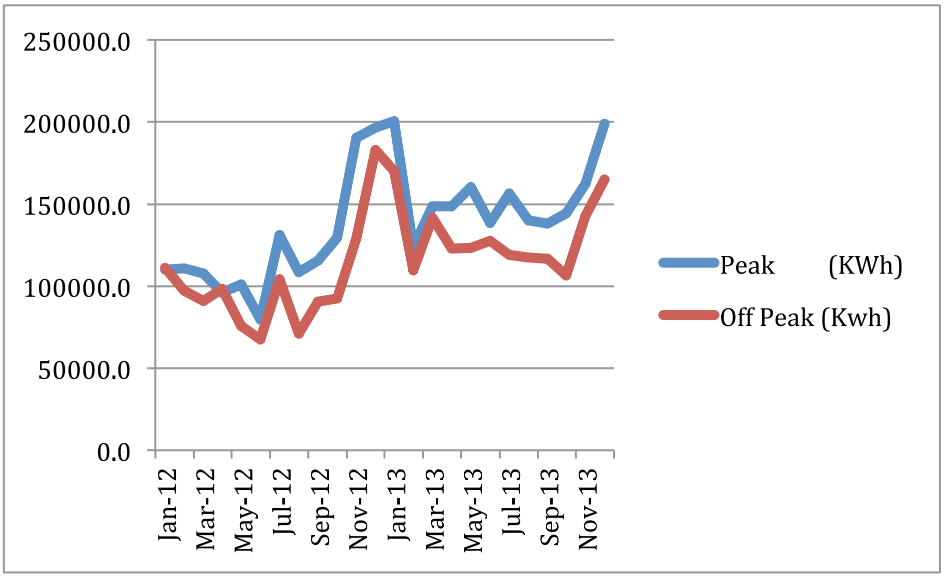

Figure 5-2: Pattern of monthly peak and off-peak electricity use

Waste production and management

The site predominantly produces waste from crop processing sourced from the farms own plantings in the local area, although crop is increasingly transported from their other sites to the region.

The processing operation is in continuous operation, producing waste year round. Most processing is associated with sweet corn, broccoli and broad beans (estimated at around 50%, 30% and 10% of total waste respectively). No detailed recording of waste volumes is undertaken.

As a proportion of total crop transported to site, waste is a relatively large proportion: waste volumes are estimated at 50% of total corn volume, 30% of beans and 15-20% of broccoli.

Larger waste volumes are produced in the six warmer months (40-50t/day) than in the cooler months (15-20t/day) reflecting the processing of larger crop volumes. This coincided broadly with energy use, which is higher in warmer months.

Waste is produced at multiple points in the processing chain, and is aggregated and stacked for transportation off-site using two trucks dedicated to waste management. Waste must be moved quickly to avoid attracting pest birds and animals.

The current approach to waste disposal is as stock feed for cattle, a solution that has been developed specifically for the purposes of waste management. Remaining waste is opportunistically sold as stock feed to neighbouring cattle farmers. Returning waste to land as ‘green manure’ is not considered an option as the fields are in constant operation.

A cost-effective waste management solution that allows for a reduction in disposal and management costs and that is integrated with their processing operation would appeal to the farm operators.

5.1.3 Quantitative analysis

The above profile of waste production/management and energy use/cost has been translated into model inputs. In this translation process a number of assumptions are made:

- Production of waste sweet corn, brassica vegetables, legumes and other vegetable waste broadly consistent with the composition of total waste and waste per crop described above.
- A specific estimate of the biogas yield for sweet corn different to the generic assumptions (sweet corn is assumed to be in the ‘other vegetables class’ in the reference case) due to the much higher yield expected. This estimate is based on data from a UK government biogas information portal (National Non-Food Crops Centre no date) and an equal proportion of maize silage and maize grain (as a proxy for the sweet corn waste described above) but adjusted down to account for differences between theoretical potential and practical conditions was used. A yield of 218 Nm^3 of biogas per tonne of waste sweet corn is assumed.
- Average tonnes per annum (approximately 11.5 kilo-tonnes per year or 32 tonnes per day) consistent with the average tonnes during warmer months and cooler months described above.
- Sizing of the biogas plant and equipment such that a peak throughput is approximately 30% higher than average throughput or equally that average throughput is 75% of peak throughput (this considers that storage will smooth out some but not all of the variability in waste feedstock).
- Energy use and tariff assumptions based on energy bill data provided.
- A net value of logistics of 25 cents per tonne based on personal communication with relevant farm staff (incorporating offset fertiliser, spreading costs and current value of waste) and associated calculations.

Other key assumptions included a weighted average cost of capital (equal to the interest rate if fully funded by debt) of 8%, that the majority (70%) of energy is used to offset the packing facility’s energy with remaining for irrigation and farm use and the majority of energy production (60%) used to offset peak load. Summary results are provided in Table 5-1.

Table 5-1: Summary of case study 1 quantitative analysis results

Result Variable	Value
Waste throughput	11.5 kt p.a.
Energy output	3.7 GWh p.a. (569 kW_e capacity of engine with a 75% utilisation factor)
Upfront cost	$3.7m
Profitability (NPV)	$4m
Profitability (IRR)	19.3%
Simple Payback	6 years

5.1.4 Conclusions and caveats

The above estimate of profitability suggests that the site could be suitable for the adoption of AD. Two of the greatest uncertainties in this analysis are the:

- Biogas yield from waste, in particular from sweet corn waste. A more precise estimate would require audit of the total weight and composition of waste volumes and laboratory testing of the potential biogas yield from a sample; and
- Net cost of logistics. A more precise estimate for this figure would require detailed analysis of waste management practices, digestate nutrient value and spreading costs.

A ‘breakeven analysis’ was therefore undertaken to identify at what values of biogas yield and net digestate value would result in a $0 NPV. Possible values include:

- 101 Nm3 of biogas per tonne of sweet corn waste and net benefit 25 cents per tonne of digestate; and
- 218 Nm3 of biogas per tonne of sweet corn waste and net cost of $31 per tonne of digestate.

The actual values for these variables are likely to be more favourable than these breakeven values suggesting that the site presents a strong case for AD. Further analysis is recommended, in particular audit and laboratory testing of feedstock and detailed cost analysis of plant costs and net digestate value (or cost). Additionally, production of energy is estimated to be a high proportion (75%) of expected demand. Therefore, an hourly analysis of the coincidence of energy production and demand should be undertaken to establish whether these can be aligned.

5.2 Case study 2: carrots in Western Australia

5.2.1 Overview

Case study 2 involved a large carrot property north of Perth, Western Australia. The business produces, processes and packages carrots predominantly for the export market, from two nearby sites totalling over 500 hectares. The central site also houses their processing plant.

The operation produces 2-2.5 crops per year, and their processing production is ongoing 52 weeks a year. The plant receives crops from both sites for processing, but does not receive crops from other producers. They produce packed out volume of around 500 t per week, and produce waste volumes from the processing plant of around 100 t per week.

Figure 5-3: Carrots at case study 2 farm

5.2.2 On-farm context and drivers for biogas

Energy use

The farm is a high energy user, with electricity costs totalling around $1m per year. On-farm electricity use is driven by irrigation activities (including groundwater pumping and distribution), and electricity use in the processing plant. The processing plant uses power for machinery and cold rooms, however the size of the cold rooms is smaller than for some other vegetable processing operations due to the nature of the crop and the continuous operation of the site (packaged product can leave the site soon after packaging).

This energy profile provides a reasonable block of base load with a spike in summer as irrigation electricity use increases. Processing plant energy use is predictable and similar day to day.

Increasing power bills are a concern to the operation, and 100kW of solar panels will soon be in operation. Solar power may be complementary with biogas, as biogas provides a consistent base load supply and solar provides a greater proportion of energy during peak times.

The differences between peak and off-peak tariffs do not significantly drive behaviour.

Waste production and management

In the context of staff and management time, waste management does not feature as a pressing concern for the operation or a major problem.

Waste volumes are estimated to average 14 tonnes per day, with some variation around this volume. A waste component of around 20-25 per cent of processed crop is produced exclusively within the processing plant.

A small proportion of waste is produced and left on-field in harvesting, which is then left to dry before being rotary hoed back into the soil as part of preparation for the next crop. This provides some organic matter to the soil, and is produced as part of an efficient harvesting process. It is not being considered for potential feedstock in a biogas plant.

While the operation is continuous, waste volumes vary day to day, so a response to this variability may be required for a biogas plant to ensure continuous feedstock. Fortunately, the crop type stores well for short durations, and a simple storage site could be constructed for this purpose. Pest animals are not considered a problem.

Stable fly[27] management in the area limits the application of un-composted organic waste to land, as rotting crop residue is considered a significant breeding site.

As product cleaning is an important part of the processing operation, contamination load is not considered a concern for potential biogas use of the waste. Current processing also collects the waste into a central location.

Current waste use may be best described as a least cost disposal approach to waste management. Three current options exist for the site:

1. Sale to local cattle farms for a minimal price: highly variable and relatively small volumes
2. Sale to juice manufacturers: highly variable and relatively small volumes
3. Disposal on-site.

The first two options provide minimal revenue, but are highly irregular and do not provide a consistent waste management solution. On-site disposal involves minimal contracting and labour costs, and is undertaken on parts of the property that are unsuitable for cropping. Thus, it does not compromise production.

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[27] Stable fly is a blood-sucking parasite and is one of the most important pests of cattle and horses. It is also a pest of dogs, cats, pigs, humans and many other short haired mammals. Injury is caused by irritation from its painful bite and loss of blood.

Other waste management options have been considered, but none found to be suitable. For example, a shortage of land prevents the establishment of their own feedlot.

Nevertheless, an alternative such as biogas may provide a cost-effective solution.

5.2.3 Quantitative analysis

Major key assumptions for case study 2 were:

- Production of root and tuber vegetables (carrot) waste of about 100 tonnes per week as effectively the only feedstock
- Sizing of the biogas plant that assumes consistent (effectively no variability) throughput
- Energy use and tariff assumptions based on the sites location and size and a total energy bill of approximately $1m per year
- A net value of logistics of $1.47 per tonne based on personal communication with relevant farm staff (incorporating offset fertiliser, spreading costs and current costs of waste management) and associated calculations
- Given the consistency of waste feedstock throughput it is assumed that the plant may be utilised to a high level (95% utilisation of electricity generator). This ‘baseload’ production profile removes the ability to produce relatively more during peak times (and less during off-peak times) and therefore a uniform distribution of energy use (equal offset energy during peak and off-peak hours) is assumed, as well as an equal offsetting of processing facility energy use and other (irrigation and farm house) energy use.

As with case study 1, a weighted average cost of capital (equal to the interest rate if fully funded by debt) of 8% is assumed.

Summary results are provided in Table 5-2 below.

Table 5-2: Summary of case study 2 quantitative analysis results

Result Variable	Value
Waste throughput	5.1 kt p.a.
Energy output	578 MWh p.a. (69 kW_e capacity of engine with a 95% utilisation factor)
Upfront cost	$1.7m
Profitability (NPV)	-$0.8m
Profitability (IRR)	1.5%
Simple Payback	18 years

5.2.4 Conclusions and caveats

An AD plant for this site is not expected to be profitable (-$0.8m NPV). This is because the plant configuration described does not produce a sufficient rate of return on the substantial initial investment (1.5% compared to an 8% cost of capital).

Consistent with conclusions reached in the reference case modelling, it is the case there is insufficient scale for the plant to be cost effective and other drivers of profitability would be needed.

Sensitivity testing suggests that approximately twice the amount of waste would be required for positive profitability. Coupled with the circumstance that the site has very large electricity use relative to potential AD output (modelled energy generation is approximately 12% of demand) supplementing with other feedstock from nearby sources could be a potential option. It has, for example, been identified that chicken manure may be available as possible supplementation. Additionally, profitability could be further improved if the waste heat from AD could be used to supply nearby sources of heat demand that have been identified.

An important consideration in any biogas feasibility assessment is the value attributable to the digestate, either used on-farm as a soil amendment (with fertiliser replacement value) or potentially sold as a commercial product (such as a potting mix). Digestate can be applied in ‘whole’ digestate form, or separated into solid and liquid forms and applied separately. It can also be dried and pelletised.

It is often assumed that the digestate will provide a value to the farmer if applied to fields, by reducing fertiliser costs and improving soil health. While these qualities typically exist, the potential also exists to disrupt precise production methods often associated with fertigation of carrots.

In this case study, product quality and consistency is paramount to the production process. The soil type is consistent across the operation, and fertiliser application is extremely precise across the crop to maximise crop consistency.

Application of either whole digestate through a liquid spreader, or separated digestate with the liquid component injected into the aerial irrigation network and the solid component spread on ground, may produce a new management challenge in the context of this specific production process. The digestate may be better sold to commercial nurseries or garden centres as a potting mix. This would require the establishment of supply chains for product sale. For this case study we have thus conservatively assumed a digestate value of 10% of the estimate used in the central analysis, reflecting the potential limitations.

This type of issue would need to be considered in detailed project planning, but it underscores both the precise nature of production in the horticulture industry, and the case-specific context of each prospective biogas project.

5.3 Case study 3: carrots, onions, brassicas, swedes and beans in Tasmania

5.3.1 Overview

Case study 3 involves a large vegetable farm based in northern Tasmania. The business produces a variety of fresh vegetables for the domestic Australian market, as well as export. Crops include carrots, potatoes, onions, broccoli, swedes, beans and beetroot.

The main processing site is located near Devonport where the majority of the farm area is also located (380 hectares). Another 270 hectares of productive land is located approximately 100km away. All processing takes place at the main site, which operates year round.

Being a cool climate region, crop production (and therefore waste production) is heavily weighted towards the warmer months (December to May), with significantly lower volumes produced in the remaining months. This coincides with electricity use, which is dominated by cooling costs and irrigation.

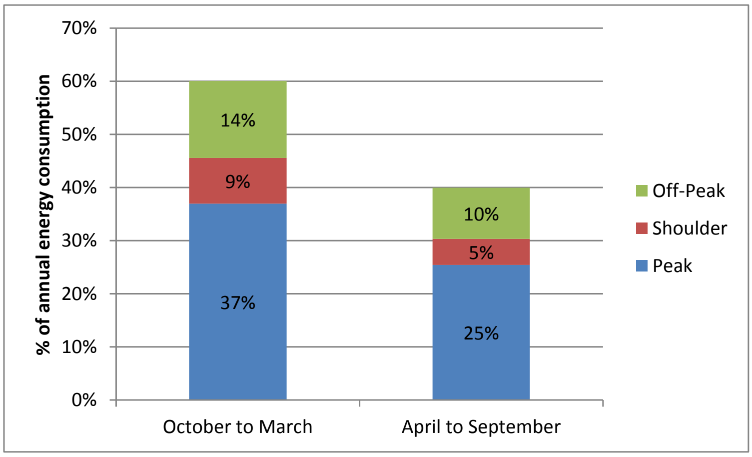
Figure 5-4: Carrot crop at case study 3 farm

5.3.2 On-farm context and drivers for biogas

Energy use

The farm is a relatively high electricity user, with an annual electricity cost at their processing plant of around $500,000 per year. Electricity use is driven at this central site by cooling costs in the processing plant, with some machinery and irrigation costs. Electricity costs at this site are around two thirds of their total electricity costs.

As illustrated below, energy use varies somewhat by season and to a larger extent by peak/shoulder/off-peak at one of the representative main sites. This variability in demand is only likely to be an issue if AD electricity production is high relative to demand. On the other hand if expected AD output is much lower than demand (as our analysis indicates) this is not a cause for concern.



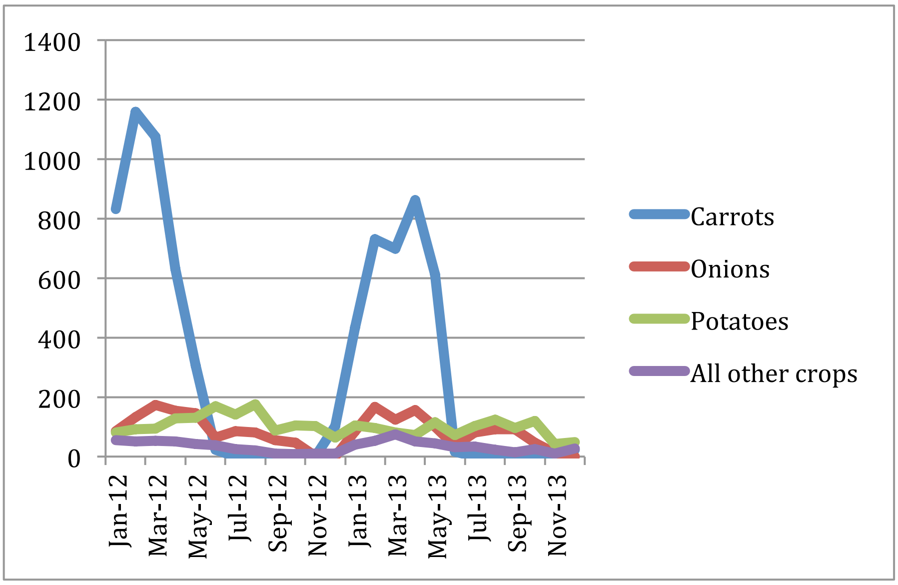
Source: Marsden Jacob analysis of bill data

Figure 5-5: Proportion of energy use at main site

Waste production and management

Waste management is a real if not prominent concern for the farm managers, who use a range of arrangements depending upon waste type and volume.

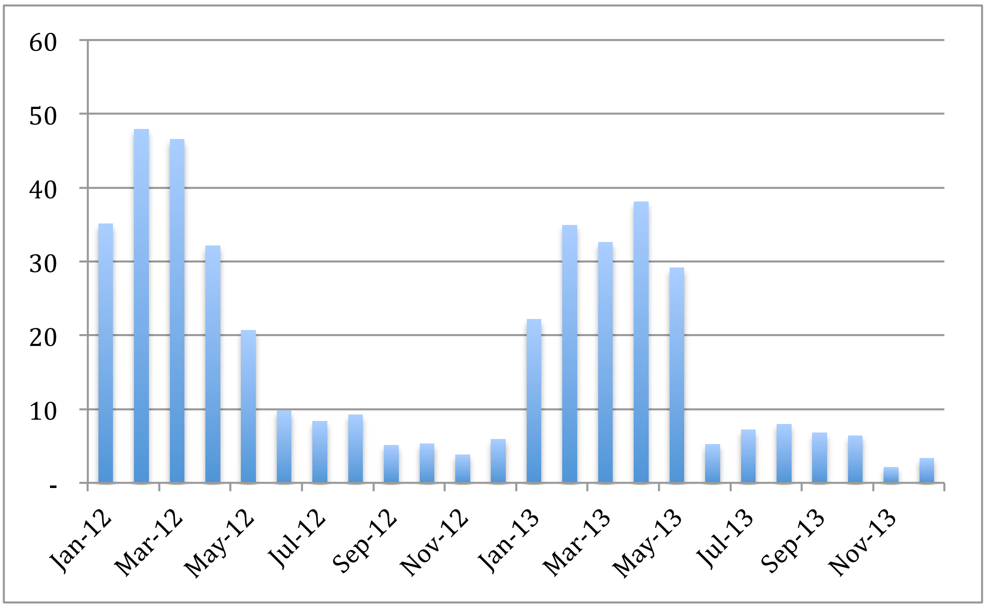
The proportion of waste produced for each crop varies from 2 per cent to as much as 20 per cent. Waste volumes are dominated by carrot waste, as can be seen in Figure 5-6 which shows monthly waste volumes by crop type. This illustrates both the dominance of carrots in waste production, but also shows the seasonality of waste production. Waste production from December to May is 2-3 times higher than in remaining months, driven largely by carrot harvest.



Source: RMCG analysis based on farm data

Figure 5-6: Monthly waste volumes for all crop types (tonnes)

Average daily waste production varies from over 40 tonnes per day in peak summer months to as little as five tonnes per day for several months from June to November (Figure 5-7). This variability in waste production would require careful consideration in any planning for biogas. Responses could include storage of waste to even out variability, and/or augmentation of these waste volumes with other sources (discussed further below).



Source: RMCG analysis based on farm data

Figure 5-7: Average daily waste production by month (tonnes)

Additional potential biogas feedstocks

In addition to the waste volumes described above, the farm produces wheat and silage that could be appropriated from other uses and used to augment a biogas plant (Table 5-3). Around 1,250 tonnes of wheat grain is produced with a further 800 tonnes of straw. Both are currently sold but could be used if required. A further 650 bales of silage are produced on the farm, and half mixed with vegetable waste and fed to cattle. The remaining volume is sold.

Table 5-3: Potential additional feedstocks

Crop	Tonnes per year	Tonnes per month equivalent
Wheat grain	1250	104
Wheat straw	813	68
Silage	80	7

Source: RMCG analysis based on farm data

Current use of waste

The primary use of current waste is to supply the farm's own cattle feedlot with feed. The vegetable waste is mixed with silage to provide an appropriate mix. Given the variable waste volumes produced, surplus volumes are sometimes produced, which are sold to local dairy farmers. Onion waste is unsuitable for cattle and is generally disposed of onsite. No capital costs are incurred for on-site disposal.

5.3.3 Quantitative analysis

Major key assumptions for case study 3 were:

- Production of mainly root and tuber vegetables (carrot) waste of about average 10 tonnes per day (60% of total waste) and other vegetables of about 7 tonnes per day (40% of total waste)
- Sizing of the biogas plant and equipment such that a peak throughput is approximately 2 times higher than average throughput or equally that average throughput is 50% of peak throughput is assumed (this considers that storage will smooth out some variability in waste feedstock but a large residual variability remains)
- Energy use and tariff assumptions based energy bill data provided
- A net value of logistics of $1.03 per tonne based on personal communication with relevant farm staff (incorporating offset fertiliser, spreading costs and current value of waste) and associated calculations.

The above assumptions include assuming a digester capacity that is twice the average daily input of waste feedstock. This would result in a significant underutilisation of the plant. Therefore a second scenario, assuming a smaller digester but fully utilised, was undertaken. This improves utilisation but results in lower scale. The two scenarios are compared and the configuration resulting in a higher NPV (or lower negative NPV) would be preferred.

As with case studies 1 and 2, a weighted average cost of capital (equal to the interest rate if fully funded by debt) of 8% is assumed.

Summary results are provided in Table 5-4 below.

Table 5-4: Summary of case study 3 quantitative analysis results

Result Variable	Value (Scenario 1)	Value (Scenario 2)
Waste throughput	6.4 kt p.a.	3.2 kt p.a.
Energy output	767 MWh p.a. (117 kW_e capacity of engine with a 75% utilisation factor)	384 MWh p.a. (46 kW_e capacity of engine with 95% utilisation factor)
Upfront cost	$3.9m	$1.3m
Profitability (NPV)	-$2.9m	-$0.8m
Profitability (IRR)	-5.3%	-2.2%
Simple Payback	Not recovered in time horizon modelled (20 years)	Not recovered in time horizon modelled (20 years)

5.3.4 Conclusions and caveats

An AD plant for this site is not expected to be profitable (-$2.9m NPV in scenario 1 or -$0.8m NPV in scenario 2). This is for similar reasons as in case study 2 (low annual return). Scenario 1 is particularly unprofitable since a larger relative plant size (per tonne of waste feedstock) is required to process the variable throughput of feedstock.

In this case, there is insufficient scale exacerbated by high variability in feedstock resulting in significantly negative NPVs. However, as noted above additional potential feedstocks in the form of wheat grain, wheat straw and silage are available. Coupled with the estimate that energy production for Scenario 1 is expected to be about 21% of available demand to offset, there is scope for supplementation.

The net costs and benefits would need to be properly investigated. Sensitivity analysis indicates that a plant with total waste use smoothed across the year to be uniform (to avoid requiring to 'over-size' the plant) and total waste increased by an additional 25% (resulting in 8 kt p.a.), could be profitable. This is assuming that the additional waste volumes are of a similar composition to the modelled case (vegetables).

However, the estimate of additional feedstock necessary for profitability would differ if it was assumed that wheat grain, straw or silage was used. On the one hand, wheat produces a higher yield of biogas. On the other hand, the opportunity cost of the wheat is expected to be much higher. On balance, the variability in vegetable waste feedstock production is a difficult challenge to overcome and the site does not appear suitable for AD.

5.4 Case study 4: ‘Cluster model’ in Western Australia

5.4.1 Overview

The ‘reference case’ explored in detail within this analysis is a biogas plant sited on a single vegetable farm, using waste volumes produced on-site and digestate applied on-farm. This central analysis has been chosen because it presents as the most likely configuration for a cost-effective biogas operation.

However, as noted throughout this document, a variety of configuration options exist, such as augmenting own waste with off-farm waste, selling electricity to the grid, or selling digestate as a commercial soil amendment product (such as potting mix to commercial nurseries).

Of particular interest to smaller farms is the potential to ‘cluster’ the waste from a number of farms (vegetable or other operations such as piggeries or poultry farms), thus increasing economies of scale, and potentially reducing the unit cost of energy production. The benefits of energy production and digestate could potentially be shared among participants, although not without complications. The key benefit of a ‘cluster’ model is that, if feasible, it expands the scope of biogas using vegetable waste beyond the largest operators to smaller farms.

5.4.2 Context

This case study discusses a potential cluster model proposed for the Gingin area north of Perth, which is home to a number of vegetable farms of different sizes, along with other primary production enterprises that could also contribute waste to a cluster model. In the absence of specific data for a cluster model, there was no quantitative feasibility assessment undertaken as part of this project. Instead, a discussion on the opportunities and challenges to a cluster model is provided below.

Gingin is a horticultural and agricultural area 1.5 hours north of Perth in Western Australia (**Figure 5-8**).

An issue facing the area is stable fly, which affects stock and native animals, as well as humans. Stable fly breeds in fresh manures, and so restrictions on the application of animal and green manures on agricultural land exist in the region. This influences waste management decisions for all such waste producers, resulting in mulching and incorporation of wastes, and spraying with pesticides. A regional solution that contributes to the reduction in stable fly management costs and stable fly breeding would be of benefit to the shire as a whole.

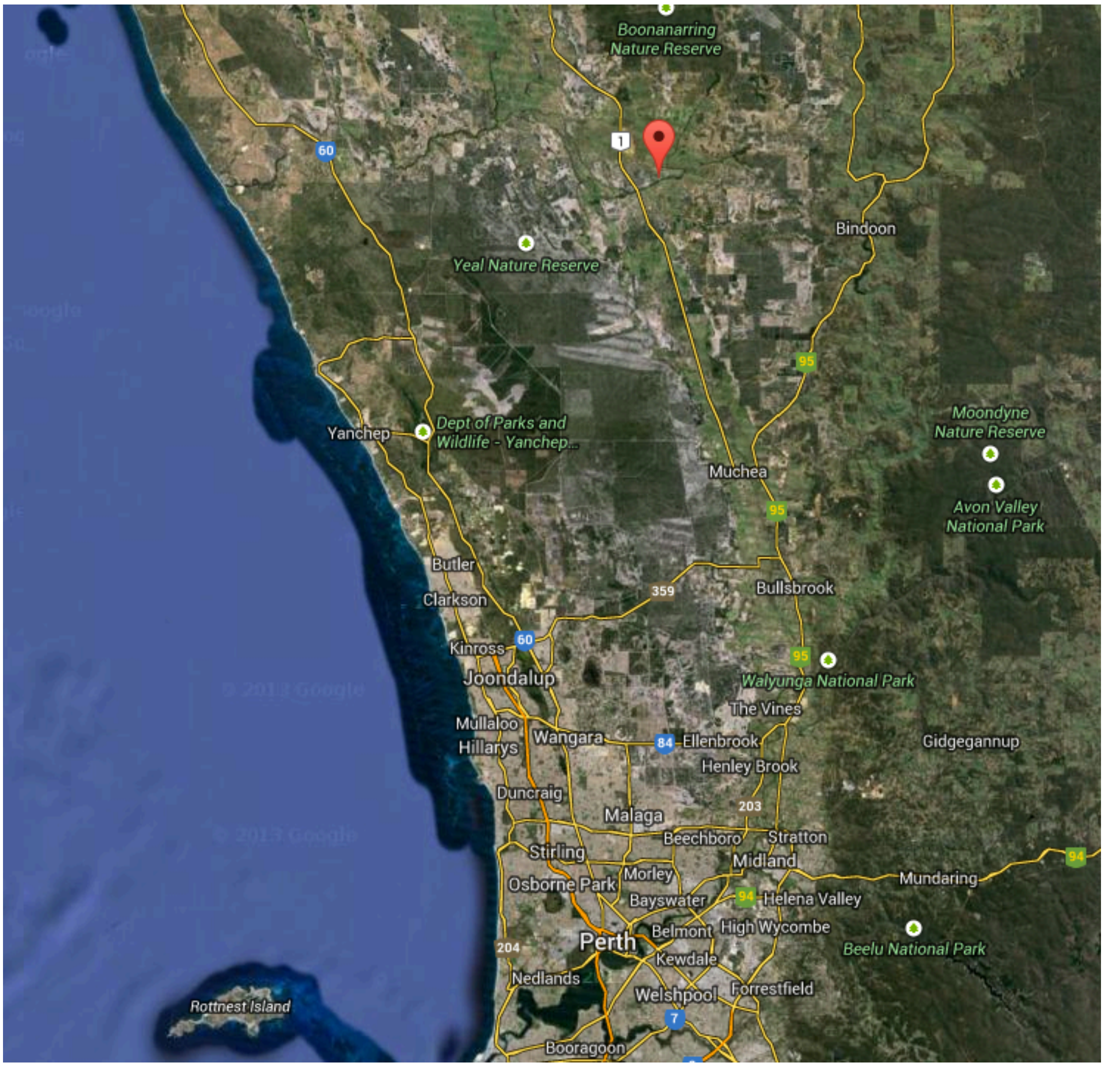


Figure 5-8: Location of Gingin in WA

5.4.3 Cluster model proposed

The cluster model proposed for the area is a 'regional cluster' of properties within a 40km radius. It is estimated that 20 vegetable farms are in operation within this area, with an area under production of around 1,500 hectares. In addition, a variety of other types of agricultural production operates in the area, including:

- Two feedlots
- Two abattoirs
- Two piggeries
- Several chicken farms
- Olive groves.

All of these produce organic wastes that require management expenditures and could contribute wastes to a regional biogas plant. Additional waste volumes from commercial and industrial wastes may also be considered, such as food waste from commercial food outlets.

Under this proposed cluster, one biogas plant would receive waste from these various sources, at a centrally located site. Locating the plant within a light industrial area may be preferred, to minimise odour concerns and to be close to potential users of energy and heat.

Participants may be invited to have their waste removed free of charge to motivate their involvement in the cluster, with the costs of transportation borne by project proponents.

5.4.4 Issues

There are a number of issues with this kind of cluster model that would need to be addressed to progress this idea further.

Waste transport

Of immediate concern to a cluster of this scale is the significant cost of waste removal and transportation that would need to be addressed in the project business case. Traditional commercial organic waste disposal costs vary but can be in the order of $50-$200/t to collect and transport. This cost reflects the capital cost of the collection truck and waste bins, and the operating and labour costs associated with transport.

Biosecurity and contamination management

The question of where to locate the site needs consideration of biosecurity concerns. It is likely that farm owners would have considerable reservations about incorporating vegetable wastes from other farms in the region, based on concerns about spreading diseases and pests. As noted, locating the site in a light industrial zone may be a preferred solution.

Contamination management is also heightened when taking multiple waste types from multiple sources. This can be addressed with appropriate management (education, monitoring), but not without cost.

Energy use to maximise value

A critical issue to address in a regional cluster is the form of arrangement for energy use that maximises the financial value of the energy produced. It is usually the case that substituting for existing electricity use on-site or ‘behind the meter’ provides the highest financial value for electricity provided by biogas. In general, electricity fed back into the grid produces revenue valued at around one fifth or one quarter the value of energy used on-site that substitutes for grid electricity.

A biogas plant serviced by a regional cluster is likely to produce energy far exceeding the baseline energy use of one vegetable farm. Coupled with the biosecurity issues described above, an alternative arrangement would likely be required. Options may include:

- Locating the plant on the site of a large electricity user of sufficient size to benefit from the biogas electricity
- Producing enough electricity to service a number of sites and distributing the electricity from a central location to individual sites for offsetting behind the meter energy use
- Producing biogas at a central site and then distributing the gas from a central location to individual sites with their own electricity generation equipment.

Digestate use

Similarly, issues around digestate use in a single farm project relate to the specific needs of the production process, and compare to the costs of the current waste management approach. A regional cluster will involve multiple waste providers of different scale and waste type. Their demand for digestate use will range from zero (such as chicken farms) to high, but in varying forms. Digestate volumes for a regional cluster will be large and will suffer from the same transport cost pressures described previously.

The potential exists to produce a commercial, branded digestate product that could be sold in retail outlets. However, establishing supply chains for such a product would be a significant undertaking.

Ownership

Related to the issue of maximising energy value is the question of who would own the project and the biogas plant. It was suggested that the Shire of Gingin could coordinate and potentially fund and own the plant, with electricity and other benefits used in community assets.

However, as highlighted previously, any electricity that feeds into the grid produces lower financial benefit than electricity used to reduce electricity taken from the grid. As such, community assets located in different locations would be unable to maximise the financial value of the biogas.

A regional cluster plant of the scale described in this case study would require a significant investment. Finding a private sector owner for such a plant with multiple feed stocks and multiple suppliers may be extremely challenging. As such, plant ownership may be a key issue to be resolved in development of the project.

Contractual arrangements

The associated challenges highlight the need for clear and potentially complex contractual arrangements around ownership, waste value (or collection cost), energy use and value, and digestate management and use.

Establishment of the overall project business case would need to be undertaken, as well as identifying the costs and benefits for each participant.

6 Extension and adoption plan

6.1 Purpose

The aim of this plan is to outline the extension undertaken as part of this project, and guidance on adoption for the future. This is important to consider to maximise the return on investment to levy paying vegetable growers in assessing the feasibility of on-farm biogas generation.

6.2 Extension activities undertaken

A number of extension activities were undertaken with industry and growers during the project. These included:

- AUSVEG Podcast: RMCG Project Manager, Kym Whiteoak, was interviewed by Tim Shue, AUSVEG Communication Specialist, in April 2014
- VegeNotes Issue 42: prepared for Stefani Cefola, Public Relations and Marketing Consultant, Corporate Communications (Tas) Pty Ltd. The complete article is provided in Appendix 5
- Victorian Bioenergy Conference: request to present preliminary findings to delegates organised by Kelly Wickam, Sustainability Victoria, in May 2014
- Queensland Urban Utilities: request to present the preliminary findings to a select group of interested stakeholders organised by Cameron Jackson in May 2014.

There was also the added benefit of undertaking the case studies with growers. These included:

- Sweet corn, brassica and leafy in south east Queensland
- Carrots in coastal plains, Western Australia
- Carrots, onions, brassicas, swedes and beans in Tasmania
- Lettuce, in Western Australia through the ‘cluster model’.

This allowed a detailed assessment of biogas feasibility on-farm using the framework and model developed as part of this project. The grower was able to obtain a greater understanding of the potential for biogas based on their scale, crop type, energy use and logistics. The avoided cost of having to undertake the feasibility assessment themselves by hiring a consultant and an improved awareness of the technical aspects of biogas were just some of the benefits of the extension undertaken as part of this project.

6.3 Considerations for adoption

6.3.1 Target area and audience

The target areas for adoption of biogas are larger farms with high energy crops, high cost waste management and high electricity use in the main vegetable growing regions in Australia.

The target audiences are the vegetable industry, growers, packers, consultants, industry development officers, researchers, horticulture industry service providers and supply chain participants.

6.3.2 ADOPT model

The ADOPT (Adoption and Diffusion Outcome Prediction Tool) model, developed by the Future Farm Industries CRC and CSIRO, can be used to explore the extent and rate of adoption of new innovations such as biogas technology (Kuehne et al. 2013).

The model includes a series of question based on four main areas. These are outlined below.

1. Population-specific influences on the ability to learn about the innovation

The ability of the target population to learn about the innovation – this is about learning the benefits or relative advantage. Constraints will slow the time to peak adoption, they do not affect peak adoption level. Factors include:

- Group involvement
- Advisory support
- Existing skills and knowledge and
- Awareness of the technology in their district.

2. Relative advantage for the population

Is the advantage gained from adopting the innovation, sufficient to the target population to adopt? Factors include:

- Enterprise scale
- Family succession/management horizon
- Profit orientation
- Environmental orientation
- Risk orientation
- Short-term constraints.

3. Learnability characteristics of the innovation

This is about the innovation and not the target population. Some innovations are easy to learn while others are more difficult. Factors include:

- Trialability
- Innovation complexity
- Observability.

4. Relative advantage of the innovation

The relative advantage of the innovation (not the perception of the target population). Factors include:

- Relative upfront cost of the innovation
- Reversibility
- Profit benefit
- Time for profit benefit
- Risk effect
- Environmental costs and benefits
- Time to environmental benefit
- Ease and convenience.

6.3.3 ADOPT analysis for biogas technology

The ADOPT model is an important tool for considering who is the target audience for biogas adoption in the Australian vegetable industry and how readily it should be expected that the technology will be taken up.

We undertook an analysis of the Biogas technology by answering the series of questions established in the ADOPT model. A summary of the results is outlined in Table 6-1 and Figure 6-1 (Kuehne et al. 2013). The results predict a peak level of adoption of 3% of the industry being reached in approximately 30 years. The detailed results are provided in Appendix 6.

Table 6-1: Predicted adoption levels[28]

Adoption component	Result
Predicted years to peak adoption	31
Predicted peak level of adoption	3%
Year innovation first adopted or expected to be adopted	N/A
Year innovation adoption level measured	N/A
Adoption level in that year	N/A
Predicted adoption level in 5 years from start	0.3%
Predicted adoption level in 10 years from start	1.3%

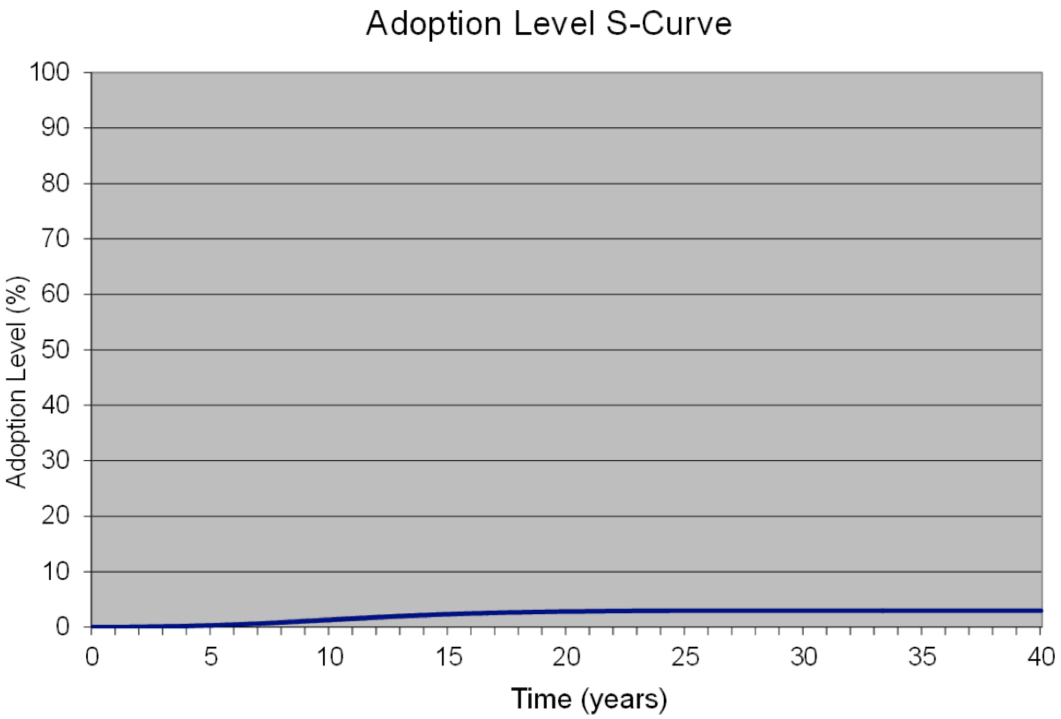


Figure 6-1: Predicted adoption curve

6.3.4 Implications for future extension approach

Given the limitations and characteristics of the technology it is expected that adoption will occur within a small segment of the industry. There are many reasons for this including the high capital cost, difficultly in trialling the technology in stages and changes required to the farming system. It is also apparent that only a small segment of the industry will have conditions suitable for biogas production.

This assessment is critical in guiding future extension efforts. Activities should be specifically targeted to a small segment of the industry – the larger farms with high energy crops, high cost waste management and high electricity use. Investment in one-on-one extension with this segment is likely to provide significant benefit.

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[28] The predictions of 1) 'Peak Adoption Level' and 2) 'Time to Peak Adoption Level' are numeric outputs that are provided to assist with insight and understanding and like any forecasts should be used with caution.

7 Conclusions and Recommendations

7.1 Conclusions

This study was commissioned to provide insight to the industry as to the financial and technical feasibility of producing biogas on vegetable farms in Australia.

One challenge for this assessment is the lack of an existing commercial biogas plant in operation on a vegetable farm in Australia. This limits insights developed from current practice, and requires adaptation of insights from biogas plants in different contexts,[29] or from planned (but not operating) biogas plants on vegetable farms in Australia.

Nevertheless, a number of key findings from this analysis are observable:

- **Feasibility is highly variable:** factors affecting biogas financial feasibility will vary significantly by farm. Establishing an understanding of high level feasibility for any farm will require detailed analysis using farm specific data to provide necessary accuracy of results.
- **Potentially feasible for larger operations:** our analysis suggests that financial feasibility of biogas is a genuine possibility for larger Australian vegetable farms (producing in the order of 10 kt of waste per year or higher, although this threshold size could be lower depending on feedstock and/or other factors).
- **Other factors contribute to feasibility:** a number of other factors contribute to the feasibility of biogas, including crop type (sweet corn is a high energy crop), consistency of waste supply and energy use, and the current costs of waste management.
- **'Cluster' model adds complexity:** for smaller farms, the potential exists to 'cluster' several neighbouring farms, or for a biogas plant to be established to compile waste from a variety of sources. However, this type of collaboration increases the complexity of arrangements for sharing costs and benefits of biogas. Significant further work would be required to further establish the feasibility of different cluster models.
- **Technical feasibility a reflection of cost:** while a relatively high technology option for waste management, the technical requirements for operating a biogas plant appear to be largely addressed in ongoing service arrangements with biogas service providers, reflected in the cost of this ongoing arrangement. Ongoing management actions of the plant can be expected to be codified in management plans, and of limited burden on farmers.
- **Regulatory burden not excessive:** Regulatory arrangements for biogas are not prohibitive but will require engagement with environmental regulators in project development, as part of the service arrangement with the biogas provider. A risk exists that the infrequency of biogas projects makes environmental regulators and local government wary, which may slow regulatory approvals. However, meeting regulatory requirements on land application can be expected to be codified in a management plan, without significant ongoing attention.

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[29] For example, from biogas plants on piggeries and wastewater treatment plants in Australia, or from vegetable farms overseas. The context of these are likely to be significantly different from vegetable farms in Australia, limiting insights drawn from them.

- **Digestate use and management will require careful consideration:** The value of digestate use will depend upon the cost of current waste management, and the scale of any value currently being generated by its use (for example, as a stock feed). Use of the digestate can provide a potentially significant value as a fertiliser replacement, but it must be aligned with the needs of the operation regarding soil health and fertiliser application, given the precision of fertiliser use in Australian vegetable farms.

As noted above, the feasibility of biogas on-farm will depend upon the specific context of each operation. However, the following key factors will drive biogas feasibility on-farm:

- **Scale of operation**: the cost-effectiveness of biogas generally increases with scale. While other factors will need to be considered, an input volume of 25 tonnes per day or more would warrant further consideration of biogas on farm. Below this volume is less likely to produce a cost-effective investment.
- **Type of waste**: different organic wastes produce different volumes of biogas per unit. The specific biogas efficiency of each waste product would require testing as part of a feasibility assessment,[30] however some general information is available. Sweet corn is considered favourable for biogas, while lettuce is predominantly comprised of water and is considered of low biogas potential.[31]
- **Electricity value**: retail tariffs vary significantly by type of site and to some extent by jurisdiction. The price of electricity will of course influence biogas feasibility, with higher prices increasing the value of electricity generated with biogas. In general, displacing energy imported from the grid will be significantly higher in value than energy sold into the grid, based on the difference between retail tariffs and the wholesale value of electricity.
- **Nature of current waste management**: biogas value will be influenced by the costs and revenues associated with a farm's current waste management practices. Our case studies suggest that current waste management costs are not necessarily significant management concerns, but they do require time and attention. Similarly, biogas digestate use has costs and a small fertiliser replacement value, but the nature of digestate management will depend upon farm needs.[32]
- **Consistency in feedstock and electricity use**: in general, consistency in both waste production and electricity use are preferred features to highly variable waste supply and electricity use. Biogas plants produce energy consistently, and are thus most efficient when supplied with a consistent volume of input and feed a consistent energy source. Both of these issues can be overcome (for example, with storage) but at an increased cost.

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[30] Testing typically costs around $2,000-$3,000 per waste type, and the biogas efficiency of different waste types is often commercial in confidence information.

[31] However, lettuce may be combined with other waste types to produce a high-methane mix.

[32] For example, farms with highly specific fertiliser application methods may prefer not to apply digestate to their crop area, preferring to sell the digestate as a 'biofertiliser' product.

7.2 Recommendations

7.2.1 Overview

Our analysis has highlighted the complexity of determining biogas feasibility for individual farms. This also reinforces the observation of many growers interested in biogas to address inefficient waste management systems, however no grower in Australia having installed the biogas technology. The proof of the technology on a commercial vegetable farm is currently lacking in Australia.

There are many assumptions that are made at the feasibility stage and these may/or may not translate into practice. For individual situations there are numerous possibilities associated with the use of energy, current production of waste trends and volumes and potential management of waste. Whether a biogas plant is feasible depends on many different possibilities for that individual business.

The analysis also suggests that the biogas technology is likely to be feasible for a small segment of the industry (large farms which generation large waste volumes and have high energy needs). For this reason future activities should be focused specifically on this segment.

7.2.2 Immediate actions

We therefore make the following recommendations to assist the development of biogas technology where appropriate.

1. Biogas feasibility tool

As a matter for immediate attention, the development of a biogas feasibility tool would ensure that the analysis undertaken in this project would be available for use by the industry. This tool was proposed in the initial project submission as an optional variation. The tool would be designed for use by growers/their advisors and would consist of an excel model with a user-friendly interface. The grower would be able to provide input information to run different scenarios considering different management options. Whilst the tool would facilitate a ‘what-if’ approach it would still be necessary to undertake a detailed feasibility analysis with a technology provider should the biogas option appear to stack up.

2. Extension approach providing support and access to providers

To assist in the use of the tool we recommend one-on-one support provided to growers interested in the technology. This would involve a site visit and a one hour session of running through a number of scenarios relevant to the business. The discussion would also involve suggestions for relevant technology providers in the region and possible technical/management aspects that would need to be covered with these providers.

7.2.3 Actions for consideration

In addition to the two priority recommendations for immediate consideration we suggest that these additional recommendations be considered for further development.

3. Additional analysis of challenges and opportunities for the cluster model

Whilst there are a number of challenges associated with the cluster model there may be merit in this approach. Our initial analysis has identified how the cluster model may operate and factors that would need to be considered to assess feasibility. We propose that this model be further explored in two to three regions around Australia.

Two types of 'clustered' models present as options:

1. Two or more neighbouring farms, combining waste volumes and sharing benefits amongst themselves
2. Larger, regional clusters that could potentially incorporate a variety of different waste streams (vegetable, other agricultural such as piggeries or poultry farms, food waste). Operations at this scale might require full time management by a dedicated AD service provider, and would need detailed management arrangements for digestate use given the scale.

4. Further exploration of additional benefits for greenhouse production

The focus of this current study was on large properties producing large volumes of waste and high energy requirements. Greenhouse production was not explored as they generate small waste volumes. However, this sector has high energy needs and in some instances also uses heat and CO_2. Provided there was sufficient waste volume that could be sourced, there may be additional benefits associated with the provision of heat and CO_2 from a biogas facility. This scenario warrants further investigation focusing on an existing greenhouse facility of sufficient scale.

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Appendix 1: International and domestic policy environment: climate change and energy

High oil prices, tight energy markets and evidence about climate change are among the reasons policy makers around the world are increasing to support the production and use of alternative, renewable energy sources. In 2010 a total of 280 TWh of bioenergy electricity, i.e. 1.5% of world electricity generation, was generated globally, up from 1.3% in 2007 (International Energy Agency 2014). It is projected to increase to 2.4% by 2030 (Bogdanski et al 2010). “Modern” bioenergy (i.e. produced other than from traditional burning of firewood), and specifically production of biogas from agricultural residue/waste (biomass), has increased in popularity with Organisation for Economic Co-operation and Development (OECD) countries in recent years, due to its ability to address the issue of renewable energy production while also utilizing an abundant resource that would otherwise require disposal (Bogdanski et al 2010).

Policy mechanisms for bioenergy and biogas take the form of regulations, targets, mandates, incentives (ranging from capital grants, loan guarantees for bioenergy production plants or feed-in tariffs), tax rules and/or standards. Transitional economic support measures have especially been used to address the cost competitiveness of bioenergy projects in the medium term (International Energy Agency 2012).

The approach to implementing policy mechanisms varies considerably between countries. Furthermore, it is often difficult to separate out the high level policy and/or support measures for biogas, as heat and power generation from biomass generally fits within broader renewable energy portfolios. A number of countries have established national or regional targets for renewable energy, while only a few have defined specific targets for bioheat and/or biopower, including Germany, Ireland, Japan, New Zealand, Norway, Romania and the US (OECD 2010). Specific details are outlined in Table A1-1.

In the European Union, renewable energy production in the agriculture sector falls under the policies within the Common Agricultural Policy (CAP).[33] It is a common policy to control agricultural markets within the 27 member states of the EU, and it covers air quality, animal health and welfare, biodiversity and land management, climate change, soils and water quality. The CAP provides agricultural subsidies and implements programs to support farming, the environment and rural development. The new CAP regulations, approved in December 2013 for implementation in 2015, include further incentives to enable farming to become more efficient and competitive in order to address food security, sustainable management of natural resources and reduction of GHG emissions (European Commission 2012).

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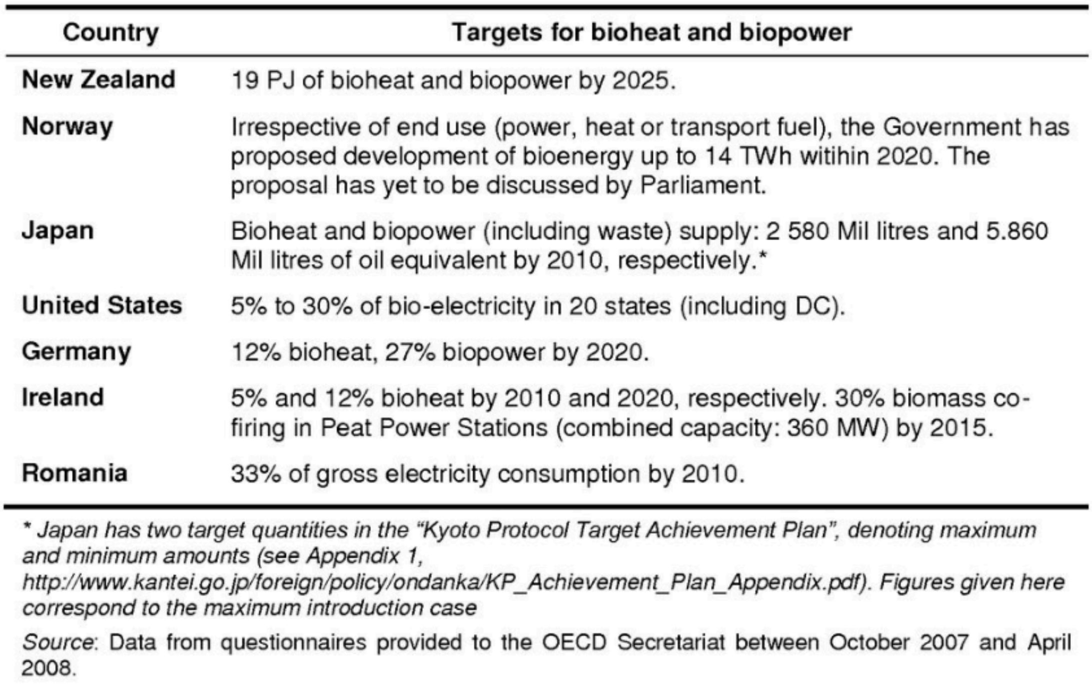
[33] There is an Emission Trading Scheme (EU ETS) that operates within the European Union (EU ETS). The EU emissions reduction target is 21% below 2005 levels by 2020. However, it only covers 45% of the EU’s greenhouse gas emissions, namely electricity generation and aviation fuels and therefore does not cover agricultural emissions (European Commission 2014).

Table A1-1: Specific targets for bioheat and biopower (OECD 2010)



Country	Targets for bioheat and biopower
New Zealand	19 PJ of bioheat and biopower by 2025.
Norway	Irrespective of end use (power, heat or transport fuel), the Government has proposed development of bioenergy up to 14 TWh witihin 2020. The proposal has yet to be discussed by Parliament.
Japan	Bioheat and biopower (including waste) supply: 2 580 Mil litres and 5.860 Mil litres of oil equivalent by 2010, respectively.*
United States	5% to 30% of bio-electricity in 20 states (including DC).
Germany	12% bioheat, 27% biopower by 2020.
Ireland	5% and 12% bioheat by 2010 and 2020, respectively. 30% biomass co-firing in Peat Power Stations (combined capacity: 360 MW) by 2015.
Romania	33% of gross electricity consumption by 2010.

** Japan has two target quantities in the "Kyoto Protocol Target Achievement Plan", denoting maximum and minimum amounts (see Appendix 1, http://www.kantei.go.jp/foreign/policy/ondanka/KP_Achievement_Plan_Appendix.pdf). Figures given here correspond to the maximum introduction case*

Source: Data from questionnaires provided to the OECD Secretariat between October 2007 and April 2008.

Closer to home, New Zealand has a renewable energy target for all electricity of 90% by 2025 and an emissions reduction target of 50% from 1990 levels by 2050 (Ministry for the Environment 2011). In 2010, renewables contributed 74 percent of electricity generation (Ministry of Economic Development 2011). Successful delivery of national targets will be driven through two platforms – the New Zealand Emissions Trading Scheme (NZ ETS) and greater investment in renewable energy and in energy efficiency and conservation. The NZ Bioenergy Strategy developed in 2010 demonstrates how bioenergy is a key government R&D priority in this area (BANZ 2010).

There are also voluntary mechanisms being developed by the agriculture sector in order to address the nexus between climate change mitigation, food security and sustainability.

The Greenhouse Gas Action Plan (GHGAP) is an industry-led voluntary initiative that has set a target to reduce annual GHG emissions from English agricultural production by 3 MtCO2e by the third UK carbon budget period (2018 – 2022), compared to a 2007 baseline (Industry Delivery Partners Group 2011). Within the UK, agriculture is responsible for 9% of GHG emissions (DEFRA 2011) and consequently has accepted that it needs to play a proportionate part of the UK's legally binding emissions reduction target of at least 80% by 2050, as measured against a 1990 baseline.[34] The key focus is on increasing production efficiency and thereby reducing emissions per unit of output. Specifically Action 7 of the GHGAP is to "Consider opportunities for energy efficiency and renewable energy generation – in the efficient use and potential for on-site supply of electricity, heat and vehicle and heating fuels" (DEFRA 2011).

There is currently much uncertainty surrounding the domestic situation for climate change and renewable energy policy.

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[34] To support progress against the UK *Climate Change Act 2008*, a carbon budgeting system that caps GHG emissions from the UK 'carbon' economy over five year periods, has been established with the first three carbon budgets running from 2008 – 2012, 2013 – 2017 and 2018 – 2022.

As in other countries, Australian governments have been implementing policies to reduce emissions for more than two decades. There is an agreed national greenhouse gas emissions reduction target of 5% below 2000 levels by 2020 and a renewable energy target for 20% of Australia's electricity to be sourced from renewable energy sources by 2020. Depending on international negotiations there is the potential for Australia's greenhouse gas emissions reduction target to increase to 15-25% of 2000 levels by 2020. A range of market-based schemes have been implemented to promote emissions reductions, including national schemes such as the Renewable Energy Target and state-based schemes.

Since 2011 the Renewable Energy Target has operated with two parts: the Large-scale Renewable Energy Target (LRET) and Small-scale Renewable Energy Scheme (SRES) (Clean Energy Regulator 2014). These schemes create a financial incentive for investment in renewable energy sources through the creation and sale of certificates. The SRES focuses on domestic solar photovoltaic systems, solar water heaters and heat pump systems. As of February 2014 the biannual review of the RET commenced (DoE 2014).

The Australian carbon pricing mechanism (a cap-and-trade emissions trading scheme) was legislated in 2011[35] and commenced in July 2012. The scheme is administered by the Clean Energy Regulator and covers approximately 60 per cent of Australia's carbon emissions including from electricity generation, stationary energy, landfills, wastewater, industrial processes and fugitive emissions (via liable entities who emit more than 25,000 tonnes CO_2-equivalent per year). Vegetable growers have no direct liabilities under the existing scheme.

In late 2013, the in-coming government advised of its intention to repeal the Carbon Tax legislation and implement the Direct Action Plan. The centerpiece of the Direct Action Plan is the Emissions Reduction Fund (ERF), which is to purchase emissions reductions through a reverse auction (Commonwealth of Australia 2013). Following the proposed abolishment of the Carbon Tax, electricity prices are proposed to be reduced[36] and a series of incentives will be made available for improving energy efficiency, renewable energy production and/or land sector abatement. The White Paper for the ERF is due for release in April 2014 (DoE 2014).

A recent study completed by Rogers and Montagu (2013) provided detailed analysis of the climate change policy context for the vegetable industry. The report noted that in the medium term there are limited opportunities for the industry to participate in the CFI and generate revenue from carbon storage and emission reduction activities, unless emission reduction methodologies were developed (Rogers and Montagu 2013). Emissions reduction activities are those that can be proven to be genuine and additional (i.e. are not part of mandatory requirements of doing business or paid for under another program). There are already accepted emissions reduction methodologies under the current Carbon Farming Initiative (CFI) legislation (DoA 2014), which will continue to apply under the Coalitions ERF (Commonwealth of Australia 2013). None currently apply to vegetable production.

The study by Rogers et al (2013) also detailed funding and grant opportunities for growers, industry and processors for improving energy efficiency (either irrigation improvements, reducing cooling costs or on-farm energy generation), generating carbon credits or adapting to climate change. Since the time of that report, many of the federal funding programs listed are no longer available (either they are on hold and are proposed to be removed as part of the repeal of the carbon tax or their funding has

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[35] Under the Federal Government's *Clean Energy Act 2011*

[36] "Lower retail electricity by around 9 per cent and retail gas prices by around 7 per cent than they would otherwise be in 2014-15 with a $25.40 carbon tax." (DoE 2014)

been cut in line with federal budget cutbacks) or are under review (RET and associated programs). Two federal programs that relate to bioenergy are still in operation:

4. The Clean Energy Finance Corporation (CEFC) provides support through co-finance and investment, directly and indirectly, in clean energy projects and technologies. Investment is assessed on a case-by-case basis and could include project finance, corporate loans or aggregation funding. Two anaerobic digesters projects in horticulture/egg industries have already been financed by CEFC (Clean Energy Finance Corporation 2014). Note: As with the carbon pricing mechanism, the Commonwealth Government intends to repeal the CEFC's legislation.
5. Australian Renewable Energy Agency (ARENA) is a renewable energy investment fund providing financial assistance to improve the competitiveness of renewable energy technologies and increase the supply of renewable energy in Australia (ARENA 2014). Financial assistance is available for research, development, demonstration, deployment and commercialisation of renewable energy and related technologies, or sharing of knowledge and information about renewable energy technologies.

Opportunities for State-based grants and incentives could be considered through the Rural Industries Research Development Corporation (RIRDC). The 'Bioenergy, Bioproducts and Energy' R&D portfolio aims at making information on bioenergy available to primary producers (RIRDC 2013).

Appendix 2: Electricity demand and tariff analysis

Retail electricity charges for all large customers in Australia are determined by a market of competing retail electricity suppliers. This also applies to small customers except in Tasmania and Northern Territory where regulators determine prices charged to small customers. There is limited public domain data on prices offered to large customers.

The data used for the estimation of retail electricity prices by jurisdiction is summarised in Table A2- 1. These tariffs were considered representative for this study.

AEMC (2013) provides national analysis of residential prices (both current and future outlook). The data provided in this report provides a useful basis for filling gaps as well as a basis for forecasts of future prices. A major simplifying assumption made here is that relativities between residential prices in different jurisdictions can be applied to prices for large consumers as well. While this may not precisely be the case, it provides a reasonable basis and is just one of the factors (along with the fact that farms may be on tariffs quite different from the estimate of the ‘average’) accounted for in the sensitivity analysis. A summary of residential electricity price movements is provided (Table A2- 2) with additional qualifications on interpreting the numbers described in the notes.

The electricity tariff(s) applicable to a given farm will vary significantly by circumstances. Very small operations may be on a single electricity meter and tariff. Others may have one meter and tariff for the farmhouse and another tariff applying to irrigation pumps (with one or more meters). A very large operation may have the farmhouse on a residential tariff, specific tariffs for irrigation electricity use and a large business tariff (with a demand component) applying to the processing facility.

While it is not practical to precisely estimate price in all possible scenarios, representative prices have been estimated by making some simplifying assumptions. These provide a useful basis to estimate the value of energy for a given situation, and are summarised in Table A2- 3.

Table A2- 1: Tariff components (GST Exclusive)[37]

		Energy Charges (c/kWh)				Fixed Charges (c/day/metre)	Demand Charges ($/kW)
Tariff Code	**Tariff Name**	**Flat**	**Peak**	**Shoulder**	**Off-peak**	**Service fee**	**Demand**
QLD							
Tariff 11	Residential (flat rate)	26.73				50	
Tariff 12	Residential (time-of-use)		30.97	22.41	19.43	114	
Tariff 22	Business (time of use)		25.50		18.67	130	
Tariff 45	Over 100 MWh medium (demand)	11.67				2,708	30.61
Tariff 46	Over 100 MWh large (demand)	11.67				4,275	29.41
Tariff 47	High voltage (demand)	11.21				2,787	23.50
NSW							
5700	Residential	31.11				125	
5740	Business	36.00				151	
470	Irrigation Standard Block	36.00				151	
480	Irrigation - 2-Rate - Peak		31.75		18.65	413	
ACT							
Residential	Residential	18.30				67	
Business	Business	25.20				99	
TAS							
Tariff 31	Residential	24.37				86	
Tariff 22	Small business	28.82				93	
Tariff 73/74	Irrigation		29.05		12.745	306	
NT							
Domestic	Domestic	24.66				46	
Commercial	Commercial	28.47				72	
WA							
Tariff A1	Synergy Home Plan	23.55				39	
Tariff L1	Synergy Business Plan	25.45				37	
Tariff S1	Synergy Large Business Demand LV		16.46		11.20		30.00
Tariff T1	Synergy Large Business Demand HV		17.11		12.10	51	30.68

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[37] Sources:

- Queensland – QCA (2013)
- New South Wales – Origin Energy (2013)
- Australian Capital Territory – ActewAGL (2013)
- Tasmania – OTER (2013)
- Northern Territory – Power and Water Corporation (2013)
- Western Australia – Synergy (2013)

Table A2- 2: Summary of residential electricity price movements 2011/12 to 2014/15

	National	Queensland (see note 4 below)	New South Wales (see note 5)	Australian Capital Territory	Victoria (see notes 3 & 6 below)	South Australia	Tasmania	Western Australia	Northern Territory
A. Comparison of nominal residential electricity prices between 2011/12 – 2014/15									
Base year (2011/12) price (c/kWh)	25.9	22.1	25.4	16.9	28.8	29.9	26.2	26.2	21.7
Current year (2012/13) price (c/kWh)	29.6	25.6	30.4	19.1	31.9	33.7	29.2	28.4	23.8
Final year 2014/15 price (c/kWh)	31.3	27.9	31.0	20.2	35.2	33.3	31.1	29.7	31.8
Total increase (c/kWh)	5.4	5.8	5.5	3.3	6.5	3.4	4.9	3.5	10.1
Average annual rate of change from base year	7%	8%	7%	6%	7%	4%	6%	4%	14%
Average annual rate of change from current year	3%	4%	1%	3%	5%	-1%	3%	2%	16%
B. Nominal change from base year (2011/12) to final year (2014/15) of each component in c/kWh									
Transmission	0.8	0.2	1.9	0.5	0.1	0.7	1.3	0.7	0.0
Distribution	2.5	3.4	1.3	1.4	3.3	5.0	2.0	0.4	1.1
Wholesale	1.4	0.7	2.0	1.5	3.0	-2.1	0.8	2.0	8.9
Retail	0.7	1.5	0.3	0.0		-0.3	0.8	0.5	0.2
Total (c/kWh)	**5.4**	**5.8**	**5.5**	**3.3**	**6.5**	**3.4**	**4.9**	**3.5**	**10.1**
C. Nominal change from current year (2012/13) to final year (2014/15) of each component in c/kWh									
Transmission	0.3	0.1	0.5	0.2	0.1	0.4	0.6	0.6	0.0
Distribution	1.4	1.9	0.4	1.0	2.4	1.9	0.4	0.9	0.7
Wholesale	0.0	0.4	-0.2	-0.1	0.9	-2.2	0.6	0.0	7.2
Retail	0.0	-0.1	-0.1	0.0		-0.5	0.3	-0.2	0.1
Total (c/kWh)	**1.7**	**2.3**	**0.5**	**1.2**	**3.4**	**-0.4**	**1.9**	**1.3**	**8.0**

Notes:

1. Values are nominal (not adjusted for inflation) and exclusive of GST.
2. Numbers may not add due to rounding.
3. Retail component values are inclusive of the Victoria wholesale energy component. The grouping of these values for Victoria is indicated by the shaded area.
4. Queensland prices and component values do not incorporate recent pass through approvals by the AER in respect of feed-in tariff costs for 2011/12, or retail price proposals under the QCA's draft retail price determination for 2013/14.
5. New South Wales transmission network component values reflect distribution pricing rather than transmission price rises.
6. Victorian prices shown are based on published standing offers and are likely to overstate the actual prices paid by representative residential customers receiving supply on market offers. According to the Essential Services Commission in Victoria, based on 2011/12 prices, the published standing offers are, on average, 12 per cent higher than current market offers. This would reduce the estimated 2011/12 Victorian standing offer price of 28.8 c/kWh by 3.1 c/kWh, resulting in an average market offer price of 25.7 c/kWh.

Table A2- 3: Representative tariffs by demand component

Demand Component	Tariff Component	QLD	NSW	ACT	VIC	SA	TAS	NT	WA
Farmhouse and other	Peak (c/kWh)	26.81	33.22	23.95	26.81	26.81	26.60	28.86	26.63
Farmhouse and other	Offpeak (c/kWh)	19.79	25.59	17.46	19.79	19.79	12.92	19.70	18.13
Farmhouse and other	Service fee (c/day)	122.03	278.04	82.90	122.03	122.03	108.90	58.77	38.28
Irrigation	Peak (c/kWh)	31.75	31.75	31.75	31.75	31.75	27.31	31.75	31.75
Irrigation	Offpeak (c/kWh)	18.65	18.65	18.65	18.65	18.65	18.69	18.65	18.65
Irrigation	Service fee (c/day)	413.13	413.13	413.13	413.13	413.13	263.21	413.13	413.13
Processing facility	Demand ($/kW/month)	29.41	29.41	29.41	29.41	29.41	29.41	29.41	30.34
Processing facility	Peak (c/kWh)	13.01	13.01	13.01	13.01	13.01	13.01	13.01	16.78
Processing facility	Offpeak (c/kWh)	7.64	7.64	7.64	7.64	7.64	7.64	7.64	11.65
Processing facility	Service fee (c/day)	4275.15	4275.15	4275.15	4275.15	4275.15	4275.15	4275.15	51.07

Appendix 3: Regulatory arrangements

1. Flaring standards and regulation

Table A3- 1: Australian Standards that apply to all gas burning appliances (Australian RIRDC 2008)

Standard	Title	Description
AS 1375	Industrial Fuel Fired Appliances Code	▪ AS 1375 states "*sets out the safety principles relating to the design, installation and operation of industrial appliances that involve the combustion of gas or oil, or other fuel in air suspension, or the generation of combustible vapours in such appliances*". ▪ It is clear that both open and enclosed flares are industrial appliances that involve the combustion of gas, so AS 1375 is applicable to both.
AS 3814/ AG 501	Industrial and Commercial Gas-fired Appliances	▪ AS 3814 "*provides minimum requirements for the design, construction and safe operation of Type B appliances that use town gas, natural gas, simulated natural gas, liquefied petroleum gas, tempered liquefied petroleum gas, or any combination of these gases either together or with other fuels*". The standard specifically excludes "*simple atmospheric burners that are not fitted into a combustion chamber and burn in an open ventilated space under the control of an operator*". ▪ An open flare satisfies the exclusion requirement provided it is considered to be under the control of an operator. The enclosed area of an enclosed flare may be considered to be a combustion chamber. A dictionary definition of a chamber is "a natural or artificial enclosed space or cavity". A common feature of the fuel gases listed in AS 3814 is that they are hydrocarbon based, their composition is regulated, and they are or were sold to consumers. Biogas is none of those so it is questionable whether a biogas burning appliance could be considered a Type B appliance. However, a Biogas flare using LPG as a pilot gas would use one of the listed fuels (LPG) in combination with biogas, and would therefore come under the scope of AS3814.
AS 5601/ AG 601	Gas Installations	▪ AS 5601 "*sets out requirements for consumer piping, flueing, ventilation and appliance installations which are associated with the use or intended use of fuel gases such as town gas, natural gas, liquefied petroleum gas in the vapour phase, tempered liquefied petroleum gas, simulated natural gas or any similar substance. The requirements cover piping systems from the outlet of— (a) the consumer billing meter installation; or (b) the first regulator on a fixed gas installation where an LP Gas container is installed on the same site; or (c) the first regulator on site (if no meter is installed) where LP Gas is reticulated from storage off the site; to the inlet of the appliance.*" ▪ AS 5601 has a similar fuel constraint to AS 3814 and biogas flares would only be subject to AS5601 if LPG were used as pilot fuel. Furthermore it is very specific in what sections of a gas system the standard refers to. In the case of most small on-farm biogas flare systems there may be none of the items listed in (a)-(c). A biogas flare may only be subject to AS 5601 if it uses LPG as a pilot fuel.

Table A3- 2: Summary of flaring regulations and responsible authorities (Australian Pork and Prime Consulting International (Australia) Pty Ltd 2013)

State	Regulation	Authority	Comment
NSW	▪ Gas Supply Act (NSW) 1996 ▪ Gas Supply (Consumer Safety) Regulation 2012	▪ Department of Planning – Hazards Unit ▪ Work Cover Authority	▪ See Part 6, Gas installations (not supplied from a gas network) to ensure that correct testing and certification are completed, where biogas installations operating under 200 kPa are regulated.
NT	▪ Dangerous Goods Regulations 2010	▪ Natural Resources, The Environment, The Arts and Sport (NRETAS)	▪ There is no direct reference to biogas, however gas supply and equipment is covered under division 3 'Class 2 dangerous goods (gases)'. Furthermore the general licensing requirements for the manufacture and storage of dangerous goods, is covered in section 3 and 4, respectively of the Regulations
QLD	▪ Petroleum and Gas (Production and Safety) Regulation 2004	▪ Office of Energy, Department of Natural Resources and Mines	▪ The Queensland Government provide an excellent portal for starting a biogas project. This includes discussion on relevant regulations – see http://www.business.qld.gov.au/industry/energy/renewable-energy/starting-a-biogas-project/approvals-and-regulations-for-biogas-projects
SA	▪ Gas Act (SA) 1997 ▪ Gas Regulations 2012	▪ Office of the Technical Regulator, Department for Manufacturing, Innovation, Trade, Resources and Energy	▪ Part 9, Division 1 and 3 of the regulations require that gas installations be carried out in line with Australian Standards. This includes Type B appliances (biogas systems) used to burn gas.
TAS	▪ Gas Act (Tas) 2000 ▪ Gas Safety Regulations 2002	▪ Workplace Standards Tasmania, Department of Justice	▪ A safety management plan must be submitted for approval by anyone constructing a facility, including a biogas facility, in line with Regulation 16.
VIC	▪ Gas Act (VIC) 1997 ▪ Gas Safety (Gas Installation) Regulations 2008	▪ Energy Safe Victoria	▪ While there is no direct reference to biogas, Act defines gas as 'any gaseous fuel', which includes biogas. ▪ An application is required to be submitted under regulation 31. The application should address those issues raised in Schedules 7, 8, 9, 10, 11 and 12. ▪ Draft guidelines for biogas installations prepared by Energy Safe Victoria have been prepared and are attached for reference.
WA	▪ Gas Standards Act 1972 ▪ Gas Standards (Gas Fitting and Consumer Gas Installations) Regulations 1999	▪ Energy Safe WA ▪ Department of consumer	▪ Biogas flares are Type B installations but do not require certification if the gas produced is not on-sold.

2. Environmental standards and regulation

Table A3- 3: Summary of environmental standards and regulations by state (Australian Pork and Prime Consulting International (Australia) Pty Ltd 2013; Australian RIRDC 2008)

State	Regulation	Authority	Comments
NSW	▪ Protection of the Environment and Operations Act (1997) ▪ Protection of the Environment Operations (Clean Air) Regulations 2010 ▪ Clean Air (Plant and Equipment) Regulations 1997 ▪ NSW Energy from Waste: Draft Policy Statement for Public Consultation (2013) ▪ Department of Environment and Conservation (2003) Environmental Guidelines Composting and Organics Processing Facilities	▪ Department for Environment, Climate Change and Water	▪ Biogas facility must meet the Group 6 emissions standards in the Regulations 2010 ▪ Fuels being used must have minimum calorific value of 10 MJ/kg ▪ Onus on the owner to demonstrate that the site does not pose an unacceptable environmental risk (air, land, water, groundwater). This includes digestate management.
NT	▪ Waste Management and Pollution Control Act (2009)	▪ Natural Resources, Environment, The Arts and Sport ▪ Environment Protection Authority (NT)	▪ On-farm biogas emissions are not regulated ▪ Vegetable matter is not a listed waste and environmental approval are not required for reuse via on-farm biogas plants
QLD	▪ Sustainable Planning Act 2009 ▪ Environmental Protection Act 1994 ▪ Waste Reduction and Recycling Act 2011 ▪ Environmental Protection Regulation 2008	▪ Department of Environment and Heritage Protection	▪ Very clear, concise and positive position promoting biogas industry ▪ Fuel burning capacity of 500 kg/hr or greater requires a licence ▪ Generating electricity 10 MW or greater requires a licence ▪ Thermal treatment of waste vegetation requires consultation with local government, responsible for environmental enforcement (air, water, land, groundwater).
▪ SA	▪ Environment Protection Act (SA) 1993 ▪ Environment Protection Regulations (SA) 2009 ▪ Environment Protection (Air Quality) Policy 1994 ▪ Environment Protection (Burning) Policy 1994 ▪ Environment Protection (Noise) Policy 2007 ▪ Environment Protection (Water Quality) Policy 2003 ▪ Environment Protection (Waste to Resources) Policy 2010	▪ Environment Protection Authority (SA)	▪ Fuel burning licence is required under the Act for flares burning > 5 MW. ▪ Onus on the owner to demonstrate that the site does not pose an unacceptable environmental risk (air, land, water, groundwater). This includes digestate management.
TAS	▪ Environment Protection Policy (Air Quality) 2004	▪ Environmental Protection Authority (Tas)	▪ Onus on the owner to demonstrate that the site does not pose an unacceptable environmental risk (air, land, water, groundwater). This includes digestate management.
VIC	▪ Environment Protection Act 1970 ▪ Environment Protection (scheduled Premises and Exemptions) Regulations 2007 ▪ Sate Environment Protection Policy (Air	▪ Environment Protection Authority (EPA) Victoria	▪ Works approval is required for waste to energy applications (i.e. biogas plants) with a rated capacity of >1 MW ▪ Air emissions exemptions are available so long as the owner can demonstrate

	Quality Management) 2001 ▪ State Environment Protection Policy (Prevention and Management of Contaminated Land) 2002 ▪ State Environment Protection Policy (Waters of Victoria) 2003 ▪ State Environment Protection Policy (Groundwaters of Victoria) 1997 ▪ Energy from Waste (2013) EPA Publication 1559		the system meeting strict criteria (see EP Regs 2007) ▪ Various limits apply to different segments of the environment that must be achieved for compliance purposes. Satisfying this requirement will form part of works approval – this includes digestate management via land application (EPA Pub 1559) ▪ An EPA licence containing conditions requiring the occupant to demonstrate that the siting and design, construction and operation of the energy from waste plant meet best practice.
WA	▪ Environment Protection Regulations 1987	▪ Environment Protection Authority (WA)	▪ Onus on the owner to demonstrate that the site does not pose an unacceptable environmental risk (air, land, water, groundwater). This includes digestate management. ▪ No specific state based policy – it is currently being formed.

3. Biogas safety buffers

Biogas generated during anaerobic digestion is a flammable gas and installations in which flammable materials are handled or stored should be designed, operated and maintained so that any releases of flammable material are kept to a minimum. This includes minimising the extent of ‘hazardous area’ around Biogas systems.

Australia Standard 60079.1:2009 *Explosive atmospheres Part 10.1: Classification of areas – Explosive gas atmospheres* provides guidance on the classification on hazardous areas around gas installations, including biogas systems. It divides hazardous areas into three ‘zones’ – zone 1, 2, or 3 based upon the frequency of the occurrence and duration of an explosive gas atmosphere, as follows:

- Zone 0 – an area in which an explosive gas atmosphere is present continuously or for long periods or frequently
- Zone 1 – an area in which an explosive gas atmosphere is likely to occur in normal operation occasionally
- Zone 2 – an area in which an explosive gas atmosphere is not likely to occur in normal operation but, it does occur, it will exist for a short period only.

Appendix ZA.8, AS 60079.1:2009 provides specific guidance on zones for anaerobic digestors, pipes, ventilation and inlet ducts, fans blowers etc. As a general guide, keeping ignition sources 5.0 m away from biogas infrastructure (both laterally and vertically) provides adequate setback (or buffer) to allow equipment use without special requirements.

Note - this guidance is provided based on the examples provided in Appendix ZA.8, AS 60079.1:2009 and buffer distances for individual biogas systems should be developed on a case by case basis taking into consideration site specific risks.

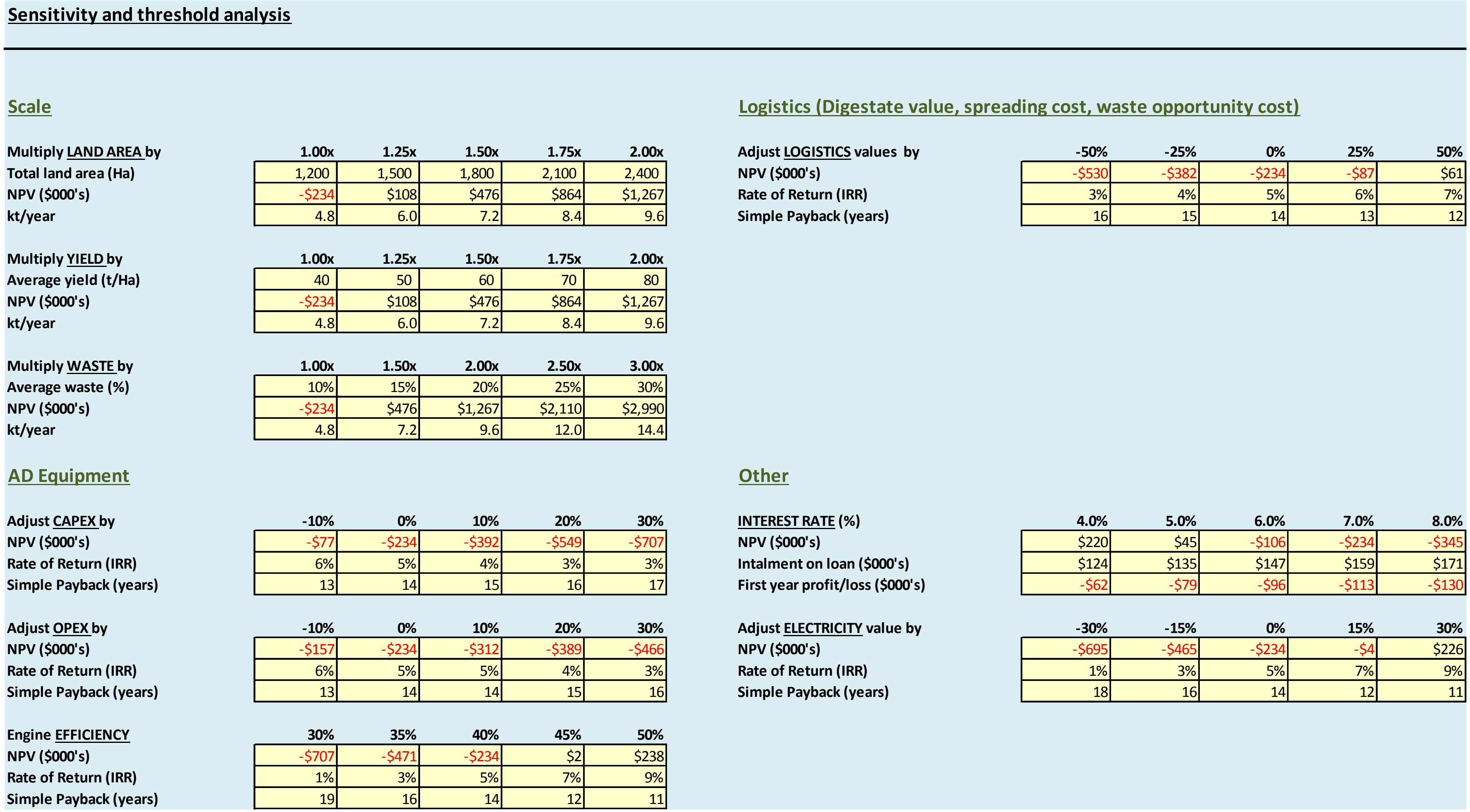
Appendix 4: Details for reference case

Annual financial projections

All figures nominal $000's

Revenue or savings	**2013/14**																				
Upfront cost	$ 1,684																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Revenue or savings		**2014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2033/34**
Energy savings		$ 114	$ 118	$ 123	$ 128	$ 133	$ 138	$ 144	$ 149	$ 155	$ 162	$ 168	$ 175	$ 182	$ 189	$ 197	$ 205	$ 213	$ 221	$ 230	$ 239
LGC sales		$ 22	$ 25	$ 27	$ 30	$ 33	$ 35	$ 38	$ 40	$ 43	$ 43	$ 43	$ 43	$ 43	$ 43	$ 43	$ 43	$ 43	$ 43	$ 43	$ 43
Costs																					
Instalment on loan		$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159	$ 159
Interest component		$ 118	$ 115	$ 112	$ 109	$ 105	$ 101	$ 97	$ 93	$ 88	$ 83	$ 78	$ 72	$ 66	$ 60	$ 53	$ 46	$ 38	$ 29	$ 20	$ 10
Operating		$ 65	$ 66	$ 68	$ 69	$ 71	$ 73	$ 75	$ 77	$ 79	$ 81	$ 83	$ 85	$ 87	$ 89	$ 91	$ 93	$ 96	$ 98	$ 101	$ 103
Labour		$ 31	$ 32	$ 32	$ 33	$ 34	$ 35	$ 36	$ 37	$ 37	$ 38	$ 39	$ 40	$ 41	$ 42	$ 43	$ 45	$ 46	$ 47	$ 48	$ 49
Logistics																					
Digestate value		$ 49	$ 51	$ 52	$ 53	$ 54	$ 56	$ 57	$ 59	$ 60	$ 62	$ 63	$ 65	$ 66	$ 68	$ 70	$ 71	$ 73	$ 75	$ 77	$ 79
Spreading cost		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Waste opportunity cost		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Straight line depreciation		$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84	$ 84
Profit/Loss		-$ 113	-$ 103	-$ 94	-$ 85	-$ 75	-$ 64	-$ 53	-$ 42	-$ 30	-$ 20	-$ 10	$ 1	$ 12	$ 25	$ 37	$ 51	$ 66	$ 81	$ 97	$ 114
Project Discounted Cashflow (DCF)	-$ 1,684	$ 89	$ 96	$ 102	$ 108	$ 115	$ 121	$ 128	$ 135	$ 142	$ 147	$ 152	$ 157	$ 163	$ 169	$ 175	$ 181	$ 187	$ 194	$ 201	$ 209
Project Cumulative Cashflow Pos.	-$ 1,684	-$ 1,594	-$ 1,499	-$ 1,397	-$ 1,288	-$ 1,174	-$ 1,052	-$ 924	-$ 789	-$ 647	-$ 499	-$ 347	-$ 190	-$ 27	$ 142	$ 317	$ 498	$ 685	$ 879	$ 1,081	$ 1,290
Cashflow to Equity (CFoE)		-$ 70	-$ 63	-$ 57	-$ 51	-$ 44	-$ 38	-$ 31	-$ 24	-$ 17	-$ 12	-$ 7	-$ 1	$ 4	$ 10	$ 16	$ 22	$ 29	$ 35	$ 42	$ 50
Net Present Value (NPV)	-$ 234																				
Rate of Return (IRR)	5.3%																				
Simple Payback (years)	14																				

Figure A4- 1: Annual financial projections for the reference case



Sensitivity and threshold analysis

Scale

Multiply LAND AREA by	1.00x	1.25x	1.50x	1.75x	2.00x
Total land area (Ha)	1,200	1,500	1,800	2,100	2,400
NPV ($000's)	-$234	$108	$476	$864	$1,267
kt/year	4.8	6.0	7.2	8.4	9.6

Multiply YIELD by	1.00x	1.25x	1.50x	1.75x	2.00x
Average yield (t/Ha)	40	50	60	70	80
NPV ($000's)	-$234	$108	$476	$864	$1,267
kt/year	4.8	6.0	7.2	8.4	9.6

Multiply WASTE by	1.00x	1.50x	2.00x	2.50x	3.00x
Average waste (%)	10%	15%	20%	25%	30%
NPV ($000's)	-$234	$476	$1,267	$2,110	$2,990
kt/year	4.8	7.2	9.6	12.0	14.4

Logistics (Digestate value, spreading cost, waste opportunity cost)

Adjust LOGISTICS values by	-50%	-25%	0%	25%	50%
NPV ($000's)	-$530	-$382	-$234	-$87	$61
Rate of Return (IRR)	3%	4%	5%	6%	7%
Simple Payback (years)	16	15	14	13	12

AD Equipment

Adjust CAPEX by	-10%	0%	10%	20%	30%
NPV ($000's)	-$77	-$234	-$392	-$549	-$707
Rate of Return (IRR)	6%	5%	4%	3%	3%
Simple Payback (years)	13	14	15	16	17

Adjust OPEX by	-10%	0%	10%	20%	30%
NPV ($000's)	-$157	-$234	-$312	-$389	-$466
Rate of Return (IRR)	6%	5%	5%	4%	3%
Simple Payback (years)	13	14	14	15	16

Engine EFFICIENCY	30%	35%	40%	45%	50%
NPV ($000's)	-$707	-$471	-$234	$2	$238
Rate of Return (IRR)	1%	3%	5%	7%	9%
Simple Payback (years)	19	16	14	12	11

Other

INTEREST RATE (%)	4.0%	5.0%	6.0%	7.0%	8.0%
NPV ($000's)	$220	$45	-$106	-$234	-$345
Intalment on loan ($000's)	$124	$135	$147	$159	$171
First year profit/loss ($000's)	-$62	-$79	-$96	-$113	-$130

Adjust ELECTRICITY value by	-30%	-15%	0%	15%	30%
NPV ($000's)	-$695	-$465	-$234	-$4	$226
Rate of Return (IRR)	1%	3%	5%	7%	9%
Simple Payback (years)	18	16	14	12	11

Figure A4- 2: Results of the threshold analysis for the reference case

Appendix 5: VegeNotes Issue 42

Biogas generation feasibility study

HAL R&D project number: VG13049

Project VG13049 is investigating the feasibility of biogas projects on vegetable farms for Horticulture Australia.

Facilitators:

Project VG13049 is being conducted by Project Leader Dr Anne-Maree Boland, from RM Consulting Group, and team, in partnership with Marsden Jacob Associates and Alison Kelly Consulting.

Introduction

Once considered uneconomic for vegetable farms, preliminary research suggests that on-farm electricity generation through Anaerobic Digestion (AD) and the production of biogas could prove viable for larger properties. AD is a process by which organic matters, such as vegetable and animal wastes, are broken down by microorganisms in an enclosed vessel. The microorganisms feed on the organic materials to produce methane, which is converted into electricity using a generator, heat and carbon dioxide (biogas) – a source of renewable energy.

AD systems typically operate at the farm (or processing plant) scale using on-site waste streams, or at a centralised scale incorporating large volumes of waste from multiple sources. Their use has been demonstrated on properties where current waste disposal is costly, or in situations where there is no revenue being generated by vegetable waste management.

About the project

RM Consulting Group (RMCG) has been commissioned by Horticulture Australia Limited (HAL) to investigate the feasibility of on-farm electricity generation from vegetable waste. Project Economist Kym Whiteoak said the rationale driving the project was “to look at how large volumes of waste could be disposed of, or managed, in the least costly way for farmers across a range of vegetable commodities”.

“Whether you are allocating waste to neighbouring farms or setting up waste disposals in feedlots, every waste management system comes with its own costs and management issues, which can create added strain for farmers,” he said.

“Although some research points to the viability of AD for larger farms, this project aims to further understand under what conditions biogas may be feasible for the generation of electricity.

“Biogas is often most cost-effective when it contributes to solving a costly or time-consuming waste management problem, which is why we are interested in understanding the scale of the problem and any barriers to implementing biogas generation on-farm.”

The project team has undertaken an initial desktop review of available literature and technical information, and preliminary consultation with industry.

Mr Whiteoak said a feasibility assessment framework was being developed that would allow vegetable growers to make an educated decision on the economic, technical and operation benefits, as well as equipment availability and implementation barriers, of introducing an AD facility into their production system.

“The framework considers a number of factors that could influence the viability of the technology, including volume and type of waste, energy consumption on-farm, likely power saving benefits and other logistics.

"Answers to these questions will contribute to determining whether the technology stacks up from a business perspective."

Mr Whiteoak said a key part of the project was the assessment of biogas feasibility four-farm based case studies – two in Western Australia, one in Queensland and one in Tasmania.

"This will allow us to test our feasibility framework on-farm, and enable those growers to get a better sense of the conditions necessary to make biogas generation a possibility for their operations.

"Potentially, these case studies will be used as a communication tool for the broader industry."

Preliminary findings

The initial desktop review, consultation with industry and modelling has uncovered four factors that govern the favourable conditions for on-farm electricity generation through AD. These are:

1. Scale – land area, crop yield and percentage waste.
2. Crop type – high energy crops (such as sweet corn) are preferable to low energy crops (such as lettuce)
3. Energy use – high enough to consume output locally, rather than export to the grid.
4. Logistics – digestate, transport and gate fees.

Mr Whiteoak said further consultation with the AD industry and individual farm businesses was required to better understand the parameters and assumptions involved in determining the feasibility of biogas. The feasibility study will be completed by May 2014.

Conclusion

Although drivers affecting the feasibility of AD will differ for each set-up, Mr Whiteoak has identified four factors as the most influential.

"The main factors to consider are scale of operation (the unit cost of energy tends to decrease with size), crop type (high energy crops such as sweet corn produce more electricity per tonne than crops like lettuce which are mostly composed of water), high and consistent energy (AD is typically set to match baseline energy use) and logistics (including high existing waste management costs and the ability to source additional consistent waste volumes, among others)," he said.

"We think biogas generation could be feasible for larger farms with an input volume above 20 tonnes a day but probably not for farms below this input volume."

Mr Whiteoak said while it would be technically possible for farmers to operate their own biogas plant, they could also consider "clustered" models whereby waste volumes are combined and costs are shared among two or more neighbouring farms.

"Larger, regional clusters could also potentially incorporate a variety of different waste streams," he said.

"Operations at this scale might require full-time management and would need detailed management arrangements for digestate use."

Bottom line

"Our research suggests that biogas will not be a viable option for every farm, especially smaller operations", he said. "It appears more likely to be viable for larger farms with high energy crops, high cost waste management and high electricity use."

Acknowledgement

Project funded through HAL by the National Vegetable Levy with matched funds from the Australian Government.

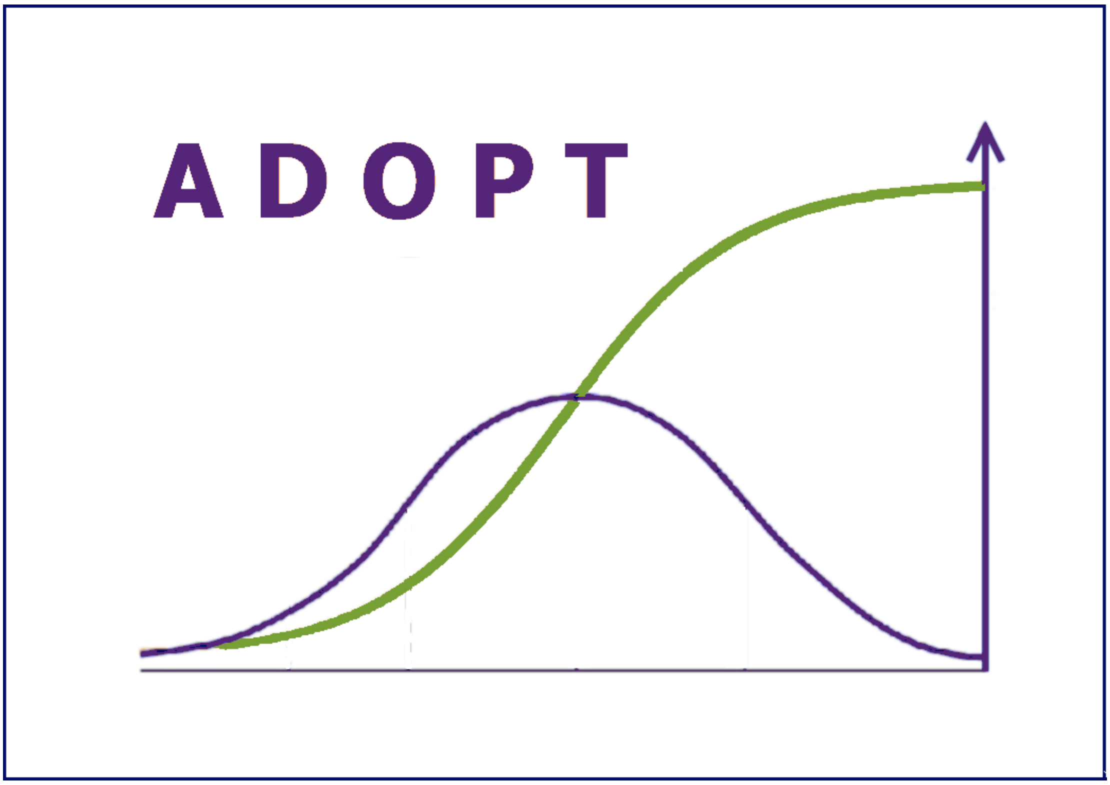
Appendix 6: Adoption of biogas on Australian vegetable farms

ADOPT: the adoption and diffusion outcome prediction tool

Adoption report for:

Adoption of biogas on Australian vegetable farms

4 June 2014



For more information about ADOPT contact:

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or
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Report Authors:

Carl Larsen and Anne-Maree Boland (RMCG)

Description of the Innovation

There is significant interest within the vegetable industry in maximising efficiency and productivity across the production process, including maximising value from waste streams. Previous analysis has suggested that generating biogas from on-farm vegetable waste could be a cost-effective option for vegetable farms.

Biogas is methane and carbon dioxide produced from the bacterial degradation of organic waste. Using anaerobic digestion, the process produces electricity, heat and a residual organic product that can be used on-farm as an organic fertiliser.

This study was commissioned to explore in more detail the feasibility of biogas on Australian vegetable farms.

Description of the Population

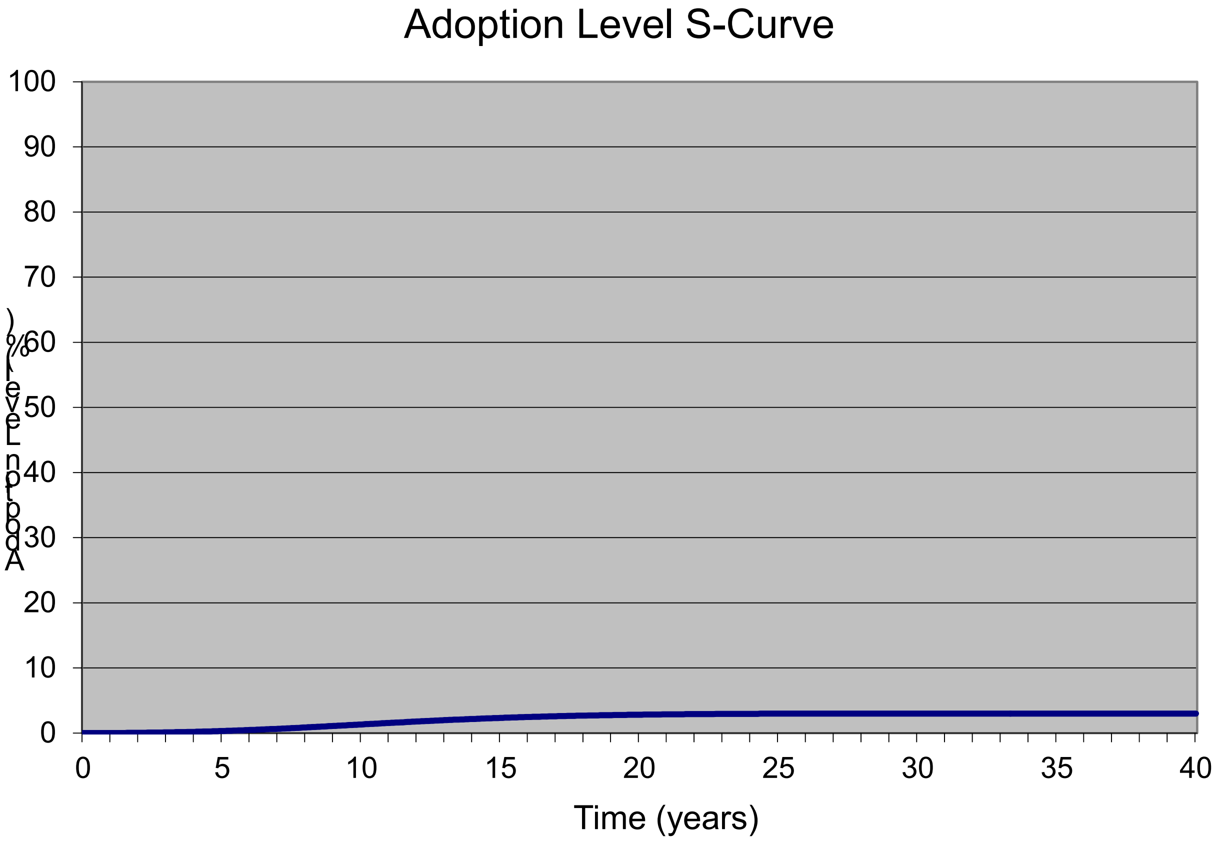
The target areas for adoption of biogas are larger farms with high energy crops, high cost waste management and high electricity use in the main vegetable growing regions in Australia.
The target audiences are the vegetable industry, growers, packers, consultants, industry development officers, researchers, horticulture industry service providers and supply chain participants.

Predicted Adoption Levels

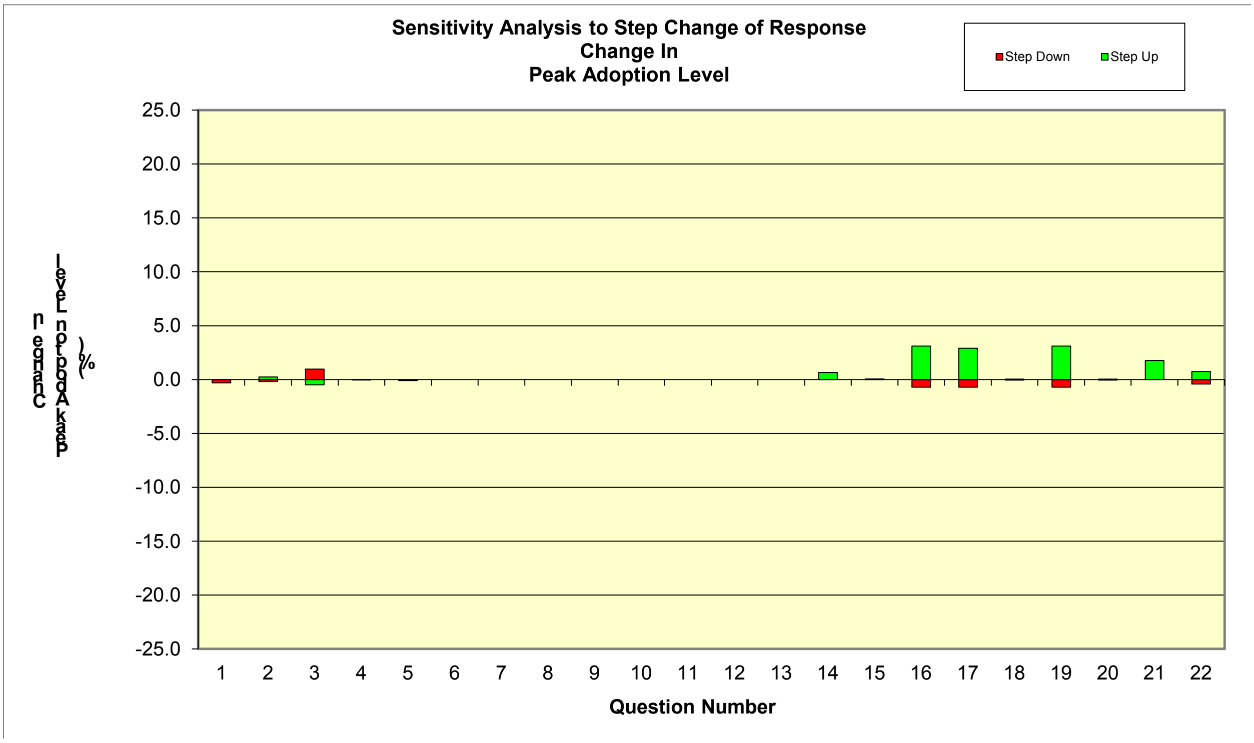
Predicted years to peak adoption	31
Predicted peak level of adoption	3%
Year innovation first adopted or expected to be adopted	N/A
Year innovation adoption level measured	N/A
Adoption level in that year	N/A
Predicted adoption level in 5 years from start	0.3%
Predicted adoption level in 10 years from start	1.3%

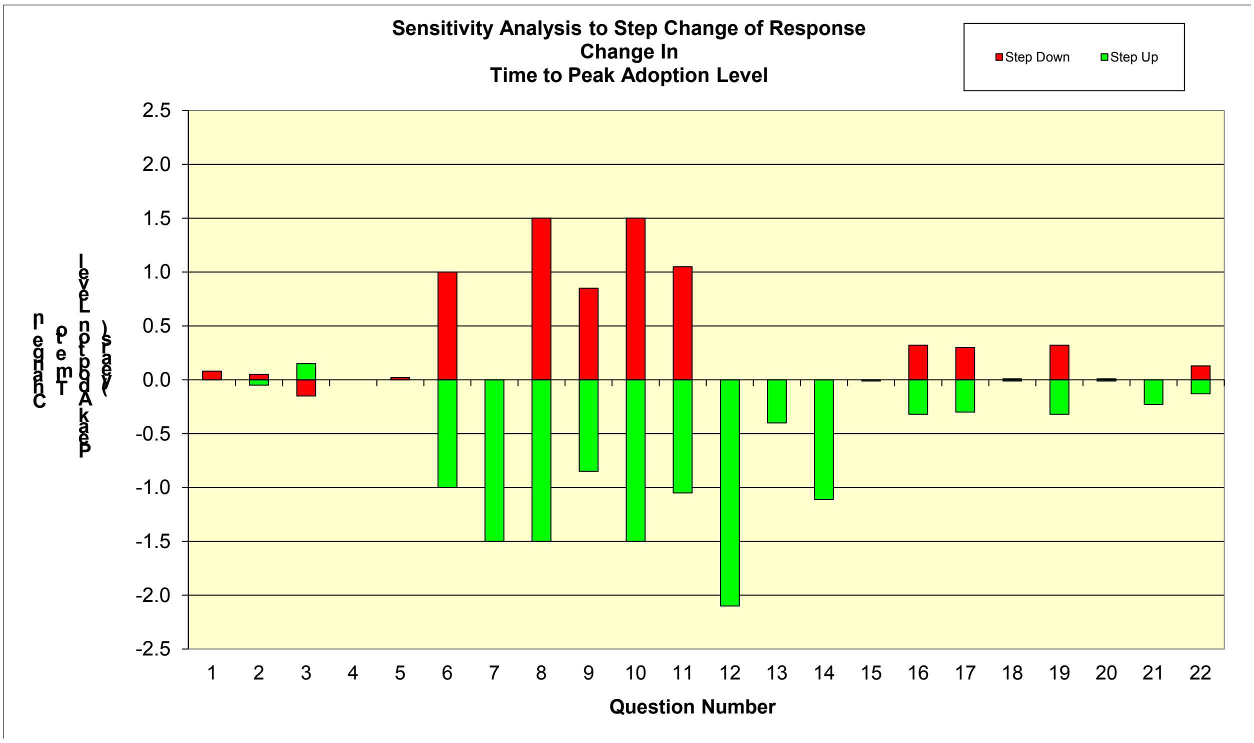
The predictions of 1) ‘Peak Adoption Level’ and 2) ‘Time to Peak Adoption Level’ are numeric outputs that are provided to assist with insight and understanding and like any forecasts should be used with caution.

Predicted Adoption Curve



Sensitivity Analysis

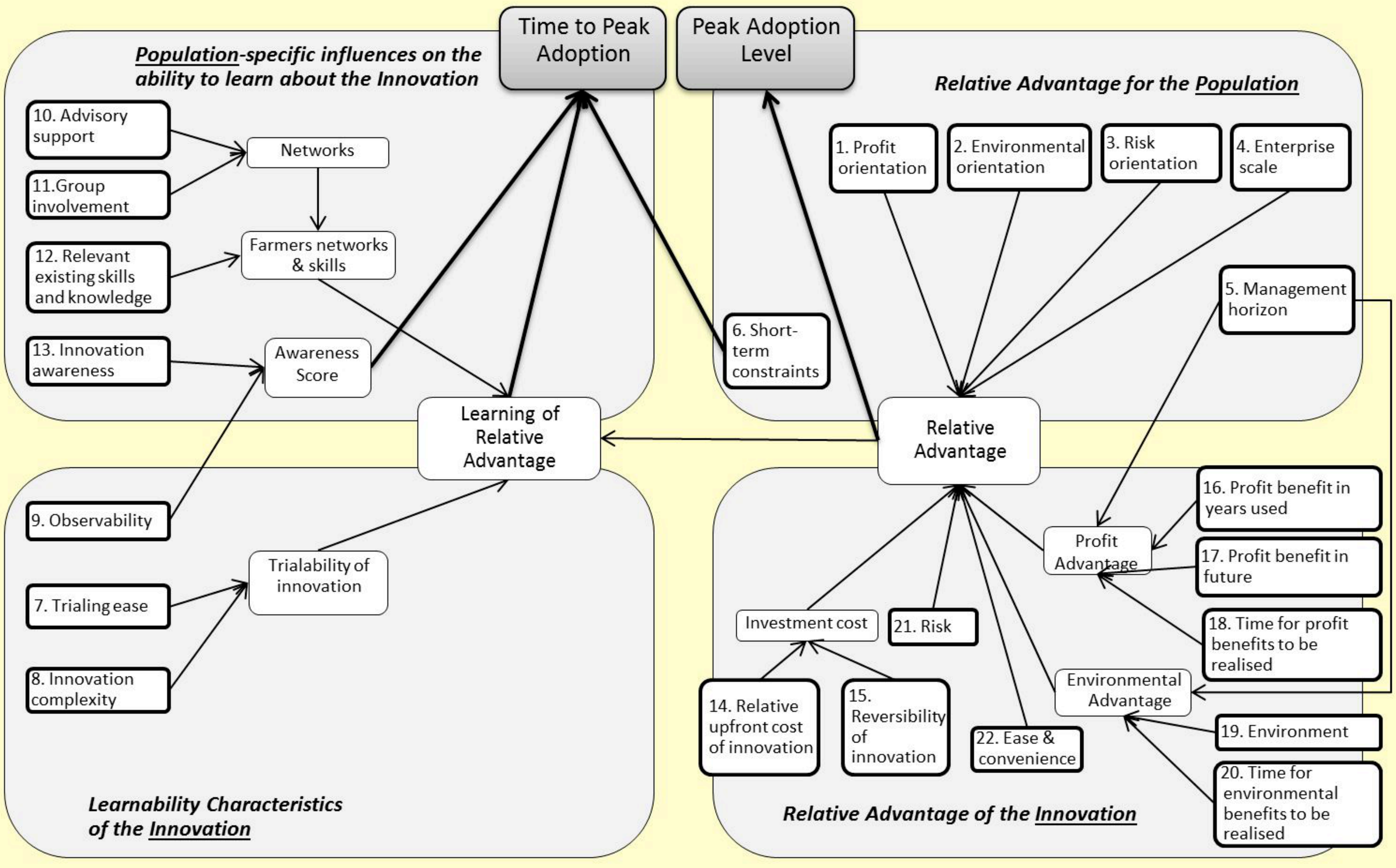




ADOPT Questions & Conceptual Framework

1. What proportion of the target population has maximising profit as a strong motivation?
2. What proportion of the target population has protecting the natural environment as a strong motivation?
3. What proportion of the target population has risk minimisation as a strong motivation?
4. On what proportion of the target farms is there a major enterprise that could benefit from the innovation?
5. What proportion of the target population has a long-term (greater than 10 years) management horizon for their farm?
6. What proportion of the target population is under conditions of severe short-term financial constraints?
7. How easily can the innovation (or significant components of it) be trialled on a limited basis before a decision is made to adopt it on a larger scale?
8. Does the complexity of the innovation allow the effects of its use to be easily evaluated when it is used?
9. To what extent would the innovation be observable to farmers who are yet to adopt it when it is used in their district?
10. What proportion of the target population uses paid advisors capable of providing advice relevant to the innovation?
11. What proportion of the target population participates in farmer-based groups that discuss farming?
12. What proportion of the target population will need to develop substantial new skills and knowledge to use the innovation?
13. What proportion of the target population would be aware of the use or trialing of the innovation in their district?
14. What is the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation?
15. To what extent is the adoption of the innovation able to be reversed?
16. To what extent is the use of the innovation likely to affect the profitability of the farm business in the years that it is used?
17. To what extent is the use of the innovation likely to have additional effects on the future profitability of the farm business?
18. How long after the innovation is first adopted would it take for effects on future profitability to be realised?
19. To what extent would the use of the innovation have net environmental benefits or costs?
20. How long after the innovation is first adopted would it take for the expected environmental benefits or costs to be realised?
21. To what extent would the use of the innovation affect the net exposure of the farm business to risk?
22. To what extent would the use of the innovation affect the ease and convenience of the management of the farm in the years that it is used?

ADOPT: Adoption and Diffusion Outcome Prediction Tool.



Information Entered into ADOPT

The above predictions are based on the following information entered into the Adoptability and Diffusion Outcome Prediction Tool.

Relative Advantage for the Population

Profit orientation	Response: Almost all have maximising profit as a strong motivation
	Reasoning: Highly commercial operations.
Environmental orientation	Response: A majority have protection of the environment as a strong motivation
	Reasoning: Commercial operations needs to demonstrate environmental credentials e.g. Environmental Assurance.
Risk orientation	Response: A minority have risk minimisation as a strong motivation
	Reasoning: Commercial operations are risk takers but manage risk carefully.
Enterprise scale	Response: Almost all of the target farms have a major enterprise that could benefit
	Reasoning: Target audience are the larger commercial producers.
Management horizon	Response: Almost all have a long-term management horizon
	Reasoning: Commercial operations require a long-term view and expect to be in operation beyond 10 years.
Short term constraints	Response: A minority currently have a severe short-term financial constraint
	Reasoning: Cost of production is increasing but larger operations are generally profitable.

Learnability Characteristics of the Innovation

Trialable	Response: Not trialable at all

	Reasoning: Biogas requres significant up front captial investment in infrastructure.
Innovation complexity	Response: Difficult to evaluate effects of use due to complexity
	Reasoning: There are a number of inter-related facotrs contributing to evaluating the costs and benefits of biogas on vegetable farms.
Observability	Response: Easily observable
	Reasoning: Difficult to observe in the vegetable industry, however there are examples outdside in other sectors e.g. intensive animal systems.

Learnability of Population

Advisory support	Response: A minority use a relevant advisor
	Reasoning: Not all commercial operations know where to seek advice from. However, 2/4 case study growers had sought advise from AD suppliers of their own accord.
Group involvement	Response: A minority are involved with a group that discusses farming
	Reasoning: Commercial operators rarely use farmer discussion groups as a forum and seek independent private advice e.g. consultants, agronomists
Relevant existing skills & knowledge	Response: Almost all need new skills and knowledge
	Reasoning: Biogas is a completely new technology in the vegetable industry in Australia.
Innovation awareness	Response: It has never been used or trialed in their district(s)
	Reasoning: There is limited application and awareness in the Australian vegetable industry.

Relative Advantage of the Innovation

Relative upfront cost of innovation	Response: Very large initial investment
	Reasoning:

	Significant capital investment up front in infrastructure and ongoing service and management requirements.
Reversibility of innovation	Response: Not reversible at all
	Reasoning: Significant infrastructure and cost means there is commitment to the technology once installed. Completely changes waste management system and practices.
Profit benefit in years that it is used	Response: Small profit advantage in years that it is used
	Reasoning: Feasibility analysis should justify the case for investment. Once implemented the advantage will be offset waste management and electricity costs.
Future profit benefit	Response: Small profit advantage in the future
	Reasoning: Based on current electricity price and waste disposal cost projections.
Time until any future profit benefits are likely to be realised	Response: 1 - 2 years
	Reasoning: Initial time lag during construction and bringing the digestor online to process all current waste produced.
Environmental costs & benefits	Response: Small environmental advantage
	Reasoning: Removal of vegetable waste from landfill.
Time to environmental benefit	Response: 1 - 2 years
	Reasoning: Commensurate with the time taken for financial advantage of the innovation.
Risk exposure	Response: Large increase in risk
	Reasoning: Due to large capital investment up front.
Ease and convenience	Response: Moderate decrease in ease and convenience
	Reasoning: Due to ongoing service and management requirements of the digestor and associated infratructure.