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Prepared by: All Energy Pty Ltd

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Locked Bag 1961
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Review of renewable energy technology adoption within the Australian Red Meat Industry

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Executive summary

It is estimated that the red meat industry (RMI) in Australia is spending $1.315 billion per annum (pa) on energy for farming, feedlotting and red meat processing (RMP) activities. It is estimated that the annual energy consumption equates to 47 peta joules pa (or 47 million giga joules pa). The three highest energy costs associated with the production and processing of red meat (farm, feedlot, factory) to the stage of being retail ready are, in order:

1) On-farm diesel use at $298 mil pa (at 22.7%)
2) Red meat processor power at $278 mil pa (21.1%)
3) Feedlot power at $273 mil pa (20.8%)

The production of mutton, lamb, beef and veal products from the farm, through to feedlot (for grain fed cattle) to the RMP. This body of work excludes retailing, distribution, cold chain and other associated activities post-factory.

This report aims to put forward only proven technologies that are available “off the shelf” at a scale that is fit-for-purpose for the chosen facility and that can provide renewable energy at commensurate or lower costs than commonly used energy sources.

Energy sources all have varying costs and unique technology requirements (refer section 3.1), hence the ongoing costs to fuel equipment must be taken into account. Further, the time scale has a dramatic impact on the economics especially for capital intensive, zero fuel cost options such as solar thermal and waste to energy systems.

By utilizing “free issue” fuels (co-created organic wastes and solar radiation) the annual fuel bill could be reduced to $0.054 bil pa (for procurement of biomass to fuel gasifiers at RMPs). This equates to a 96% reduction in annual energy costs for the RMI.

Energy Use	Renewable Energy Technology
Farm – Power	PV Solar and batteries.
Farm - Diesel	Electrification. (Bio-CNG at refuelling hubs such as large feedlots may be viable).
Farm - Petrol	
Feedlot - Power	Biogas from manure digestion for cogen and biogas boosted boiler.
Feedlot - Thermal	
RMP - Coal	30% of power demand and 15% of heat from biogas cogen. 64% of power demand and 46% of heat from gasification. 39% of heat from biomass fired boilers. 6% of power from PV.
RMP - Nat gas	
RMP - LPG	
RMP - Power	
RMP - Diesel	
RMP - Fuel oil	

Feedlots are the one section of the RMI where there is an oversupply of bio-energy due to the large amounts of cattle manure. Assuming that manure at an average age of 60 days is digested, feedlots have the potential to generate an estimated excess of 3.4 PJ of energy which equates to 7% of the entire RMI energy or 18% of on-farm energy. To facilitate transport, the biogas can be upgraded (by removing CO_2 and minor contaminants) then compressed into bio-CNG, which is the same as CNG used for bus fleets in many Australian cities (including Brisbane, Perth, Adelaide, and Sydney).

A recent study funded by AEMO[1] predicts strong growth in commercial / industrial power prices at around 4 to 16% year on year pricing increases through to 2020, then a relatively flat or declining price trend from 2020 through to 2037.

Natural gas pricing is under huge pressure as there are predicted shortfalls occurring in the east coast market, leading to industrial natural gas price offers for 2018 at $15 / GJ, which is a huge risk to 37% of RMP energy obtained from natural gas. Thermal coal prices are forecast to gradually decline over the outlook period in the order of 4 to 16% drops for the coming two financial years. For liquid fuels, prices trends are relatively flat for the coming year.

Possible actions for the Australian RMI, starting with the most critical item:

[1] De-couple from natural gas and liquid fuels for stationary energy immediately.

[2] De-couple from grid power immediately where it is economically viable to do so, with a pathway for being off-grid by 2030.

[3] Maximize the use of co-products and local energy sources (minimize reliance on third party vendors). All businesses should complete feasibility studies immediately to remove the use of natural gas and liquid fuels. For other fuel, clear options are required for when existing plant reaches its end of life. Co-products and local energy sources include manure at feedlots, organics at RMPs, locally created biomass (e.g. woodchip and milling by-products), PV solar and concentrated solar thermal.

[4] De-couple from fossil fuels and internationally traded energy commodities by 2040.

[5] Achieve energy carbon neutrality by 2040.

[6] Remove fossil based commodities from supply chain including fertilizer and polymers.

[1] https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/EFI/Jacobs-Retail-electricity-price-history-and-projections_Final-Public-Report-June-2017.pdf

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Glossary of Terms

AD Anaerobic digestion

Biogas Gaseous product of AD, normally 60% or higher CH_4 plus CO_2

CH_4 Methane (flammable gas used as a fuel in boilers and engines)

CO Carbon monoxide

CO_2 Carbon dioxide

COD Chemical Oxygen Demand

Cogen Cogeneration engine (for making power and heat)

DAF Dissolved air flotation

dw Dry weight (i.e. 0% moisture)

GJ giga joules (= 1000 MJ)

H_2 Hydrogen

H_2O Water

hr hour

kg kilogram

kJ kilo joules (= 1000 Joules)

kW kilo watts

kWe kilowatts electrical

kWh kilo watt hours = 3600 kJ

kWt kilowatts thermal (i.e. heating)

LHV Lower Heating Value (net heat value that includes the latent heat of water)

LGC Largescale Generation Certificates equal to 1.0 MWh; created under the Australian Federal Government's RET scheme.

m^3 or m^3 Cubic metres

MJ mega joules (= 1000 kJ = 0.28 kWh)

ML Megalitre

MW Megawatt

MWh Megawatt hour

ppm Parts per million

pH An indication of a solutions acidity (or alkalinity)

PJ peta joules (= 1000 TJ)

PV Solar photo-voltaic (for power generation)

RET Renewable Energy Target

RMI Red meat industry

RMP Red meat processor

s seconds (time)

Syngas Gaseous fuel; the product of gasification; containing mostly CO and H_2, as well as CO_2 and CH_4 plus other low concentration molecules.

t Metric tonne (1,000 kg)

TJ terra joules (= 1000 PJ)

TS Total solids

tpa Metric tonnes per annum

tpd Metric tonnes per day

tph Metric tonnes per day

tpw Metric tonne per week

VS Volatile solids

W Watts

WTE Waste to Energy

WWTP Waste water treatment plant

yr year

1 Background

Retooling Australia’s energy generation into renewable energy solutions will be driven by societal, consumer, financial and regulatory demands. No longer simply an alternative to landfill or composting, repurposing waste from a linear use/dispose model to a higher value or circular model means that businesses are being pushed and pulled towards higher sustainability to improve cost-effectiveness and meet customers’ demand.

Waste to energy (known as W2E) provides a unique nexus to create value whilst reducing environmental impacts such as waste stockpiling, lowering emissions to air, and preventing landfill leachates. The opportunity to convert wastes into high value products, thereby transforming the business, environmental and social costs of disposal into a sustainable business, is required for better social stewardship and is therefore compelling.

Organic wastes including agri-wastes, food manufacturing, municipal, biosolids, and other difficult to manage wastes such as used tyres, are costly to manage and typically dealt with through landfill, on land disposal or incineration. Not only does this result in high disposal costs but also results in significant environmental impacts through greenhouse gas emissions and the potential overconcentration and leaching of nutrients and degradation of products into the ecosystem.

Capturing value from wastes through energy recovery and the production of biomaterials, while recovering and recycling nutrients, will transform agricultural and manufacturing processes and help to create new high value businesses and growth opportunities for Australian manufacturing. A study undertaken in 2010 estimated that the global bio-based and fuels product market valued then at around US$148 billion, would grow to US$1.4 trillion by 2025, resulting in a Compound Annual Growth Rate of 16%.

Approximately 80% of organic waste in Australia results from harvesting and processing wastes produced by the agricultural and forestry industries. The remaining 20% of waste is present in the form of municipal wastes and bio-solids. The majority of wastes going to landfill occur around urban areas where the cost of disposal is high. The diversion of this resource to energy production (e.g., via pyrolysis and/or hydrothermal technologies) would convert this large waste stream into a source of revenue equivalent to approximately 13 million barrels of oil annually or 3% of Australia’s crude oil equivalent consumption of hydrocarbons. The use of thermochemical and allied technologies will not only produce renewable energy but also produce high value bio-materials from char and other residues.

2 Project objectives

The objectives to be achieved in this project are:

- Determining the extent to which energy costs (heating, electricity, and transport fuels) contribute to operating costs within the red meat production and processing sectors, and how they are likely to trend in the future.

- Determining the total addressable market for energy efficiency, renewable energy, and energy storage technologies in the Australian RMI.

- Highlighting the energy intensive processes across the supply chain and where high impact R&D projects should be directed.

- Economic analysis of key renewable energy technology classes.

3 Methodology and Results

3.1 Fuels

Presented below is a table summarizing the various fuels and sources of energy available. Of particular note is that the findings are *estimates only* based on a large range of market data – business will need to consider individual requirements and will need to undertake detailed analysis for specific geographic locations.

Table 3.1: Comparison of estimated costs across a suite of energy sources and technologies. Levelized Cost of Electricity (LCoE) calculations include cap ex, op ex, renewable energy credits & thermal energy.

Fuel	Cost	Unit	LHV MJ/kg	LHV MJ/L	$/GJ - calculated; fuel supply only	$/GJ – ESTIMATED. Fully costed over life of plant
PROCURED THERMAL ENERGY						
Hardwood chip, ex-mill, air dried	58	$/t	16.86		3.44	6.99 (25 year life)
Coal (bituminous)	113.23	$/t	25.9		4.37	7.92 (25 year life)
B-Grade tallow / Low grade tallow	0.38	$/L	40	36.8	10.33	12.39 (25 year life)
Natural gas	12	$/GJ			12.0	14.05 (25 year life)
Fuel oil (higher viscosity compared to processed)	0.484	$/L	37.28	34.67	13.96	16.02 (25 year life)
Processed fuel oil	0.6105	$/L	41.51	38.18	15.99	18.06 (25 year life)
LNG (incl. storage)	990	$/t	48.63	20.72	20.36	23.43 (25 year life)
Diesel (stationary and private off-road use)	$0.794	$/L	42.61	35.58	22.32	24.38 (25 year life)
LPG (incl. storage)	0.63	$/L	46.61	23.07	25.05	27.23 (25 year life)
THERMAL ENERGY SOURCED "ON-SITE"						
Anaerobic Digester for biogas from organic wastes	Free issue			0.022		7.85 for thermal only (25 year life) ($0.048 / kWh LCoE)
Solar thermal vacuum tubes - hot water (small scale; 2 kWt rating)	Free issue					22.17 (15 year life)
Concentrated solar thermal - raising steam (large scale; 3 MWt)	Free issue					9.53 (25 year life)
ELECTRICAL ENERGY						
Power - 11 kV feeder	$0.125	kWh				38.9
Power – High efficiency diesel gen set	$0.377	kWh				104.7
Power - Ergon Small Business Tariff 22A Peak	$0.63	kWh				174.8
PV Solar <99 kW	Free issue					24.4 ($0.088 / kWh LCoE; 10 year life)
PV Solar >100 kW	Free issue					21.1 ($0.076 / kWh LCoE; 10 year life)
Battery – Small scale (3 kWh)	Assumed free issue					$0.19 / kWh (for warrantied period of 15 yrs)
Battery – Large scale (129 MWh)	Assumed free issue					$0.106 / kWh (for warrantied period of 10 yrs)

Allowances have been made for equipment capital cost and installation, maintenance and operation of equipment, and staffing. No allowance has been made for wastes (e.g. blow down water, bottom & fly ash handling and disposal) or efficiency variations between equipment. Thermal energy estimates are based upon system approximately rated to 3 MWt to 10 MWt. The diesel price is based on the 27 Sept terminal price[2], plus retailing and transport of $0.04/L minus the ATO business rebate of $0.403 / L[3]. LPG used the retail bowser price[4] minus the ATO business rebate of $0.132[2].

Additional assumptions for this analysis are contained within the following pertinent sections.

[2] http://www.aip.com.au/pricing/tgp/, accessed 28 Sept 2017.
[3] https://www.ato.gov.au/business/fuel-schemes/fuel-tax-credits---business/rates---business/from-1-july-2017/, accessed 28 Sept 2017.
[4] https://www.racq.com.au/, accessed 28 Sept 2017.

3.2 Energy use and contribution to operating costs throughout the Red Meat Industry Supply Chain

Literature data was correlated with Australian Bureau of Statistics (ABS) data to estimate the 2017 energy usage and associated costs for the production of beef, veal, mutton, and lamb red meat processer (RMP) retail ready products (i.e. leaving the factory), assuming a Hot Standard Carcass Weight (HSCW) yield from live animals of 0.295 and a retail ready yield from HSCW of 0.74. It was assumed that no efficiency gains are achieved on a per kg retail ready basis as this was considered outside of the scope of these works.

3.2.1 On-Farm Energy Analysis

This section outlines the basis of the estimation of on-farm energy usage.

Table 3.2: On-Farm Energy Use Breakdown[5].

Energy Source	% Contribution	GJ pa	$ pa
Power	7 %	1,335,244	71 mil
Diesel	81 %	15,689,117	298 mil
Petrol	12 %	2,336,677	44 mil
TOTALS		19,361,038	414 mil

It can be seen from the figures above that for the on-farm aspect of the RMI, the highest impact of developments in renewable energy uptake will be in displacing diesel fuel use. It should be considered whether this is an area for research and development endeavour by Australia's RMI or whether the RMI could be an early adopter of developments by fuel industries for 'drop-in' liquid fuel solutions, disruptive technologies to replace stationary energy and government support. As a minimum, the RMI should investigate and communicate alternative transport and stationary fuel solutions such as electrification, biogas, 'drop-in' liquid fuels, increasing the efficiency of engines and equipment, and reducing the need for vehicle movements (by drones for example).

Assumptions:

- Power required 24 hours per day with spikes in morning and afternoons for staff/domestic use and for pumps / equipment use during the day.
- Power is assumed to cost an average of $0.24 / kWh or $66.67 / GJ.
- Diesel is assumed to have 38.6 GJ/kL at $734 / kL after the Australian Tax Office rebate.
- Petrol is assumed at 34.2 GJ/kL at $650 / kL after the Australian Tax Office rebate.
- Energy use, cost and solutions are assumed as follows:
- Embodied energy was excluded from this report.
- It was generally considered that individual power demands are too low for most bioenergy solutions, further the lack of demand for thermal energy further reduces the economic viability of on-farm bioenergy systems. However, there are some innovative modular gasification systems operating in the 100's kW range and some modular AD systems from 50 kW and upwards. Further refinement and mass production of these technologies will drive prices down.

[5] Wiedemann, S., McGahan E. Murphy, C., Yan, M., Henry, B., Thoma, G., Ledgard, S. (2015), "Environmental impacts and resource use of Australian beef and lamb exported to the USA determined using life cycle assessment", Journal of Cleaner Production, Vol 94, 67-75.

3.2.1.1 Feedlot

As shown in Table 3.3 and Figure 3.2 below, thermal energy constitutes the great majority of energy use at a feedlot on a GJ basis, whilst on a dollar basis thermal energy and electrical power are approximately equal. For individual feedlots, the use of energy is highly dependent upon co-located activities such as if there is grain milling and the type of milling activity e.g. dry rolled (no steam) or steam flaked. Steam flaking improves the overall feed utilization (i.e. kg grain per kg protein). Therefore, high impact projects can be directed at reducing the reliance on fossil fuels for both thermal energy and power. Potential projects include anaerobic digestion for power or cogeneration (e.g. using manure), and renewable fuel fired boilers (e.g. biogas or woodchip fired).

Table 3.3: Feedlot Energy Use Breakdown[6]

Energy Source	% Contribution	GJ pa	$ pa
Power	34	4,101,230	219 mil
Fuel for transport and thermal energy (e.g. grain steam flaking)	66	7,961,211	239 mil
TOTAL		12,062,441	458 mil

Assumptions:

- Power and thermal heat requires are predominantly for 1 milling shift per day of 8 hours.
- Power is assumed to cost an average of $0.24 / kWh.
- Fuel use costs are assumed to be an average of $30 /GJ, made up predominantly by LPG for steam flaking of grains with some diesel (10%) and natural gas usage (10%).
- For a feedlot, the greatest energy use is in the grain handling: steam for flaking and/or milling energy. A mill has a thermal boiler load approximately 7 times the power load (i.e. a mill drawing 500 kW has a boiler load in the order of 3.5 MWt). However, due to gen set efficiency losses and the use of cheaper thermal fuel (i.e. natural gas or LPG rather than diesel in the gen sets), the energy costs are found to be approximately commensurate.
- The total energy usage calculations are in keeping with previously published works, however the split in energy between power and thermal heat assumes that all operations are running on-site steam flaking systems.
- Whilst feedlots do not have the largest energy demands within the RMI supply chain, they offer the following advantages for renewable energy:
    - Large exclusion zones or buffers suitable for new plant such as boilers, collector troughs and PV solar.
    - Large amounts of organic wastes: cattle manure.
    - Being in regional areas, may have access to lower cost sources of biomass such as woodchip and forestry mulch.
    - Less sensitive receptors hence are less limited by ground level emissions requirements.

[6] Wiedemann, S., McGahan E. Murphy, C., Yan, M., Henry, B., Thoma, G., Ledgard, S. (2015), "Environmental impacts and resource use of Australian beef and lamb exported to the USA determined using life cycle assessment", Journal of Cleaner Production, Vol 94, 67-75.

3.2.1.2 Red Meat Processing (RMP)

Presented in Table 3.3 and Figure 3.3 are the annual energy consumption and energy costs estimated for Australian red meat processors. The cost of bio-energy has been excluded from this report as it is an existing form of renewable energy and also due to the complex nature of its current generation and use (i.e. approximately 58% of bio-energy is generated on-site by anaerobic digestion of co-created organics and hence used on-site on the form of biogas). The balance of the bio-energy is a range of fuels including saw dust, macadamia nut shell, wood chip, wood mill by-products (sawdust, bark, etc), briquetted flower processing by-product.

Table 3.4: Processing Energy Use Breakdown[7]

Energy Source	% Contribution to energy use	GJ pa	$ pa
Coal	18.0%	2,845,925	15 mil
Nat gas	37.0%	5,849,956	75 mil
LPG	2.0%	316,214	10 mil
Power	31.0%	4,901,315	278 mil
Diesel	1.0%	158,107	3 mil
Fuel oil	5.0%	790,535	8 mil
Bio-energy	6%	948,642	Excluded
TOTALS		15,810,693	389 mil

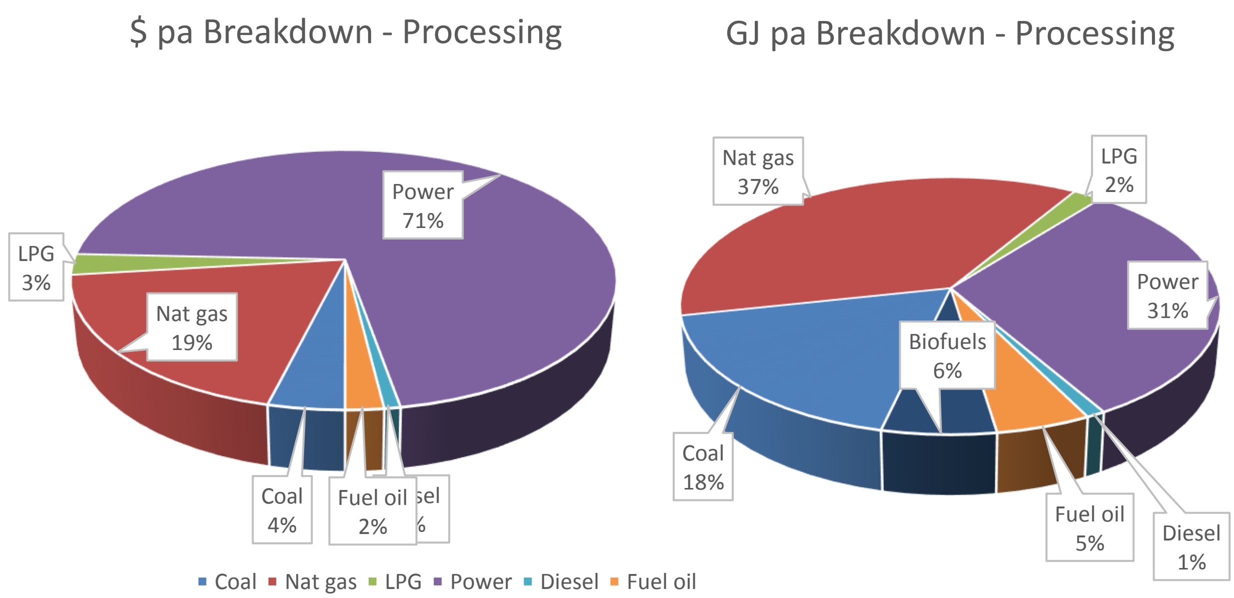

Figure 3.1: Energy value and source $pa and GJ pa Breakdown of Energy Use - Processing

The key assumptions were:

- RMPs run two shifts per day (16 hours), five day per week.
- 50 weeks per year operation.

[7] Wiedemann, S., McGahan E. Murphy, C., Yan, M., Henry, B., Thoma, G., Ledgard, S. (2015), "Environmental impacts and resource use of Australian beef and lamb exported to the USA determined using life cycle assessment", Journal of Cleaner Production, Vol 94, 67-75.

- Load profile as per figure 3.2 below is typical for a RMP.
- Power costs assumed at $0.192 / kWh accounting for all volume, capacity, environmental and access charges. This price effectively assumes that sites are on an 11 kV feeder from the grid.
- Thermal energy costs are as per Section 3.1, according to the percentages in Table 3.4.

The above figures show overwhelming reliance on grid power (on a dollar basis) at meat processing facilities (71% of energy costs), with natural gas second (19% of energy costs). It is assumed that most successful plant have implemented reasonably practicable energy efficiency measures, thus the key priority for RMP energy is research and development into reducing the reliance on grid power. Facilities should investigate renewable power options, including solar PV, energy storage and cogeneration options (e.g. biogas, gasification, backpressure turbines[8]). Disengaging from fossil fuels and fuels tied to international markets will have the benefit of collecting revenue on carbon emission reduction and shielding from rapidly increasing thermal fuel prices.

Taking a plant wide mass and energy balance approach indicates that a medium to large scale RMP operating an anaerobic digester can produce sufficient biogas to offset approximately 20 to 40% of the site's power load and towards 10 to 20% of the site's thermal load when the biogas is utilised within cogeneration engines. These percentages are highly dependent upon the digestion technology use, which organic streams are digested (e.g. red stream, green stream, paunch, screenings, dissolved air floatation sludge, etc), the efficiency of the combustion or engine system that is used and the energy demand profile of the RMP. In addition to kWh and GJ savings, when making power considerable revenue from renewable energy credits can be achieved (towards 50% of the total estimated revenue/cost savings from a biogas engine) as well as savings in utility demand (kVA) charges. When used to raise steam only, biogas can contribute to around 30% of thermal energy requirements (assuming on-site rendering).

Due to the large costs to store electricity (currently $0.19 / kWh), there is currently minimal economic incentive to store excess PV solar at RMPs. That is, if PV solar is assumed to cost $0.08 / kWh to generate, then grid power would need to exceed $0.27 / kWh for a PV solar-battery solution to be economically viable. Due to the rapid reduction in PV solar-battery technologies and the rapidly rising grid power costs, the cross over for RMPs could occur within a number of years. Assuming there is no economic incentive to export to the grid and there is sufficient power from biogas and gasification systems, a PV solar system would be sized so that all power is consumed without the need for storage. Considering a "typical" plant (refer Figure 3.4) a PV solar system would be sized to approximately 900 kWe rated output (i.e. the day time weekend load). Taking into account the kWh pa power demand for RMPs and the annualised average kWh per day per kWe installed, this equates to approximately 6% of annual power load.

[8] http://www.ampc.com.au/uploads/pdf/Environment-Sustainability/2017-1029-Final-Report.pdf, accessed 28 Sept 2017.

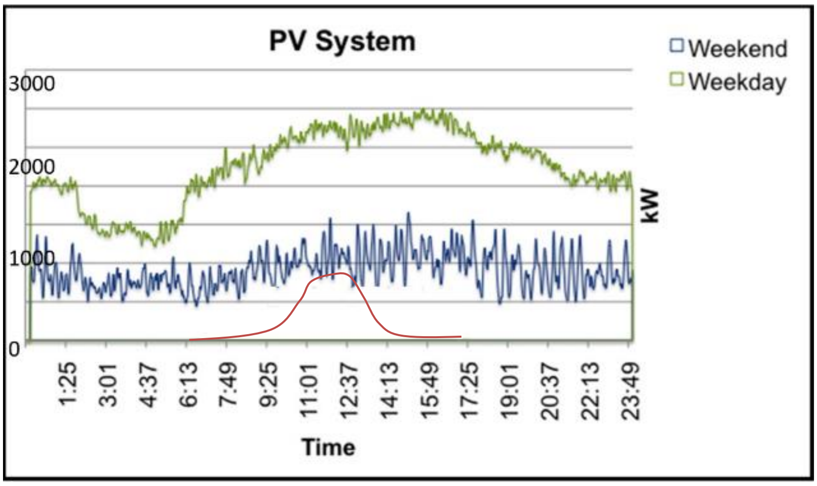

Figure 3.2: Power load for a “typical” 625 head per day processing plant running a 2-shift per weekday operation (green line) compared to the weekend average (blue line) and 900 kWe rated PV solar system.

3.2.1.3 Aggregated Read Meat Supply Chain Data

Table 3.4 and Figure 3.4 below shows the aggregated energy usage throughout the RMI supply chain, on a percentage The aggregated Australian red meat supply chain energy use is 47 peta joules (PJ; where 1.0 PJ equals one million gigajoules) of energy at a cost of $1.3 billion per annum.

Figure 3.5: Aggregated estimates of energy use throughout the RMI supply chain.

Area of Energy Use	$ pa energy cost	GJ pa
Farm - Power	71,187,726	1,335,244
Farm - Diesel	298,337,099	15,689,117
Farm - Petrol	44,410,528	2,336,677
Feedlot - Power	273,415,322	4,101,230
Feedlot - Thermal	238,836,326	7,961,211
RMP - Coal	15,137,898	2,845,925
RMP - Nat gas	74,680,295	5,849,956
RMP - LPG	10,091,932	316,214
RMP - Power	277,990,032	4,901,315
RMP - Diesel	3,198,393	158,107
RMP - Fuel oil	7,568,949	790,535
RMP - Biofuels	Excluded	948,642
TOTALS	1,314,854,499	47,234,172 (47 PJ)

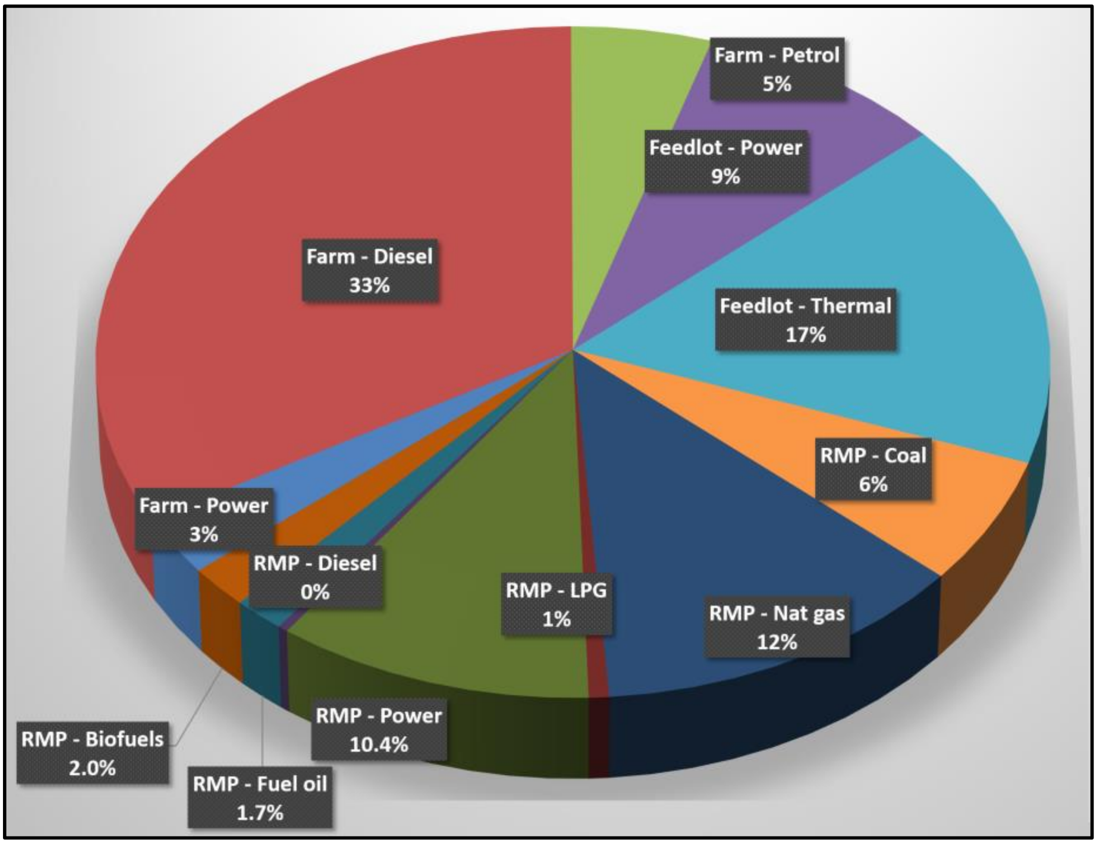

Figure 3.3: Current estimated annual energy use throughout the RMI supply chain Industry - Percentage Contribution to annual 47 PJ pa demand from farm, feedlot and red meat processor (RMP) energy demands.

3.3 Technology Options

Summarized in Table 3.6 are high level estimates for the supply and install of technologies considered within this report. These costs exclude a large number of potential project related costs that are site specific, including: council approvals, state based approvals, safety and equipment approvals, thermal, electrical and data tie-ins to existing plant, training, upgrading of existing infrastructure.

Table 3.6: Renewable technologies considered

Renewable Energy Technology	Cost per unit of output capacity	
Vacuum tube (small scale; 2 kWt)	1,967	$/kWt
CST (large scale; 3 MWt)	1,300	$/kWt
Woodchip boiler	703	$/kWt
Gaseous fuel boiler	204	$/kWt
Cogen gasifier 0.2 MWe, 0.8 MWt	7500	$/kWe
Cogen gasifier 0.4 MWe, 1.6 MWt	6250	$/kWe
Cogen gasifier >1 MWe; 2 MWt	4500	$/kWe
PV solar	1374	$/kWe
Full AD system with cogen 800kWe, 790 kWt	8875	$/kWe
Bio-CNG	160	$/GJ Bio-CNG pa

Biogas cogeneration was assumed to have 40% electrical efficiency and 39% thermal efficiency[9]. Gasification cogeneration was assumed to have 29% electrical efficiency and 47% thermal efficiency, at an overall efficiency of 76%[10]. It was assumed that the biogas cogeneration and PV solar systems can meet the energy demands for a RMP during the weekends and evenings, with the gasification and boiler required during operational hours. It is estimated that, from a dry weight perspective, paunch contains sufficient energy for providing in the order of 10 to 20% of the thermal energy required at a RMP, however the large moisture content prohibits direct use. Where paunch can be mechanically then thermally dried to 50% moisture, then mixed with the required amount of 19% moisture woodchip, a biomass fuel of approximately 24% moisture can be created which is a suitable fuel for modern gasifiers.

[9] https://www.mwm.net/mwm-chp-gas-engines-gensets-cogeneration/mwm-competencies/cogeneration-trigeneration-plants/

[10] A. Perna et al. Energy Procedia 82 (2015) 687 – 694, doi: 10.1016/j.egypro.2015.11.793

3.4 100% Renewable RMI From Farm to Factory

Table 3.7: Vision of a 100% Renewable Australian RMI Supply Chain.

Energy Use	Renewable Energy Technology
Farm – Power	PV Solar and batteries
Farm - Diesel	Electrification (Bio-CNG at refuelling hubs such as feedlots)
Farm - Petrol	
Feedlot - Power	Biogas from manure digestion for cogen and biogas fired boiler
Feedlot - Thermal	
RMP – Coal	30% of power demand and 15% of heat from biogas cogen. 63% of power demand and 46% of heat from biomass gasification cogen. 39% of heat from biomass boilers. 6% of power from PV solar.
RMP - Nat gas	
RMP – LPG	
RMP – Power	
RMP – Diesel	
RMP - Fuel oil	

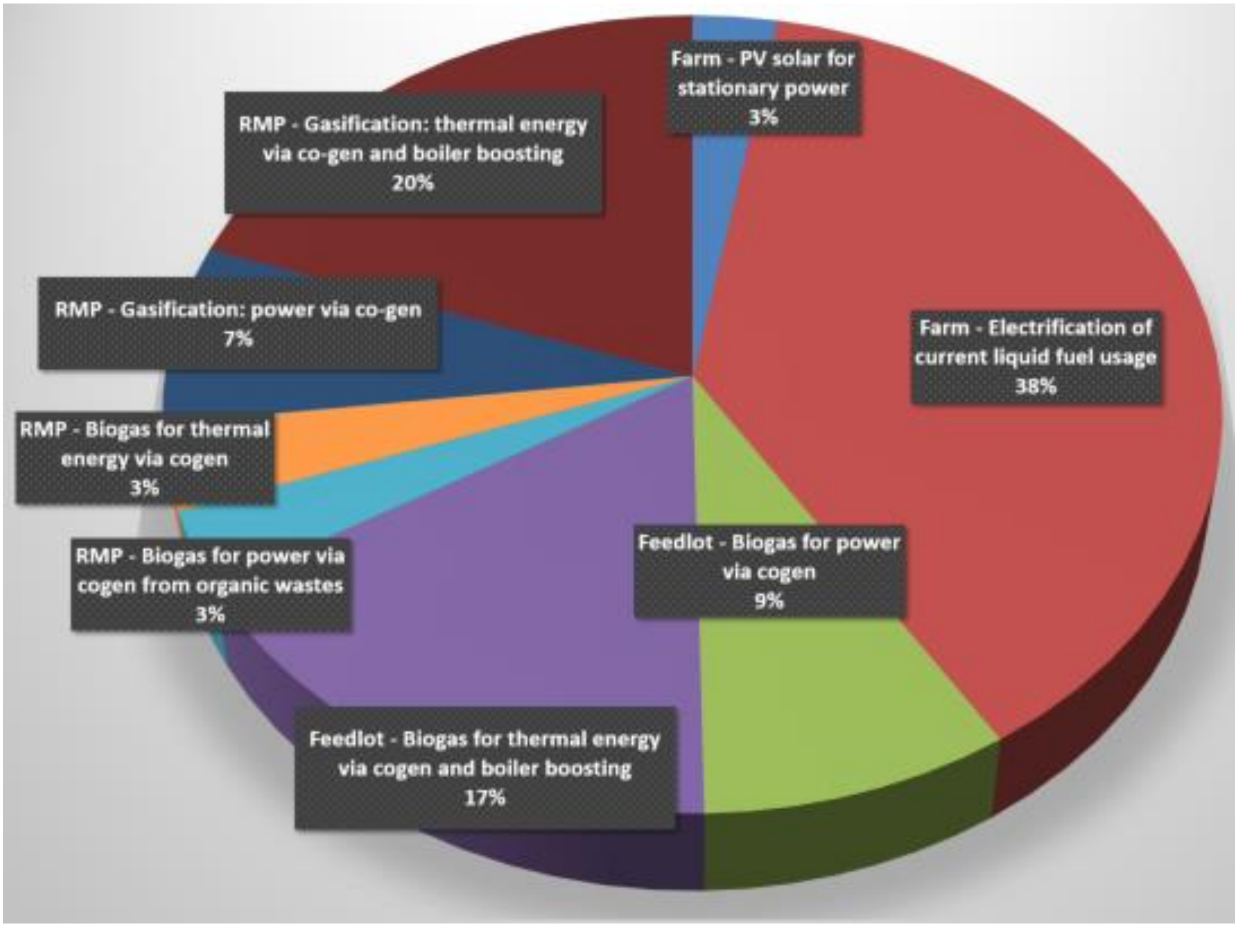

Figure 3.4: 100% renewable energy scenario for RMI supply chain.

3.4.1 On-Farm Transport Energy

Forward looking transport studies predict the eventual 100% electrification of all land based transport including light duty vehicles, commercial light trucks, and freight trucks[11]. This will require changes to onboard electricity storage (batteries) and/or generation (fuel cells) from current off-the-shelf options, which may not be available until 2050 or later to achieve 100% electrification. In the short to medium terms, options for renewable transport energy include:

- Ethanol,
- Bio-diesel,
- Compressed biogas (also called bio-CNG)

An excess of bio-CNG could be available at feedlots, whilst ethanol and bio-diesel production would likely occur by third party fuel companies. The large capital investment for the manufacture and distribution infrastructure of new fuels is better suited to concentrated fleet-level refuelling hubs (i.e. at feedlots and RMPs). However, this large capital investment lends itself to electrification which is better suited to the distributed on-farm demands. Electrification includes the scenario of H_2 production for onboard H_2 fuel cells driving electric motors; where H_2 is produced via PV solar powered electrolysis with local (i.e. on-farm) H_2 refuelling stations. On board storage density is still an issue, hence this technology may be better suited for large vehicles (i.e. with long chassis / storage area) but could be challenging for light vehicles.

3.4.2 On-Farm Stationary Energy

The distributed nature of on-farm liquid fuels for stationary energy (i.e. internal combustion engines for pumps and diesel gen sets) lends itself to electrification due to the low cost of PV-solar, the opportunity to oversize / manage motor utilization (e.g. pumping during daylight only) and the lower maintenance of electrical motors that do not require continuous fuelling. Further, there exists the challenges of consistency of power supply quality and reliability in remote locations. Extreme weather events, even in distant geographic locations, can impact grid power supply. A small scale combined PV solar + battery system (<99 kW array) has a levelized cost of power of approximately $0.28 / kWh, hence in areas dependent upon diesel gen sets or expensive grid power, a PV solar + battery solution should be considered in detail.

3.4.3 Feedlots

The huge tonnage of manure lends itself to onsite anaerobic digestion to create biogas for cogen engines with biogas boosted boilers where steam flaking is co-located. In the short term, woodchip/biomass fired boilers are a financially and technically viable options for raising steam as well as PV solar during the day for power in regional areas. Obtaining 100% power from PV solar currently has reduced economic viability, particularly in southern regions, due to the large battery storage and massive associated PV solar array that would be required. Hence, biogas can be viewed effectively as a “bio-battery” where energy is stored until required.

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11 http://www.brattle.com/system/news/pdfs/000/001/174/original/Electrification_Whitepaper_Final_Single_Pages.pdf?1485532518

In the medium to long term, domestic and international demand for Australian biomass could increase thereby increasing the effective cost per GJ of this source of energy. This is ameliorated via long term off-take agreements and selecting as technology that is suited to local fuels that have had minimal processing. For example, selecting a boiler suited to local forestry mulch or saw mill residues, rather than a boiler requiring processed wood pellets.

For the anaerobic digester and gasifier cogeneration systems (for both feedlot and RMPs), a levelized cost of electricity (LCoE) was calculated assuming that heat recovered from a cogen is valued at $6.99 (the value of thermal energy from a biomass fired boiler), $60 per Largescale Generation Certificate (equal to 1.0 MWh) was assigned to any renewable electricity generated and allowances were made for cap ex, install and operating costs.

Feedlots are the one section of the RMI where there is an oversupply of bio-energy due to the large amounts of cattle manure. Assuming that manure at an average age of 60 days is digested, feedlots have the potential to generate an estimated excess of 3.4 PJ of energy which equates to 7% of the entire RMI energy or 18% of on-farm energy. However, if the average age can be decreased to 2 days (e.g. via automated and continuous collection) there exists the opportunity to increase biogas production to be an excess of 62% or up to 39% of on-farm energy use.

To facilitate transport, the biogas can be upgraded (by removing CO_2 and minor contaminants) then compressed into bio-CNG which is routinely 150 to 300 Barg. New technologies are constantly being released for upgrading and storage of bio-CNG. Bio-CNG is the same molecule as CNG (methane) but sourced from renewable biological sources rather than fossil fuels. There has been expansive uptake of CNG in the bus fleets of many Australian cities (including Brisbane[12], Perth, Adelaide, and Sydney) and well as transport companies[13].

3.4.4 Red Meat Processors

The presence of organic wastes at RMPs lends itself to the production of biogas via onsite organic waste anaerobic digestion. However, mass and energy balances suggest that power offset of towards 30% and thermal energy offset of towards 15% would be achieved, hence more digester substrate could be obtained from other sources (e.g. co-located feedlots or other agri-businesses) but where this is not an option, additional technologies would be required such as:

- Concentrated solar power
- Concentrated solar thermal
- PV solar
- Batteries for storage of excess renewable power
- Thermal biomass systems (e.g. woodchip and biosolids boilers and gasifiers).

There could be a future scenario, depending upon energy prices and technology options, where paunch and/or anaerobic digestate can be dewatered then thermo-processed (e.g. in a boiler or gasifier) to create more energy (high level estimate that this could off-set approximately 20% of a RMPs thermal energy requirements depending upon the moisture content that can be achieved). Hence, the selection

[12] https://www.brisbane.qld.gov.au/about-council/governance-strategy/vision-strategy/reducing-brisbanes-emissions/carbon-neutral-council, accessed 28 Sept 2017.
[13] https://www.motoring.com.au/cng-first-for-caltex-54124/, accessed 28 Sept 2017.

of a multi-fuel / high moisture fuel boiler or gasifier provides such an opportunity. In the current environment, it is expected that simply procuring woodchip (ideally air dried or kiln dried wood products) provides the best financial outcome and simplified operations (i.e. do not need to undertake materials handling, drying and thermal operations of moist organics onsite).

CSP / CST systems have reasonable economics over the life of plant (e.g. 25 years), however the longer payback periods are anticipated to reduce the current interest of RMPs in solar thermal options. For example, when analysed over 25 years, CST is half the price or less of LPG, LNG and diesel fired boilers but is more expensive than biogas and solid fuel boilers. The economics of anaerobic digesters / biogas presented in this report do not include additional advantages of reduced waste management costs, reduced odours, and a greener / circular economy solution.

In the future, it is envisaged that for a RMP to be completely self-sustainable without purchasing fuel from a third party (e.g. woodchip) than a combination of biogas, CST, CSP and PV solar could be viable. Indeed, when the full costs are taken into account a full However, in a 2017 environment the economics of a solid fuel boiler and gasifier are stronger than CST / CSP.

3.5 Renewable Energy Targets

The Australian Government's Renewable Energy Target means that about 23.5 per cent of Australia's electricity generation in 2020 will be from renewable sources.

After the 2020 national target is met and in the absence of further Federal support, the industry becomes dependent on state-based schemes [14]. The states have high ambitions – the ACT 100% by 2020, Queensland and the Northern Territory 50%by 2030, and Victoria 45%by 2025 (via a reverse auction scheme), with South Australia already well past its 50 %target for 2025.

The Finkel Review estimates that Australia will get to 42% renewables by 2030; Labor's policy is for 50% renewables.

There has been a recent surge in LGC value (refer figure below), which may be due to confirmed bi-partisan support of the RET scheme and perceived shortages in future power generation.

[14] http://infrastructuremagazine.com.au/2017/05/29/australia-rises-in-renewable-energy-attractiveness/, accessed 26 June 2017.

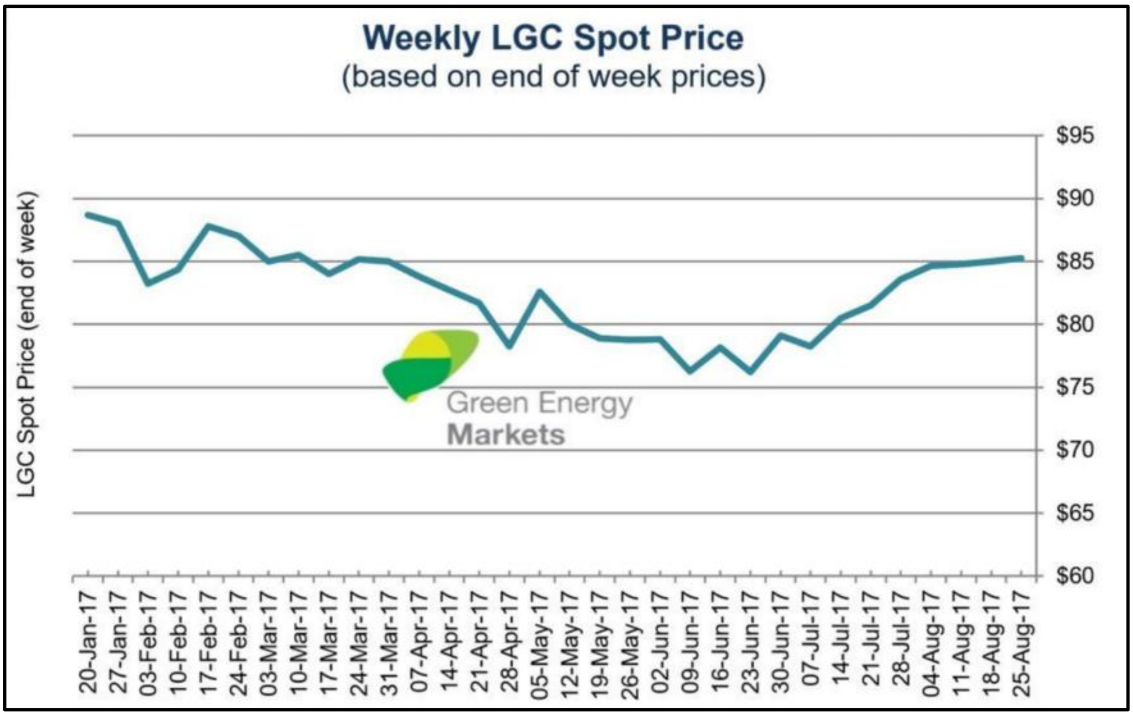

Figure 3.5: Source: Green Energy Markets. Accessed 6 Sept 2017.

3.6 Future Energy Pricing Trends

As stated by Giles Parkinson in his review article on the Finkel Report of 9 June 2017: "Why stay with the grid for a measly saving… when solar and battery storage costs are likely to be one half of the cost of the grid?"[15]

As reported by Michael West on 4th April 2016 in the Sydney Morning Herald "the more money the utilities spend the higher the return they make. They have a disincentive to be efficient", with the statement that electricity providers have been "gaming the regulators" where Powerlink "typically delivers a 20-30 per cent annual return on equity whereas most ASX companies have struggled to deliver five per cent" [16]. A summarizing statement from West's SMH article is that "with electricity prices twice as high as they should be and the cost of renewable technologies falling it is only a matter of time before more consumers move off the grid." Jessica Irvine's Sydney Morning Herald article of 26 sept 2015 showed an insight into the four yearly "Australian Energy Regulator review to determine how much electricity networks can charge customers, based on what an "efficient and prudent" business would need to charge in order to cover its costs and make a profit", where "a phalanx of about 40 lawyers representing electricity networks across Australia" were employed at a reported cost of $90 million to convince the three members of the Australian Competition Tribunal "to overturn a decision by the electricity price regulator which would have rewarded NSW households with a $100 to $300 a year saving on their power bills." [17]

[15] http://reneweconomy.com.au/finkel-decoded-the-good-the-bad-and-the-very-disappointing-84273/, accessed 26 June 2017.
[16] West, M. "Powerlink is Queensland government's golden goose", Sydney Morning Herald, APRIL 4 2016.

[17] Irvine, J. "David tackles Goliath in tribunal battle that will decide electricity bills", Sydney Morning Herald, SEPTEMBER 26 2015.

The current market structure has seen the rise of the "gen-tailers", companies that "have been able to manipulate the renewable energy targets, first going on an investment strike, forcing policy changes, and then pocketing the benefits of the high LGC price they created when they finally started signing contracts".[18]

Figure 3.7 below shows the tight grouping in 2014 of Energy Action's Price Index (Business) (EAPI) index, which provides clarity to the market encompassing pricing from energy retailers via the Australian Energy Exchange (AEX). EAPI represents the average commodity price of retail electricity paid by Australian businesses based on a Standard Retail Contract (commences in 6-months and operates for 2½ years). EAPI is created from the lowest cost offers submitted by retailers via the AEX and reflects the cost of commodity electricity to commercial and industrial customers. This figure shows that in the three years since April 2014, price increases on a state by state basis have been approximately:

- Qld: 120% increase, 40% per annum on average.
- NSW: 140%, 47% per annum
- Vic: 150%, 50% per annum
- SA: 220%, 73% per annum

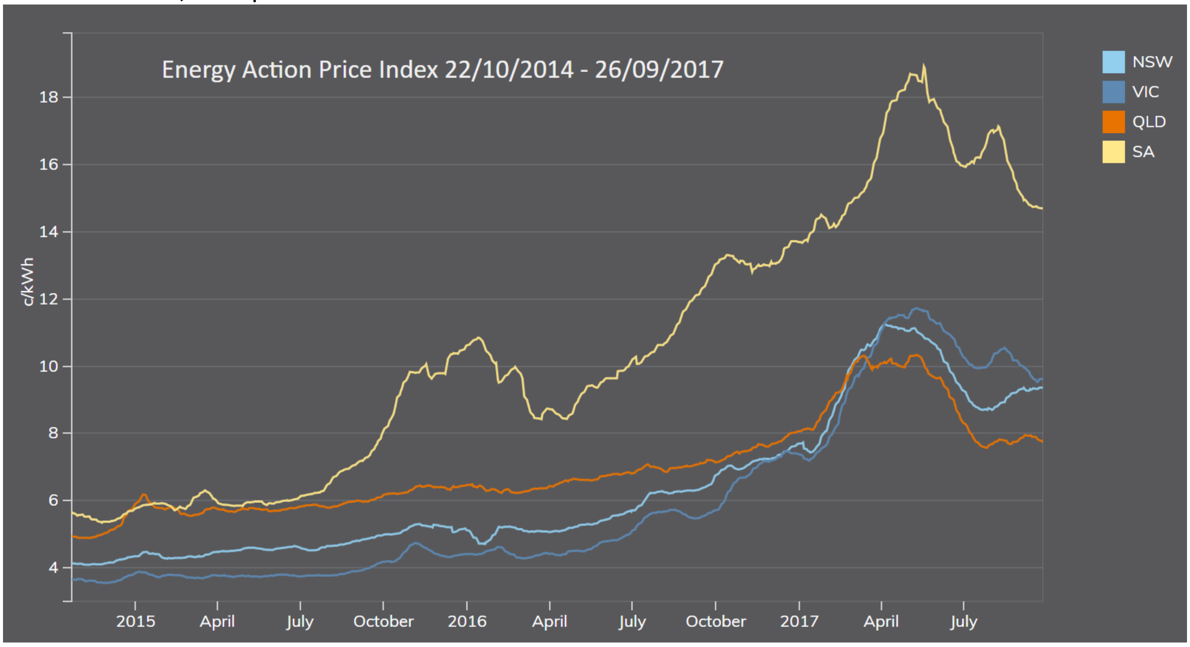

Figure 3.6: Energy Action Price Index[19].

The reasons for these price increases are complex and varied but include the general exporting of power from Qld, which has a generation over capacity, into the southern states, with a particular flow of energy into South Australia. A recent study by Jacobs published on June 19 2017[20] and funded by the Australian Energy Market Operator or AEMO (refer Figure 3.7 below) predicts strong growth in commercial / industrial power prices through to 2020, then a flat or declining trend from 2020 to 2037.

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[18] http://reneweconomy.com.au/finkel-decoded-the-good-the-bad-and-the-very-disappointing-84273/, accessed 26 June 2017.

[19] http://www.energyaction.com.au/energy-procurement/aex-reverse-auction/energy-action-price-index, accessed 28 Sept 2017.

[20] https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/EFI/Jacobs-Retail-electricity-price-history-and-projections_Final-Public-Report-June-2017.pdf

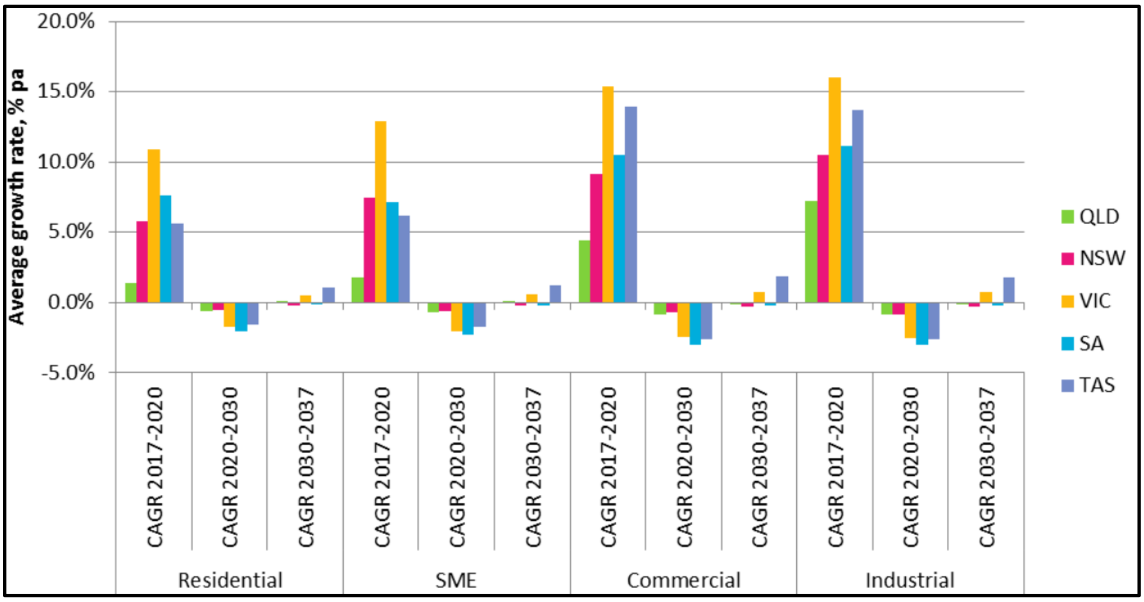

Figure 3.7: Average growth rate in power pricing 2017-2037 assuming for a neutral economic growth scenario, emissions targets maintained to 2030, 1 AUD = $0.75 US, oil at $USD 60 / bbl, neutral gas pricing[12].

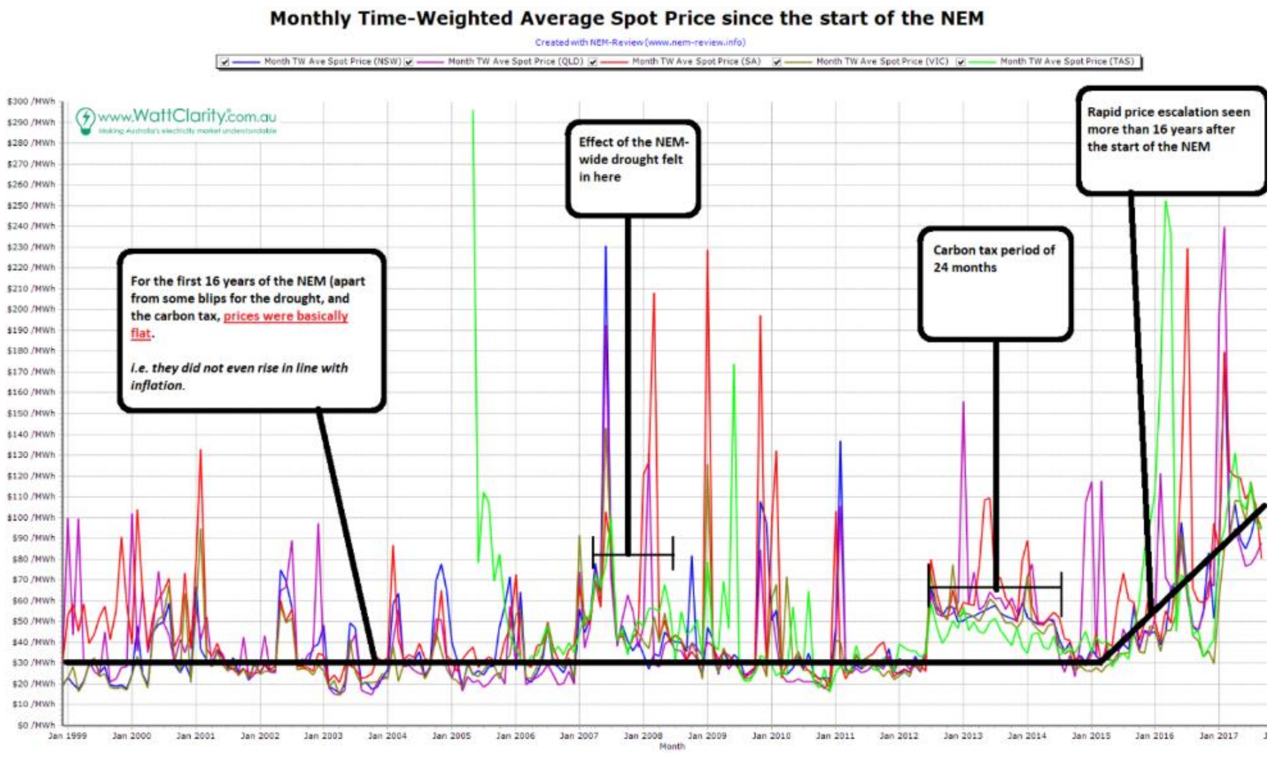

Figure 3.8: Source: wattclarity.com.au, accessed 4 Sept 2017.

On a wholesale basis, similar trends can be observed, as shown in figure 3.8, where wholesale prices appear to follow the same exponential trend. Of note (especially given the liability of the RMI to grid power prices) is the sharp jump in wholesale prices observed in 2012 at the introduction of the “carbon tax”. In one year, this was an 86%, 110%, and 130% increase for NSW, VIC, and QLD respectively. The likely reintroduction of an emissions trading scheme is expected to have similar effects on wholesale power prices.

The figure below shows why gas pressure in Australia are under pressure: there is an estimated 55 PJ pa shortfall predicted for 2018.

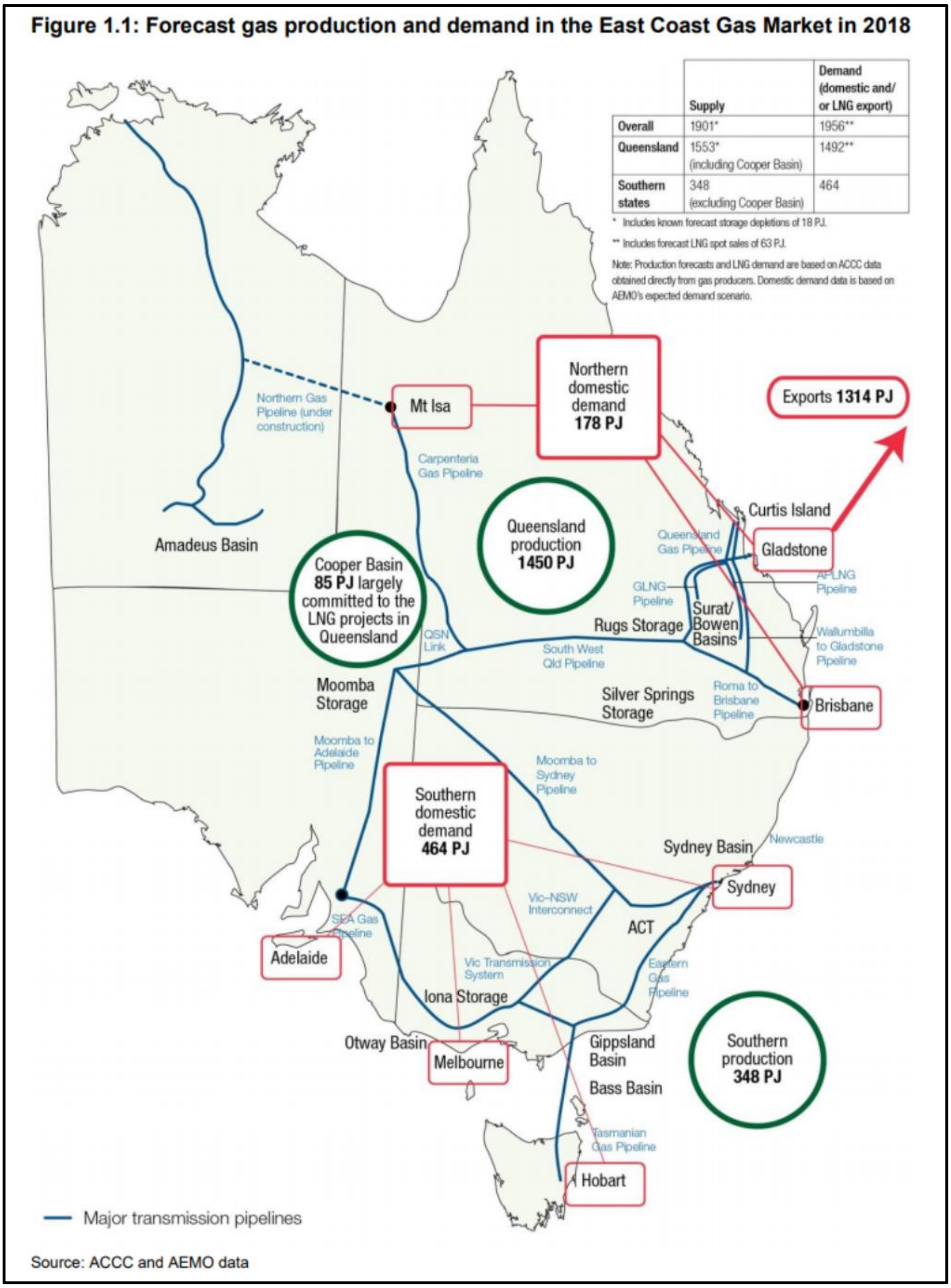

Figure 3.9: ACCC report into future gas prices[21].

21 https://www.accc.gov.au/system/files/ACCC%20gas%20inquiry%20first%20interim%20report%20%20September%202017%20-%20FINAL.PDF, accessed 28 Sept 2017.

The fall out from this is that industrial end users are seeing less offers, and offers that are received are at increasingly higher prices as shown in the figure below, which is actual data for an industrial gas user just under 1 PJ pa[22].

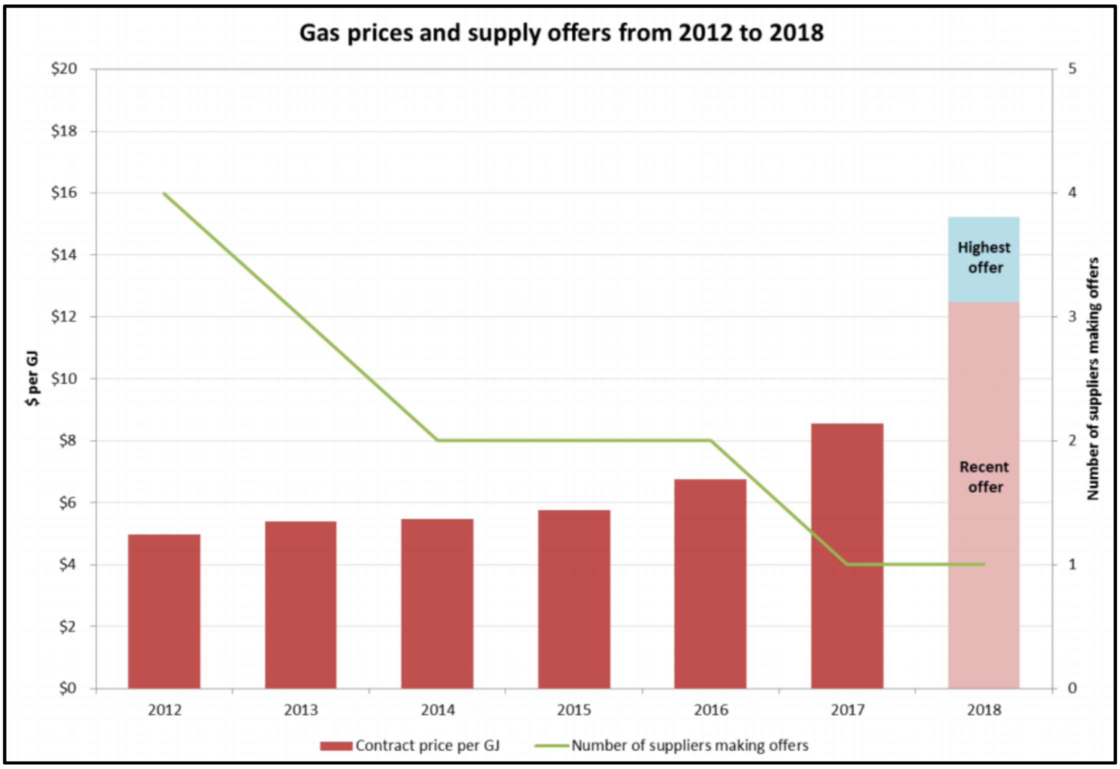

Figure 3.10: Actual nat gas pricing for an industrial end user[20].

Thermal coal prices are forecast to gradually decline over the outlook period in the order of 4 to 16% drops for the coming two financial years[23]. The trend for liquid fuel is showing a flat price trend, as evidenced by the future European diesel pricing for the coming 12 months.

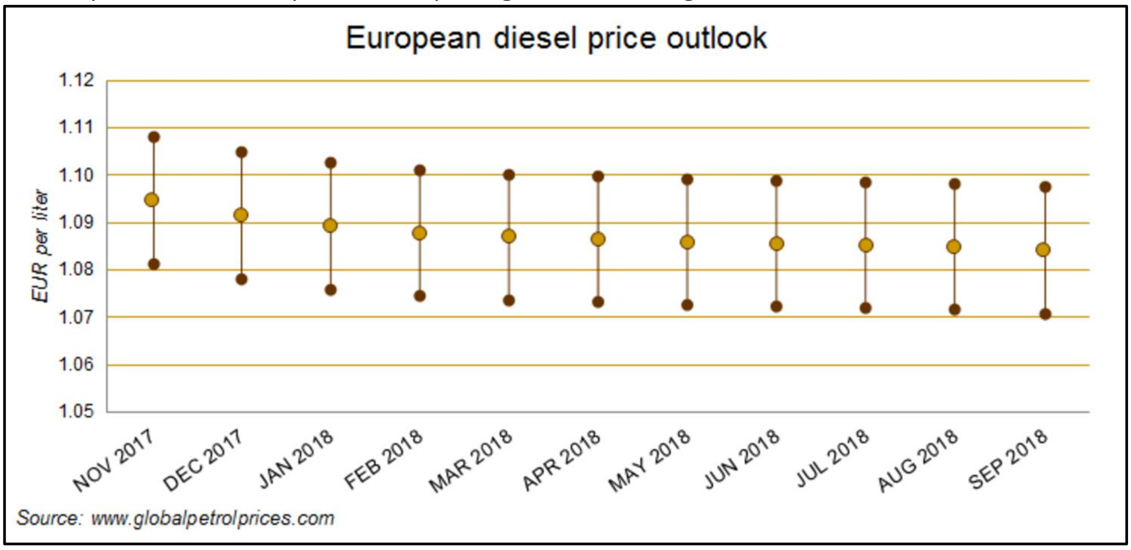

Figure 3.11: Predicted diesel prices in Europe showing a relatively flat trend for the coming year.

22 https://www.accc.gov.au/system/files/ACCC%20gas%20inquiry%20first%20interim%20report%20%20September%202017%20-%20FINAL.PDF, accessed 28 Sept 2017.

23 https://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/ResourcesandEnergyQuarterlyJune2017/documents/Resources-and-Energy-Quarterly-June-2017-Thermal-Coal.pdf, accessed 28 Sept 2017.

4 Conclusions/recommendations

4.1 Practical application of project insights

Australian RMI must:
[1] De-couple from natural gas and liquid fuels for stationary energy immediately.
[2] De-couple from grid power immediately where it is economically viable to do so, with a pathway for being off-grid by 2030.
[3] De-couple from fossil fuels and internationally traded energy commodities by 2040.
[4] Achieve energy carbon neutrality by 2040.
[5] Maximize the use of co-products and local energy sources (minimize reliance on third party vendors). All businesses should complete feasibility studies immediately to remove the use of natural gas and liquid fuels. For other fuel, clear options are required for when existing plant reaches its end of life. Co-products and local energy sources include manure at feedlots, organics at RMPs, locally created biomass (e.g. woodchip and milling by-products), PV solar and concentrated solar thermal.
[6] Remove fossil based commodities from supply chain incl. fertilizer and polymers.

Pathway for [1], in approximate order of importance from an economic perspective:
- Stationary liquid fuels (LPG, fuel oil) due to high existing and underlying cost compared to cheaper and technically viable options.
- Natural gas due to predicted industrial pricing of $15 / GJ in 2018 with continued natural gas shortages further driving up pricing.
- Power, which inherently relies on natural gas (especially peaking plants) and coal, due to strong price increases through to 2020 on top of currently high prices,
- Transport fuels, due to the large percentage of energy that it represents for the RMI
- Coal due to its lower environmental credentials and risk of future carbon pricing.

The most expensive form of energy that gets very little attention is uncontestable power in regional areas. A small business in summer on Ergon Tariff 22A is paying $0.62915 / kWh during peak times, with the general tariff at $0.3049/kWh. This is documented as being amongst the most expensive power in the world[24].

4.2 Future R&D

The future R&D activities are driven by the most expensive forms of energy currently used and by the largest contribution to energy cost. Future R&D projects include:

- More detailed understanding of the exact uses for diesel on-farm: engine sizes, stationary use, different equipment and transport vehicle uses to then inform a more detailed electrification and/or fuel swap strategy.
- Alternatives to natural gas, such as packaged multi-solid fuel boilers.
- Automated manure collection at feedlots to maximise volatile solids content (e.g. autonomous robots).
- Demonstration of disruptive technologies:
    - Electrification of light, commercial and heavy vehicles.
    - Biogas from feedlot manure, in particular collection methods to maximise volatile solids / digestible tonnages.

[24] http://www.townsvillebulletin.com.au/news/queensland-electricity-network-charges-highest-in-world/news-story/d092fb6d0d1c2d2a3a0992ea8dc48b80, accessed 28 Sept 2017.

- Exporting of renewable energy from feedlots in the form of Bio-CNG for on-farm use to displace liquid fuels.
- Gasification of biomass, paunch and other RMI wastes (wood pallets, non-recyclable plastics) as a core option, in combination with biogas and PV solar, for RMPs to be “off grid”.
- How increases in the demand for biomass will increases the cost of this fuel source. Sustainability of biomass as a fuel for the industry.
- Watching brief on drop-in fuel options.
- Efficiency gains e.g. drones for reduced transport energy, waste heat recovery, energy management systems.

4.3 Innovative Funding Options

In addition to innovative fuels and technologies, innovative funding options are required to increase the uptake of renewable energy.

4.3.1 Operating lease / rental

Structured funding solutions exist for renewable energy projects. Funders require a thorough understanding of the project and customer. Some key points as follows;

- Depending on the customers’ own accounting policies, they can provide either an operating lease / rental, finance lease or chattel mortgage. Given experience in operating lease / rental products, these are usually selected for projects such as that outlined in this report.
- Due diligence would be required to verify numbers for a specific site.
- 60 month terms are typical; 84 month terms can be offered on some energy assets.
- Subject to further due diligence, if the credit profile of the applicant is strong, the asset life exceeds 7 years, and the supplier passes accreditation checks, 84 month terms can be arranged which assists in creating a cash flow positive project.
- Larger transactions need to be individually rated for pricing purposes. More aggressive offerings can be put forward for stronger projects.

4.3.2 Australian Renewable Energy Agency (ARENA)

ARENA has legislated funding through to 2022. ARENA funds activities that are expected to advance renewable energy technologies towards commercial readiness, improve business models or reduce overall industry costs. The most suitable ARENA program for innovative energy solutions is the Advancing Renewables programme, which can take the form of a grant.

Due to the technical and commercial maturity of anaerobic digestion, ARENA may direct anaerobic digestion projects towards other sources of funding such as CEIF or CEFC (refer below).

4.3.3 Clean Energy Innovation Fund (CEIF)

The Australian Government is establishing a $1 billion Clean Energy Innovation Fund to support the commercialisation of emerging technologies. The $1 billion Clean Energy Innovation Fund will be jointly managed by the Clean Energy Finance Corporation (CEFC) and the Australian Renewable Energy Agency (ARENA), drawing on their complementary experience and expertise. Investments will have the primary purpose of earning income or a profitable return and may be in the form of debt products or equity investments or a combination of both. The refocused agencies will work together to provide capital investment in Australian businesses and emerging clean energy technologies, with ARENA bringing technical expertise in renewable energy technology assessment.

The Clean Energy Innovation Fund will be established from within the CEFC's $10 billion allocation. This fund will make available $100 million a year for ten years. The CEIF is anticipated to accept a higher level of risk in comparison to the CEFC. The Government has amended the Portfolio Benchmark Return for the CEFC's core portfolio (i.e. investments other than those in the CEIF) to 3% to 4% over the 5-year Australian Government bond rate, with the CEIF benchmark return being 1% over the 5-year Australian Government bond rate[25].

4.3.4 Private Equity

Private equity consists of equity securities and debt in operating companies, where those companies are not publicly traded. A private equity investment will generally be made by a private equity firm or a venture capital firm. Each investor has their own set of goals, preferences and investment strategies. The private equity model can be similar to the BOOM / BOOT model (refer below) except that the private equity group may only own a percentage of the Special Purpose Vehicle (SPV), perhaps even a minority stake (however it would be expected that the private equity group would retain certain minority shareholders rights).

A business can build up an equity stake in a business by:

- Completion of bankable feasibility studies and business cases,
- Design and engineering,
- Environmental approvals: council and state,
- Provisions, lease or sale of land into the SPV

Example of private equity group: Foresight Group ("Foresight") is a leading UK independent Infrastructure and Private Equity investment manager established in 1984. It has $3.25 billion of assets under management and boasts one of the UK's leading environmental infrastructure investment teams comprising 12 investment professionals.

4.3.5 Australian Bioenergy Fund

The Australian Bioenergy Fund, managed by Foresight Group ("Foresight") is targeting equity investments in projects from $2 million to $100 million, ranging from small-scale anaerobic digestion to mid-scale energy from waste developments.

By creating the equity fund of more than $200 million, the CEFC is looking to draw in private sector equity investors who recognise the bioenergy sector's potential. Foresight will bring additional management and

[25] https://www.cleanenergyfinancecorp.com.au/media/178175/board-response-to-resp-ministers-on-consultation-draft-20160503.pdf, accessed 22 Sept 2016.

operational expertise to the Australian bioenergy sector to grow and manage the fund. Figure 8 below provides a schematic on how an SPV structure could be used in the delivery of an ABF supported project.

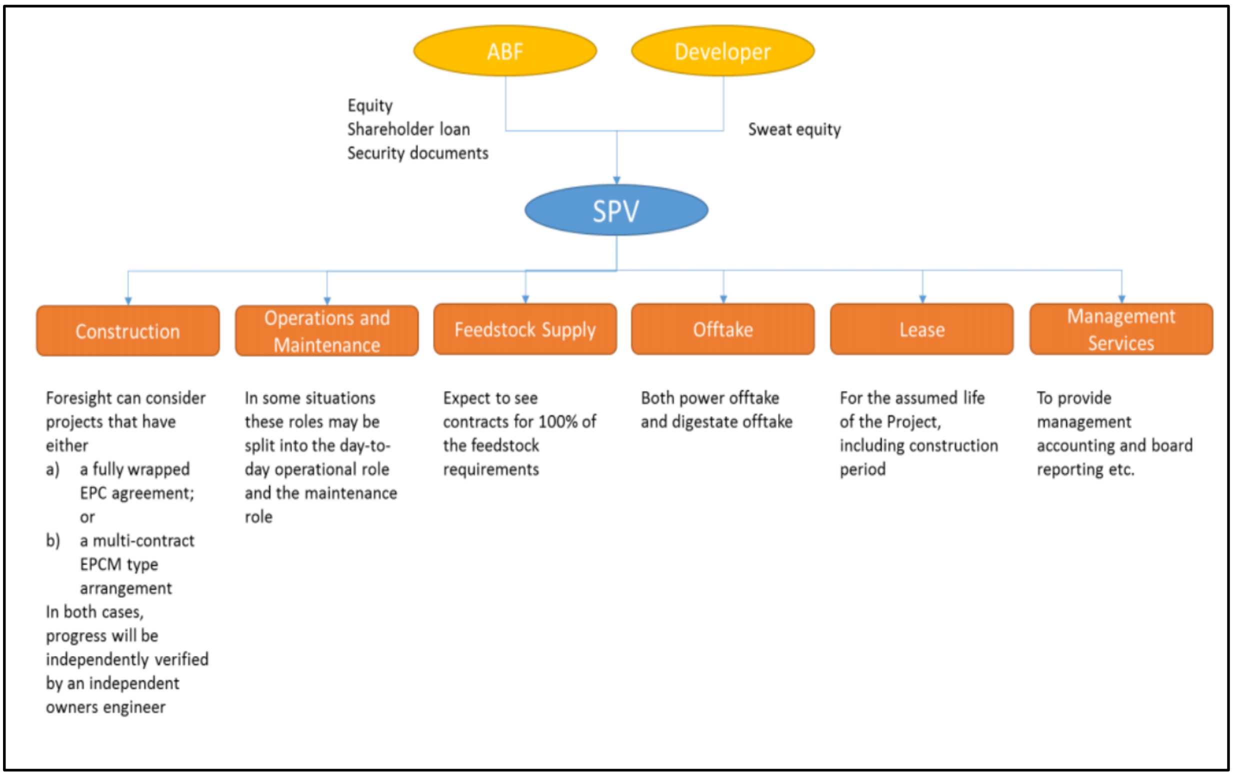

Figure 4.1: Typical investment structure for an equity funded energy project. In this diagram, the agri-business would be the "Developer".

4.3.6 Managed Service Agreements

Managed Service Agreements for the infrastructure, energy efficiency and renewable energy sectors have the following benefits:

- Do not require client capital outlay
- Structured to generate immediate savings
- Complete turnkey solutions
- Include warranties, servicing and maintenance
- Insured for errors and omissions

The table below aims to compare turnkey service agreements to leasing to loans.

Table 4.1: Comparison of turnkey service agreements to leasing to loans.

Criteria	Our Service Agreements	Lease	Loan
Security	Unsecured.	Unsecured.	Usually secured by main lender.

Maintenance	No responsibility for the client. Fixed maintenance covered in MSA & OPA payments.	Responsibility of the client.	Responsibility of the client.
Performance	Not client's risk. Errors and omissions insurance held by funder.	Client risk, mitigated by supplier warranties.	Client risk, mitigated by supplier warranties.
Upfront Capital cost	None to client. No impact on bank limits and other financing sources given a service cost.	None to client. Usually no impact on bank limits and other financing sources.	None to client, but usually impacts bank limits and other funding sources.
Economic benefit	Structured to provide positive net cash flows from the start with no upfront capital expense.	Can be structured to provide positive net cash flows from the start with no upfront capital expense.	Unlikely to provide immediate positive net cash flows due to short term financing versus long-term payback.
Balance sheet	Off-balance sheet as a service OPEX cost; tax deductible.	Can be off-balance sheet as an OPEX cost; may be tax deductible.	On-balance sheet and depreciated.

4.3.7 BOOM / BOOT

Build-Own-Operate-Maintain (BOOM) and Build-Own-Operate-Transfer (BOOT) are types of contracts which combine various types of services including: plant design, engineer, procure and build / construct; Operations, ownership of assets; Financing arrangements. The main provider is often represented by a special purpose company or vehicle (SPV) created for, and dedicated to, the project and provides the design, construction, financing, ownership and operation of the asset.

The customer undertakes to pay for the asset and service provided to them according to a rate covering both the plant operating activity and also the amortisation of the capital invested. For BOOM, the plant is routinely owned by the SPV at the end of the contract, whilst for BOOT schemes, the plant is transferred to the customer at the end of the contract, which generally lasts 20 to 30 years, but could be as short as 7 years. This style has the benefit of the technical expertise and know-how provided by main provider whilst the customer can dramatically reduce project risk and project management requirements.

4.3.8 Clean Energy Finance Corporation (CEFC)

The preferred minimum CEFC investment size is $20mil, hence the CEFC may not be a suitable funding option given the cap ex of chicken litter to energy projects at a typical meat grower facility.

In order to address smaller transactions, the CEFC preference is to establish pooled financing and partnership strategies which leverage the larger market reach of financial intermediaries such as fund managers and commercial banks.

CEFC invests using a commercial approach to overcome market barriers and mobilise investment in renewable energy, energy efficiency and low emissions technologies. Since its inception, the CEFC has committed over $1.4 billion in finance to investments in clean energy projects valued at over $3.5 billion. The CEFC invests for a positive financial return, with more than 55 direct investments and 34 projects co-financed under aggregation programs. These projects help to improve energy productivity for businesses across Australia, develop local industries and generate new employment opportunities.

The CEFC invests on a case-by-case basis, providing finance on the least generous terms possible for a project to proceed, so it is as close to market terms as possible. Where appropriate, CEFC may provide concessional finance in the form of lower pricing, higher risk and/or longer duration, but he CEFC does not make grants. CEFC prefers investment opportunities where:

- The project supports diversification of the CEFC's portfolio: geographically, by technology, by off-take (power purchase agreement or merchant sale of power), by counter parties and project sponsors
- The project has a co-financier
- There is a sufficient equity buffer against underperformance
- Project is selling power at 'merchant rates' and the loan is expected to be comfortably serviced from revenue even if actual prices received fall below current future forecast prices.

4.3.9 Debt funding

Debt funding is obtained by borrowing, with the borrower paying back with interest within an agreed time frame. The most common forms of debt finance include bank loans and overdrafts. Equipment leasing / hire purchase are also place in this category. Unlike equity financing, debt funding gives businesses complete control - the business owner does not have to answer to investors. Interest fees and charges on a business loan are tax deductible, however the business must generate enough cash to service the debt (i.e. repayments plus interest).

4.4 Development and Adoption Activities

Summarized in the table below is the estimated capital cost for the RMI to make use of 100% renewable energy.

Table 4.2: Capital cost estimate for a 100% renewable RMI from farm, to feedlot to factory.

	GJ pa	Cap ex
Farm – PV solar for stationary power	1,335,244	$0.310 bil
Farm – Electrification of current liquid fuel usage	18,025,794	$2.744 bil
Feedlot - Biogas for power via cogen	4,101,229	$2.308 bil
Feedlot – Additional capital for biogas fired boiler boosting in addition to cogen heat	7,961,21	$0.155 bil
RMP - Biogas for power via cogen from organic wastes (30% of site power)	1,470,394	
RMP - Biogas for thermal energy via cogen (15% of site heating)	1,636,406	$0.453 bil
RMP - Gasification: power via co-gen (64% of site power)	3,087,828	$0.946 bil
RMP - Gasification: thermal energy via co-gen (46% of site heating)	5,004,411	
RMP - Thermal energy via biomass boiler (39% of site heating)	4,268,560	$0.204 bil
RMP – PV solar for power (6% of site power)		$0.069 bil
		$7.189 bil

The above estimates for PV solar for stationary energy and electrification of current liquid fuels assumes optimization of equipment sizing and utilization so that no to minimal power storage (e.g. batteries) are required or, in the case of vehicles, that on-board energy storage is amortized into the cost of the vehicle.

Where biomass fuel for RMP gasification and boiler is assumed at $3.44 / GJ, the annual energy fuel cost can be reduced to $ 54 mil pa (a saving of $1.261 bil pa). Not including operating costs, the equates to a simple payback period on the capital outlay only of 5.7 years. Where a broad operating cost of $0.015 / kWh is applied for all technologies (to account for labour, oversight, major and minor overhauls), plus a maintenance cost of 5% of cap ex pa, a simple payback of 10.1 years is achieved. Detailed feasibility studies would need to be completed for individual technologies at individual sites to determine financial viability of each of these options.

5 Appendix

5.1 Heading Available Technologies – Examples and Case studies

Technology	Image and information on a sample facility
Anaerobic Digestion - Continuously Stirred Tank Reactor (CSTR) Suited to **"pumpable" wastes**: feedlot manure and run-off slurry, red meat processing (RMP) waste.	 200 kWe biogas reciprocating engines via grass fed beef paunch and piggery wastes, in Bettafield, Callide, Queensland; in operation since 2015[26].
Upgrading of biogas to transport fuel in the form of compressed upgraded biogas (Bio-CNG) Suited to **upgrading of >50% methane biogas**, which is routinely created from RMI wastes.	 5110 Lpd petrol equivalent from waste food for fuelling refuse trucks and buses, California, USA; in operation since 2013[27].
Gasification for power and thermal energy. Suited to **solid fuels / wastes**: chipped wood, sawdust. Technology could be suited to waste plastics and other solids from RMPs.	 300 kWe, 600 kWt wood chip to power and heat packaged gasifier at Holzstrom GmbH, Austria[28]; in operation since 2014.
Steam backpressure turbine. Suited for making **power from high pressure steam** or for replacing pressure reducing valves (PRVs).	 Inlet 22 Barg, outlet 10 Barg of 8 tph steam, 96 kWe; Kanoria Chemicals, India; in operation since 2013[29].

[26] http://bettapork.com.au/biogas-plant/

https://www.qff.org.au/wp-content/uploads/2016/11/160216_Utilitas_QldFarmEnergyTechForumGatton.pdf

http://www.queenslandcountrylife.com.au/story/3424681/slick-operation-at-bettapork/

[27] http://biocng.us

[28] http://www.urbas.at

[29] https://www.slideshare.net/ShreyasKrishna/turbo-tech-presentation-ect-in-speciality-chemical-manufacturing-plant-35157868

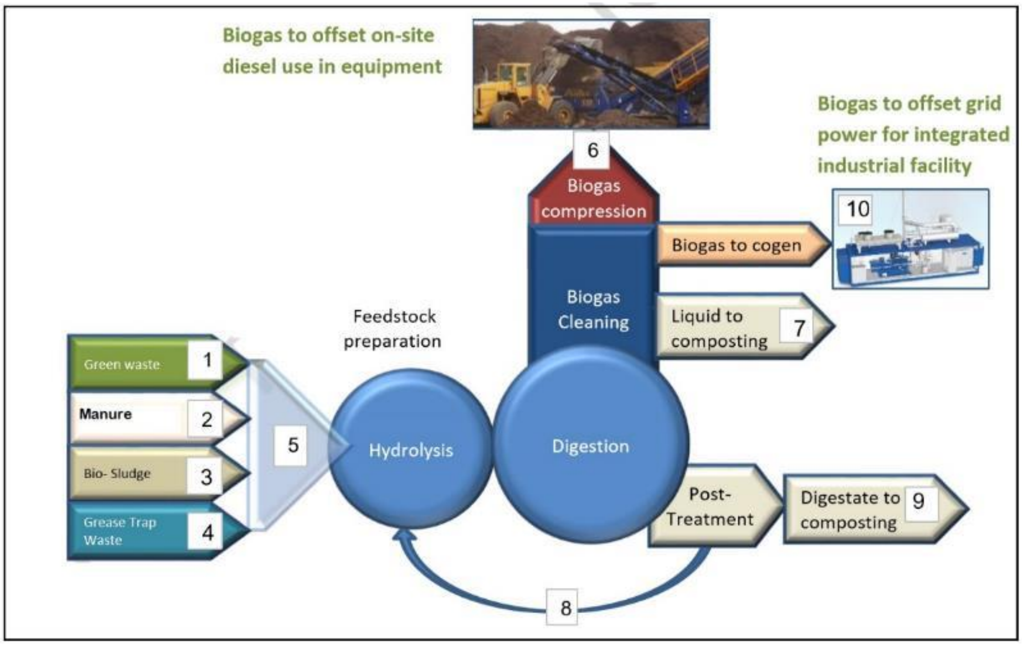

Figure 5.1: Block diagram of an anaerobic digestion CSTR and BioCNG facility.

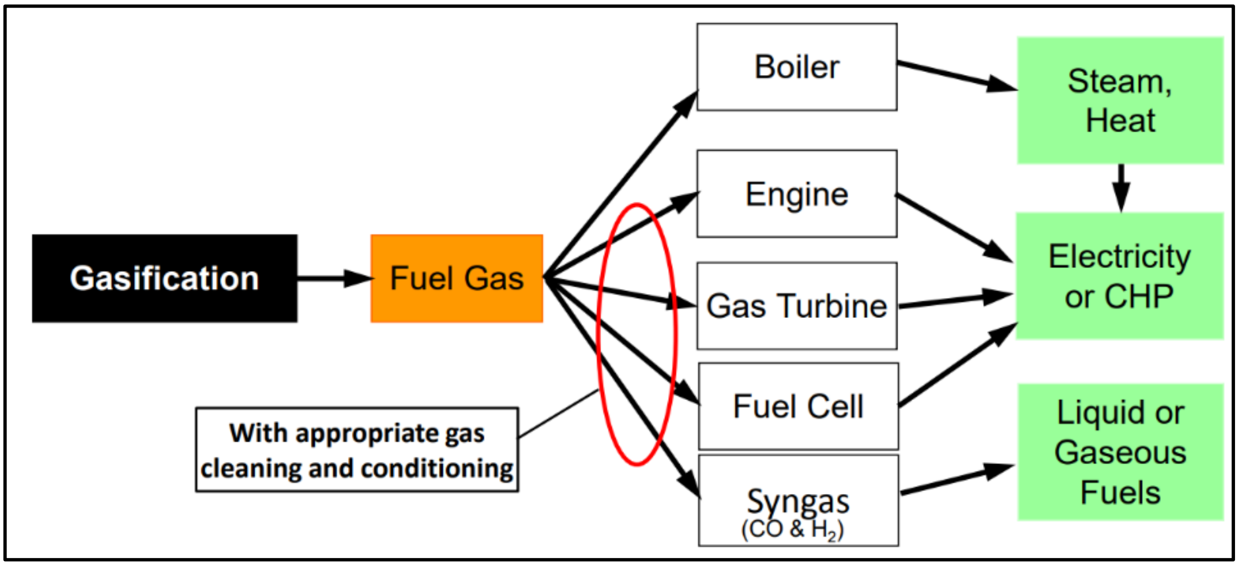

Figure 5.2: Gasification block flow diagram[30].

[30] http://www.energy.ca.gov/2017publications/CEC-500-2017-007/CEC-500-2017-007-APG.pdf

5.2 Biomass Fuel Locations

In addition to the organic wastes available from within the supply chain, wood industry by-products are an option as a source of biomass fuel which are of particular interest for fuelling gasification and solid fuel boilers. Woodchip sourced from hardwood saw milling operations is of particular interest as it is less desirable for alternatives uses such as landscaping and also has a higher density when seasoned / dried (540 to 820 kg/m^3 for gum versus 350 – 510 kg/m^3 for pine[31]). As deliveries are normally priced according to cubic meters, it is hence more economical to select a denser and dryer wood to maximise the energy per cubic metre (i.e. GJ / m^3) which then maximizes the energy content per truck delivery (hence minimizing the cost per unit of energy). It is noted that hardwood can be sourced from managed plantations; taking Queensland as an example it has around 200,000 hectares of softwood *plantations* and 50,000 hectares of *hardwood plantations*[32].

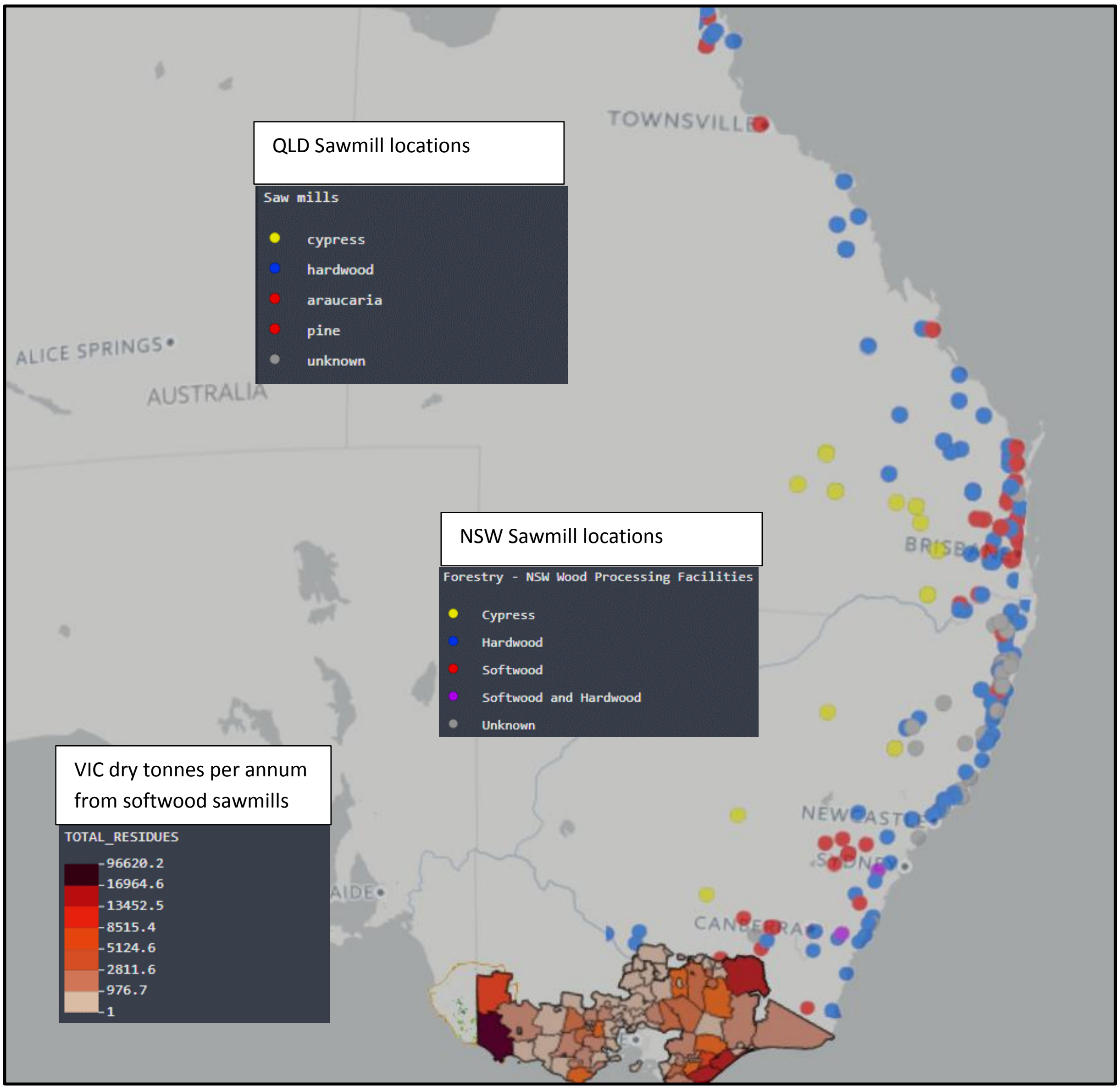

Figure 5.3: Sources of wood industry by-products Source: http://nationalmap.gov.au/renewables/

[31] http://www.engineeringtoolbox.com/wood-density-d_40.html, accessed 4 Sept 2017.
[32] https://www.business.qld.gov.au/industries/farms-fishing-forestry/forests-wood/plantation-forestry, , accessed 4 Sept 2017.