final report

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Feedlot Energy Efficiency and Cost Reduction

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Executive summary

All Energy Pty Ltd developed an *in silico* model of a representative 20,000 standard cattle unit (SCU) feedlot to determine the technical and economic viability of the following energy efficiency options: Power Factor Correction (PFC), Voltage Optimisation (VO), Energy Management System (EMS; including load shedding and demand / power generation management), Variable speed Drives (VSDs) and thermal energy efficiencies.

[1] Power Factor Correction (PFC): A 175 kVAr PFC system was estimated, via the use of the *in silico* model, to bring the average power factor from ~0.6 for a 20,000 SCU feedlot to 0.9 – 0.95, and had an estimated outlay of $9,400 (excluding GST). When there is no $/kVA charge associated with power purchased from the grid (as observed on many Queensland tariffs), there is minimal financial incentive for PFC, however it is a requirement that consumers must maintain a PF > 0.8. Note that solar photovoltaic systems once installed may reduce the site PF (this is highly site, PV size and auxiliary equipment (e.g. inverter functionality) dependent, with some case studies show drops in PF of 0.09 to 0.22[1],[2]), hence PFC may need to be considered for PV solar installations where there is a PF / kVA charge. For a distribution network charging $10.4 to $15/kVA, the simple payback period for the above listed PFC device increasing PF from 0.6 to 0.9 was estimated at 0.6 to 0.9 years.

It is recommended that all Australian feedlots that are charged a $/kVA element as part of their bill or generate their own power (e.g. via the use of diesel genets or PV solar) investigate PFC for their site.

[2] Voltage Optimisation (VO): A voltage optimization (VO) system rated to 430 kVA / 600 Amps can be procured for $60,590 with an additional estimated installation cost of $25,000 (excluding GST). The expected savings of voltage optimisation depends upon the type of equipment, from 0% saving for DC equipment (e.g. LED lighting, inverter air conditioning, office IT equipment) to approximately 3-5% for VSD driven motors; to 9-15% for motors operated at partial load, HVAC and refrigeration systems. Energy and maximum load reductions of 7%, 12% and 14% were modelled, saving $10,825, $18,558 and $21,651 thereby delivering paybacks of 7.9, 4.6, and 4.0 years respectively.

Voltage Optimisation may be a good fit for Australian feedlots with a high proportion of direct-on-line (DOL) motors, motors operated at partial load or feedlots on rural distribution networks, where voltages tend to be over-specified to ensure reliable distribution.

[3] Energy Management System (EMS), Load Shedding, and Demand Management: A quote for an energy management system to integrate an edge of grid power supply, existing 380 kVA diesel generator, and proposed 98 kW PV solar array was received at $114,300 (including supply and integration). The exact savings of an EMS can be difficult to predict due to complex and interrelated factors, however there is potential for automated detection and response to be significantly faster than manual control. An EMS can also be a useful / critical component of an effective microgrid i.e. to control a diesel genset as solar radiation and motor loads change during a shift. With larger solar arrays, an EMS

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[1] livingpower.com.au/power-factor, accessed 29 Apr 2019.

[2] comarcond.com/wp-content/uploads/2017/05/Informativa-fotovoltaico_-eng.pdf, accessed 29 Apr 2019.

can control the timing of loads to match periods of high solar generation, or spread loads during periods of low solar generation.

An example scenario run was using an EMS to control the speed of a VSD on a hay grinder, mill ventilation fan and bore pumping system saving 25% of energy use (kWh basis); and controlling 98 kW of solar generation capacity, with predicted savings of $23,691 or 12% of the modelled grid power costs (Ergon Tariff 45). This is in line with case studies which show an average saving of approximately 10%, with greater savings to be made with a better understanding of critical/noncritical motors and automated load shedding. Thus, the simple payback for a $114,300 EMS system was estimated at 4.8 years.

It is hence recommended to consider an EMS, especially where there are multiple embedded generation systems (i.e. solar and diesel gensets), and where can be automation of energy management for load shedding (i.e. momentarily pausing motors), spreading (i.e. changing the time of day when a motor operates), and demand management (i.e. turning down motor speeds to reduce kW loads). As a minimum, energy monitoring software should be considered in order to visualise how a site consumes power and where efficiency gains and cost saving can be made. An example of this would be to shift hay grinding and/or use of water transfer pumps to periods of the day when power is cheapest or outside of milling hours to reduce the maximum grid draw.

[4] Motor Variable Speed Drives (VSDs):

As an indicator of potential savings, a VSD was modelled for the mill ventilation fan and costed at $7,759. This drive was conservatively designed factoring in the site-wide utilization factor and a high throttle speed; with an estimated reduction in power consumption of 25%, saving $4,595 per annum, with the simple payback estimated at 1.7 years. Since Australian feedlots tend to have minimal motor control automation, motors are often operated unloaded or partially loaded. Thus, it is recommended for feedlots to consider VSDs for larger motors and motors that run unloaded or partially loaded (this could include augers, conveyors, fans and mills). The best economic returns for VSDs often occur when motor replacement or rewinding is required (rather than swapping out a newly purchased DOL for a VSD motor). Hence, understanding the opportunities for VSDs within your feedlot now will mean that you are aware of the opportunities if a sudden motor replacement is required.

[5] Thermal efficiencies: the following opportunities relate to grain wetting (tempering) and steam flaking operations where hot water and / or steam are required. Thermal energy cost reduction opportunities analysed were:

- Fuel changing e.g. from LPG, LNG or natural gas to biomass; using solar thermal for boiler make-up water pre-heating and tempering water heating. Typical fuel costs were modelled for Australian feedlots at $15/GJ for Victorian natural gas, $20/GJ for NSW natural gas, and $25/GJ for rural Queensland LPG. Over this range, the fully costed (factoring fuel and boiler purchase over life of plant) payback for biomass ranges from 7 – 3 years.

- Routinely, up to 11 to 15% of thermal energy requirements is the specific heat of water for boiler water pre-heating (depending upon incoming water temperature and final temperature of warm water produced), hence there is a limit in the percentage of heat that can be provided via flat plate collectors or vacuum tubes and economizers generating warm water only. Simple paybacks for boiler make-up water pre-heating via flat plate collectors was estimated at 3.2, 2.4, 1.9 years (up to 80 °C, routinely 60 to 70 °C). Simple paybacks for waste heat recovery e.g. HX on gensets, economizers: 2.1, 1.6, 1.3 years (aim is to control outlet temp up to about 95 °C to prevent steam flashing).

- Insulating / lagging of boilers, steam lines and elevated temperature equipment (e.g. steam chests, valves, flanges, tempering bins) otherwise not lagged was estimated to have a payback generally under 6 months.

- Elevated temperature grain wetting to reach target moistures used in conjunction with higher quality steam can reduce steam usage by towards 50%. Simple paybacks are difficult to estimate and will depend upon a large number of factors (i.e. whether process changes can be easily made; availability of high quality steam), however could be as low as 1.3 years where warm water for tempering is created via the use of a boiler economiser or heat exchanger on a diesel genset.

GLOSSARY

EMS	Energy Management System
Genset	Generator set including the engine and alternator
GWh	Gigawatt hours
HHV	High Heating Value (gross heating value that does not include latent heat of water)
hpa	hours per annum
hr	hour
IRR	Internal Rate of Return (discount rate that makes the net present value (NPV) of all cash flows from a particular project over a particular period of time equal to zero).
kg	kilogram
kVA	Kilo Volt Amperes
kVAr	Kilo Volt Amperes reactive
kW	Kilowatts
kWe	Kilowatts of electrical load
kWh	Kilowatt hour
kWt	Kilowatts of thermal load (e.g. heating requirement for sheds)
LHV	Lower Heating Value (net heat value that includes the latent heat of water)
MJ	Megajoule
MSB	Main switch board
MW	Megawatt
MWh	Megawatt hour
NMI	National Meter Identification (power metering)
NPV	Net Present Value (sum of all cash flows over a given period)
PV	Solar photo-voltaic (power generation)
REC	Renewable energy certificate
RET	Renewable Energy Target
SCU	standard cattle unit (600 kg live weight)
t	Metric tonne (1,000 kg)
tpa	Metric tonnes per annum
tpd	Metric tonnes per day
tph	Metric tonnes per day
tpw	Metric tonne per week
W2E	Waste to Energy
yr	year

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1 Background

A long list of energy efficiency technologies suited to Australian feedlots was generated based upon previous works, published data, site visits, discussions, and published MLA projects. The following opportunities to reduce energy costs at Australian feedlots were analysed:

[1] Low power factors (PF)[3]

Low PF results in either a very high kVA charge being paid or oversized generator rating and fuel consumption for a given kW load.

[2] Over-spec voltage

Feedlots located in rural areas near or at the fringe of the distribution grid are likely receiving three phase power at more than 415 V, as grid operators tend to step power higher to ensure supply over long lines. Over-spec voltage reduces power use efficiency and reduces motor lifespan.

[3] Low levels of automation and reliance on manual operation

Tends to lead to very large load spikes from manually starting all motors at once (also see “Poor motor starter choice” below) and difficulty in implementing energy management practices such as load shedding and demand management.

[4] Motor type options

Direct-on-line (DOL) motor starters draw up to ten times the normal running current during starting, spiking the site kVA. The peak kVA observed in any instant in a month is charged for that entire month, so feedlots should aim to keep the peak as low as possible. This can be slightly mitigated by star, delta, or star-delta starters, however more efficient options exist.

[5] High thermal fuel costs

Natural gas, liquid petroleum gas (LPG) and LNG (liquid natural gas) are not the lowest cost fuels available in Australia. The lowest cost fuels and heat sources were found to be heat recovery, solar thermal (for raising up to 80 to 95 °C hot water) and biomass. Lagging and use of higher temperature wetting water in conjunction with higher quality steam provide efficiency gains.

The above issues make a significant contribution in the estimated 4.1 petajoules of electrical energy Australian feedlots consume per annum (or 1,139,000 MWh), which in Q1 2019 had an estimated cost of $317 million[4].

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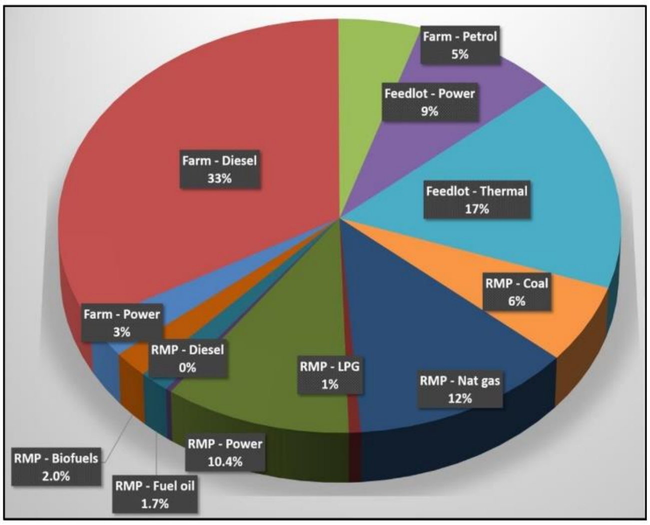
[3] Power Factor (PF) is defined as the ratio of real power producing work to apparent power flowing in the circuit, calculated as kW/kVA from -1 to 1. Typically, PF is observed between 0.5-0.9 in industry. To understand the relationship between kW and kVA, consider buying a beer in a pub: one pays for the entire glass (kVA – apparent power), comprised of the useful portion of the beer (kW – active power), and the head (kVAr – reactive power). kVA is then the vector sum of kW + kVAr.

[4] Assumes an average all in power cost of 27.79 cents per kWh equivalent, based upon regional power at 22.65 cents per kWh (70% of supply) and diesel genset power at 39.80 cents per kWh (30 % of supply).



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 1: Current estimated annual energy use throughout the RMI supply chain and associated annual energy cost for farm, feedlot and red meat processor (RMP) energy demands. Source: MLA project V.SCS.003 (Sept 2017).

To address the above issues, All Energy proposed the following technologies and assessed their economic viability for a “typical” South East Queensland 20,000 SCU feedlot:

[1] Power Factor Correction (PFC)
[2] Voltage Optimisation (VO)
[3] Automated Energy Management Systems (EMS)
[4] Motor Variable Speed Drives/Variable Frequency Drives (VSD/VFD)
[5] Thermal fuel cost reduction.

2 Project objectives

The objectives of this project are to:

(1) Determine strategies to improve energy efficiency of a 20,000 SCU steam-flaking feedlot including feed milling and feed delivery

(2) Define the energy efficiency change of the strategy
    a. Energy cost efficiency ($)
    b. Energy sustainability efficiency (CO_2 equivalent)
    c. Energy use efficiency (MJ)

(3) Determine the economic feasibility (cost benefit and payback period) of the strategy

(4) Produce an MLA tips and tools factsheet summarising strategies to improve the energy efficiency of the feedlot.

3 Methodology

3.1 Data Collection

Representative site power characteristics were derived from the most recent dataset of five months of Ergon 30-minute data. The power profile is summarised below.

Table 1: Site load characteristics

	Value	Unit
Maximum Load	326	kW
Average Load (8 hrs Milling)	165	kW
Cumulative Consumption	1,325	kWh/day
	483,290	kWh/annum
Average Power Factor	0.61	

The load profile averaged over three months is presented below, and shows operation starting up at approximately 6:30am, increasing during the mill campaign with a variable load as different motors are utilized (e.g. hay buster, elevators, mills, etc), then decreasing over a period of approximately 2 hours, finishing around 3 to 4pm. The constant night-time pumping of 40 kW starts from approximately 9:00 pm to 5:30 am to pump drinking water during the off-peak periods.

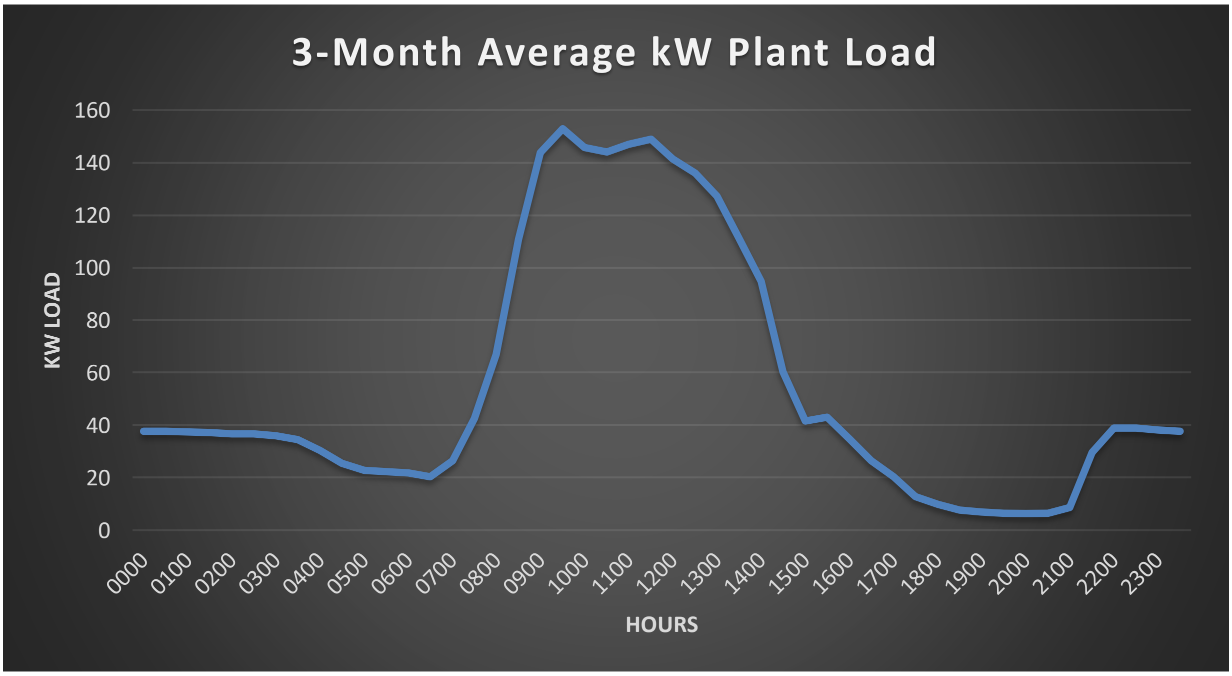


Figure 2: Typical power load profile for a feedlot.

Power loads were found to not be impacted by weather conditions or seasons, as exhibited in Figure below. Overlaying the 3-month average from Figure 2 with a sample of a “summer” day (shown as 5/3/2018, the earliest available day in the data set) and winter day (5/6/2018) shows the high uniformity of power consumption characteristics throughout the year.

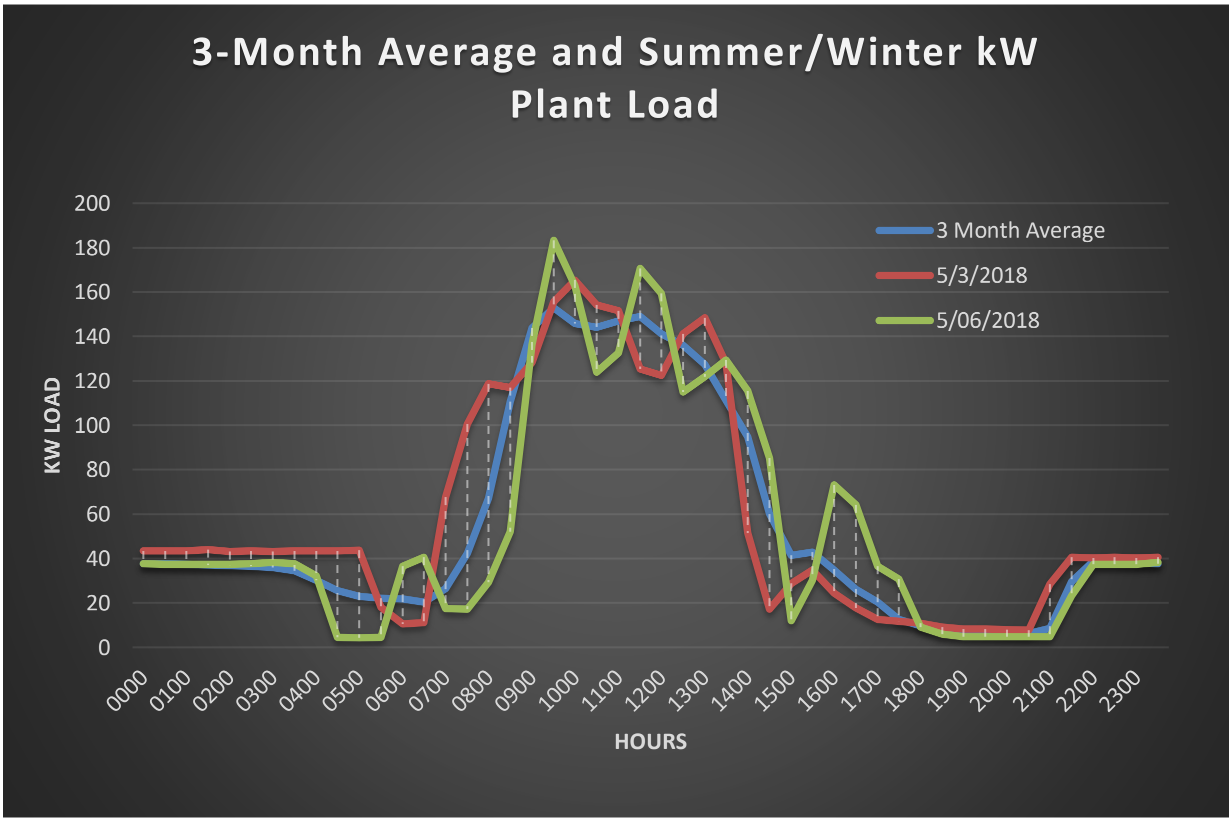


Figure 3: Typical power load profile for a feedlot compared to summer and winter day

The consumption of fuel for heat (i.e. LPG thermal energy) is presented below, showing the monthly burn of LPG, MWt equivalent, and flows of steam to the steam chest (98.6% of steam) with some minor steam usage for vegetable oil tank heating (1.4% of steam).

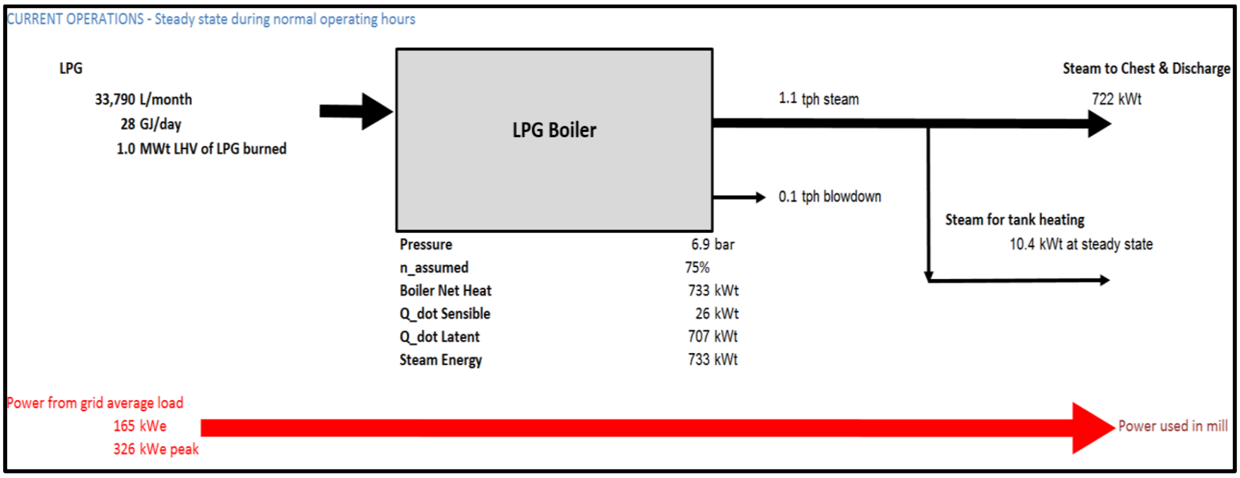


Figure 4: Steady-state thermal energy requirements for a steam flaking operation.

The annual costs of the above energy consumption were calculated as shown in Table below.

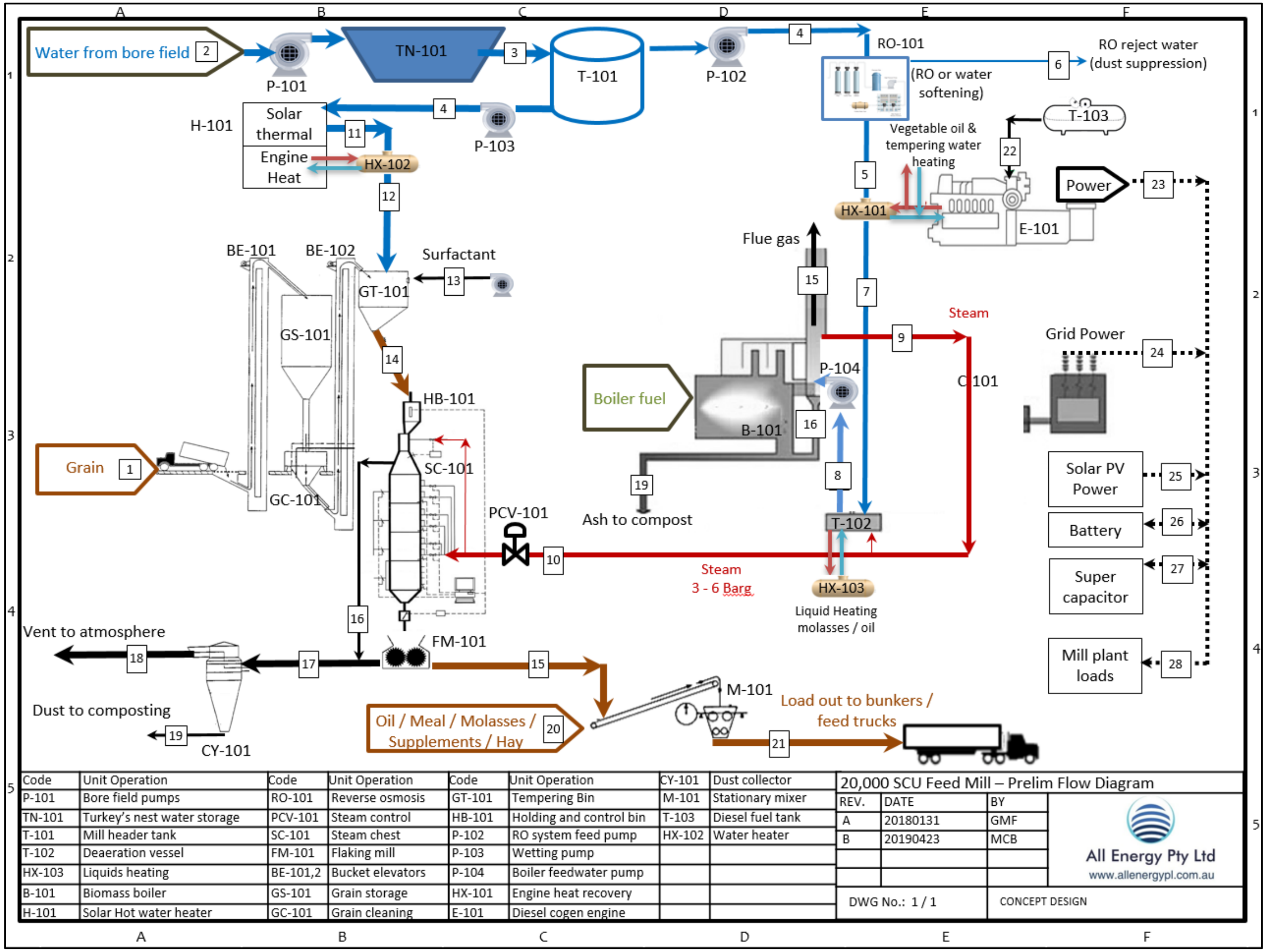
Table 2: Annual Heat and Power Consumption and Costs

	Cost/Unit	**Units Consumed**	**Annual Cost**
LPG	$0.57 /L	405,480 L/annum	$230,824

Power			
Peak	$0.5 /kWh	222,314 kWh/annum	$110,757
Off Peak	$ 0.18 /kWh	260,977 kWh/annum	$45,783
Supply	$1.85 /day	365 days	$674
			$157,214
Total annual energy costs: $388,038 per annum			

3.2 Generic Feedlot Process Flow Diagram

An important document missing from global literature is a single page, high level process flow diagram for a steam flaking operation that shows tie-ins to water handling, grain handling, power source options, thermal system integration options and key unit / equipment operations. Hence, a generic process flow diagram, or PFD, was created for this project for a feedlot operating in power grid-parallel mode. This can be a useful tool for people new to feedlots or for feedlot personnel to rapidly explain the flow of materials and energy through a steam flaking operation.



Code	Unit Operation	Code	Unit Operation	Code	Unit Operation	CY-101	Dust collector
P-101	Bore field pumps	RO-101	Reverse osmosis	GT-101	Tempering Bin	M-101	Stationary mixer
TN-101	Turkey's nest water storage	PCV-101	Steam control	HB-101	Holding and control bin	T-103	Diesel fuel tank
T-101	Mill header tank	SC-101	Steam chest	P-102	RO system feed pump	HX-102	Water heater
T-102	Deaeration vessel	FM-101	Flaking mill	P-103	Wetting pump		
HX-103	Liquids heating	BE-101,2	Bucket elevators	P-104	Boiler feedwater pump		
B-101	Biomass boiler	GS-101	Grain storage	HX-101	Engine heat recovery		
H-101	Solar Hot water heater	GC-101	Grain cleaning	E-101	Diesel cogen engine		

20,000 SCU Feed Mill – Prelim Flow Diagram

REV.	DATE	BY
A	20180131	GMF
B	20190423	MCB

DWG No.: 1 / 1

CONCEPT DESIGN

Figure 5: Generic steam flaking feedlot Process Flow Diagram (PFD)

3.3 Power Load Model Build-Out

To size effective energy efficiency equipment, the plant motor load list was developed based on the site PFD, motor commissioning and test report data[5], site visits, and discussions with the mill manager, project manager, and executives.

Table 3: Site Motor Load List

Load Type	Maximum Measured Current (A)	Installed Capacity (kVA)	Rated Power (kW)	Power Factor	Starter	Load Start Time	Load End Time	Note
Conveyor	7.5	5.4	4	0.74	Star	0630	1100	intermittently
Conveyor	7.5	5.4	4	0.74	Star	0630	1100	intermittently
Dispense	6.0	4.3	3	0.70	Star	0730	1200	intermittently
Dispense	6.0	4.3	3	0.70	Star	0730	1200	intermittently
Conveyor	19.2	13.8	11	0.80	Delta	0730	1200	intermittently
Conveyor	9.8	7.1	5.5	0.78	Delta	0730	1300	intermittently
Conveyor	7.5	5.4	4	0.74	Star	0730	1300	As needed
Elevator	7.5	5.4	4	0.74	Star	0730	1300	intermittently
	12.7	5.3	2.2	0.42	Single Phase	0630	1400	Power pack operates on a pressure switch
Conveyor from steam chest	3.3	2.4	5		Delta	0630	1400	
Mill	91.6	65.8	55	0.84	Delta	0630	1400	
	1.2	0.9	0.55	0.62	Star	0630	1400	
		0.0	32					
	4.3	3.1	2.2	0.71	Star	0630	1100	
Fan	5.5	3.9	3	0.77	Star	0630	1100	Daily
Conveyor	3.2	2.3	1.5	0.66	Star	0630	1100	Daily
Conveyor	7.9	5.7	4	0.70	Delta	0630	1100	Daily
Conveyor	7.5	5.4	4	0.74	Star	0630	1100	As needed
Conveyor	7.5	5.4	4	0.74	Star	0630	1100	As needed
Truck receival conveyor No. 1 to 4	20.7	14.9	11	0.74	Star	0730	1430	As needed, only on week days as trucks arrive
	14.1	10.1	7.5	0.74	Star	0730	1430	As needed, only on week days as trucks arrive
	2.1	1.5	1.1	0.74	Star	0730	1430	As needed, only on week

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[5] All motors rated to 415 Volts three phase except where noted

Load Type	Maximum Measured Current (A)	Installed Capacity (kVA)	Rated Power (kW)	Power Factor	Starter	Load Start Time	Load End Time	Note
								days as trucks arrive
	14.1	10.1	7.5	0.74	Star	0730	1430	As needed, only on week days as trucks arrive
Elevator	20.7	14.9	11	0.74	Star	0730	1430	As needed, only on week days as trucks arrive
Conveyor	20.7	14.9	11	0.74	Star	0730	1430	As needed, only on week days as trucks arrive
Conveyor	14.1	10.1	7.5	0.74	Star			As needed, only on week days as trucks arrive
Conveyor		0.0	11		Star	0630	1400	
Conveyor		0.0	4		Star	0630	1400	
Pumping			40			2130	0500	
Tub Grinder			97			1500	1800	
Office			3			0800	1600	

When designing the model, there were challenges in assigning numerical values for loads nominated as being “intermittent” (i.e. assigning run hours, on/off times, motor loads, etc). Intermittent loads were approximated by using a goal seek to equate the daily calculated kWh consumption to the average of 1,325 kWh by varying a plant load factor[6], calculated to be 0.64.

Presented below are two pie graphs showing the contribution of each load to the total installed kW and daily kWh consumption, with the four largest pieces of plant, the mill, mill fan, pumping, and tub grinder noted individually and other smaller loads aggregated.

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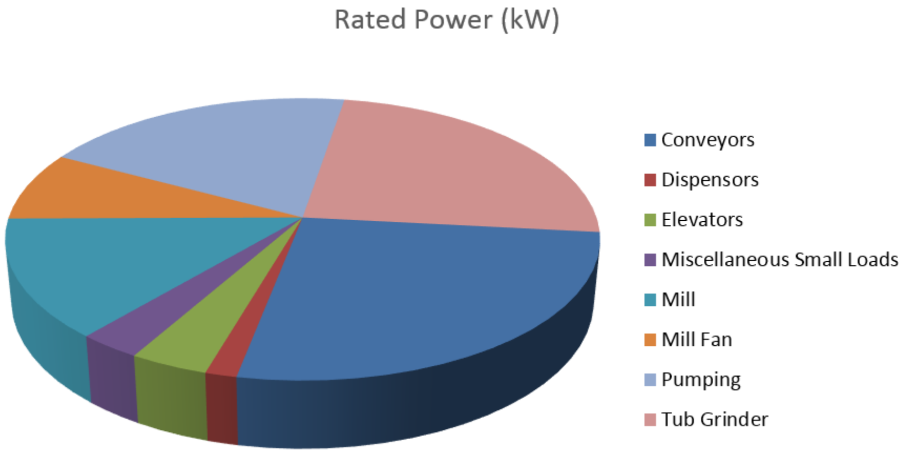
[6] Load Factor = Average Load / Peak Load



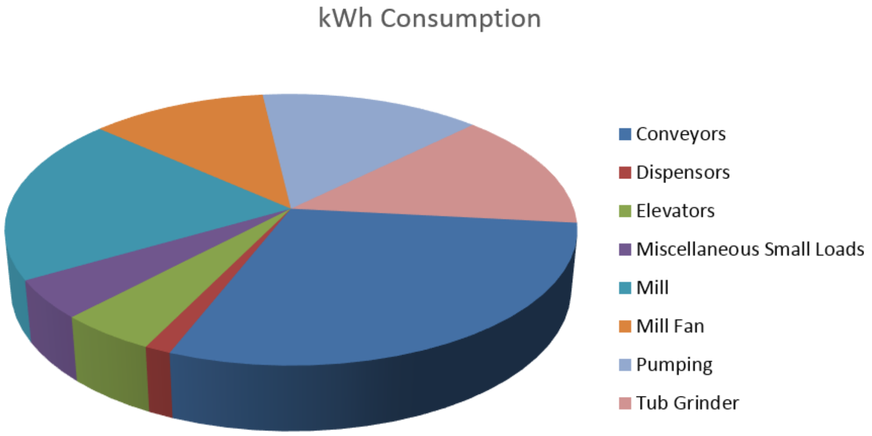


Figure 6: Major Plant Contribution to Peak Load (kW) and Daily Consumption (kWh)

4 Results

4.1 Power Factor Correction (PFC): Very low power factors (PF) have been observed at feedlots with grain milling operations, with the average PF at Australian feedlots sat at approximately 0.6 - 0.7 but can drop to as low as 0.4 at times. This is below the PF commonly required by the electricity distributor of 0.8. Further, a low PF means that a feedlot is potentially paying significantly more than necessary, either in excessive $/kVA costs, or significantly overrated kVA gensets and fuel consumption, for a given kW peak load. The diagram below show the correlation between kW, kVAr and kVA[7].

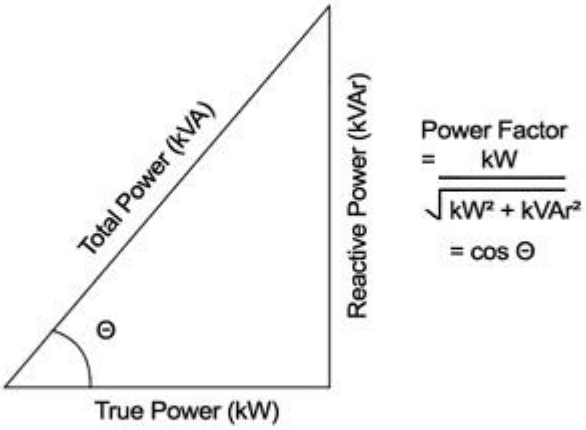


Figure 7: Power Factor Vector Representation

The diagram below shows how, by increasing the PF towards unity (1.0) the apparent power (kVA) and reactive power (kVAr) is also reduced[8].

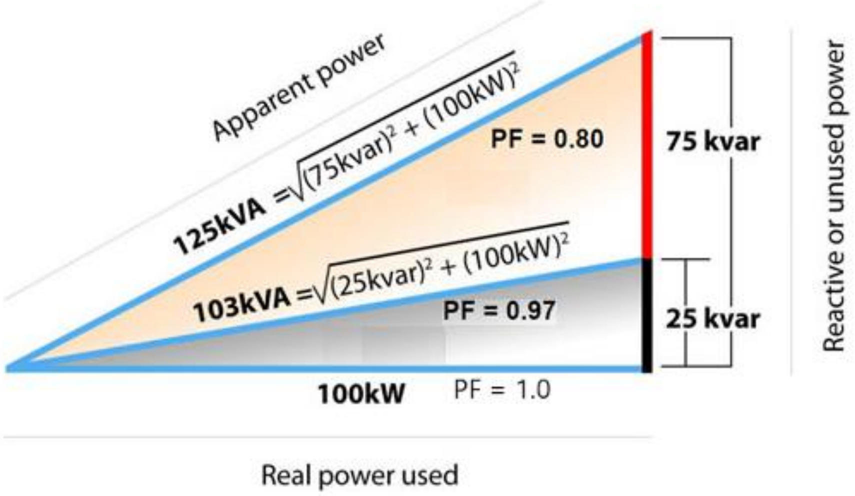


Figure 8: Representation of Apparent, Real, and Reactive Power.

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[7] http://engineering.electrical-equipment.org/power-quality/ac-power-back-to-basics.html, accessed 30 Apr 2019.

[8] Based upon http://buckles-smith.com/tech-blog/understanding-power-factor, accessed 30 Apr 2019.

PFC uses reactive elements (capacitors and inductors) to bring the site PF closer to 1. PFC is claimed to also improve motor life[9]. For feedlots on tariffs with either no kVA demand charge or a $/kW charge only, there is minimal economic motivation for PFC.

A 175 kVAr PFC system was sized to bring the average power factor from ~0.6 to 0.9, and priced at $9,400[10] supplied and installed (excluding GST). With no $/kVA charge as part of a feedlot's electricity bill, there is minimal economic justification for PFC, however it is officially a requirement that consumers must maintain a PF > 0.8. Note that solar photovoltaic systems once installed will reduce the site PF, so PFC may need to be considered if following this route. For a distribution network charging $10.4 to $15 /kVA/month, the simple payback period for such a PFC device increasing PF from 0.6 to 0.9 was estimated at 0.6 to 0.9 years[11].

4.2 Voltage Optimisation (VO): It is estimated that 90% of Australian businesses receive electricity at a higher voltage than required[12]. Many feedlots are located in rural areas near or at the end of power distribution lines, hence networks may distribute power at a higher voltage to ensure quality at the end of the line, which may mean that equipment at these feedlots are receiving power above the voltage required to operate motors, thus impacting efficiency, increasing energy consumption and prematurely wearing plant. Voltage Optimisation can reduce the active power consumed by an equivalent magnitude of voltage reduction and reduce reactive power by a ratio of 1:1.7 or more. For example, according to the AS60038 Standard Voltages requirements, three phase supply voltage is 400V with a tolerance between +10% and -6% and a utilization range of +10% and -11%. However, local operators may follow a different standard. The specification of power supply voltage by legislation is common in Australia and is intended to ensure safe and efficient operation of electrical appliances. It is common for legislation to place maximum and minimum limits on the allowed power supply voltage. In Queensland, Part 2 of the Electricity Regulation (Qld) 2006 previously set the minimum or 'floor' at 225.6 volts and the maximum 'ceiling' at 254.4 volts for single phase. This represented a nominal voltage of 240 volts +/- 6 per cent for single phase[13] (hence, Ergon Energy in Queensland previously used 415V ± 6% for three phase systems[14]), however Queensland has now adopted AS60038 (i.e. 230 V single phase; 400 V three phase +10 % -6 %), and by 1 July 2020 Queensland's electricity networks are aiming to operate within a 'preferred operating range' of +6/-2%[15]. This preferred range aims to optimise the network to ensure electrical appliances operate more safely and efficiently.

Incoming voltages exceeding the required equipment voltages results in energy wasted in the form of heat hence wasted costs (since the electricity will have already been paid for once it passes the meter)

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[9] Savings from motor life and maintenance were not factored in cost benefit analyses here

[10] CapTech: https://www.captech.com.au/

[11] For a site with a typical maximum kW demand of 150 kW as observed over the 3-month average load data

[12] http://energywise.net.au/voltage-optimisation/

[13] https://www.dnrme.qld.gov.au/__data/assets/pdf_file/0005/1279571/decision-ris-qld-statutory-voltage-limits.pdf

[14] https://www.ampc.com.au/uploads/cgblog/id396/2016-1005_Final_Report_final.pdf

[15] https://www.dnrme.qld.gov.au/energy/initiatives/statutory-voltage-limits, accessed 29 Apr 2019.

and potentially reduces the lifespan of electrical appliances. It is estimated that approximately 90% of grid powered sites are operating at an over-voltage level[16].

The best life and most efficient operation usually occurs when motors are operated at voltages very close to the nameplate ratings. High voltage reduces power factor, thus increasing the losses in the system. High and low voltages can cause premature motor failure, as will voltage imbalance.

An assumption often made is that since low voltage increases the amperage draw on motors, then high voltage must reduce the amperage draw and heating of the motor. This is not the case. High voltage on a motor tends to push the magnetic portion of the motor into saturation. This causes the motor to draw excessive current in an effort to magnetize the iron beyond the point where magnetizing is practical.

As a case study, voltages were measured within a site serviced via the Ergon network in Q4 2018 at 419.6 V on a non-VSD motor. Allowing a voltage loss buffer (throughout the site's system) of 2%, the incoming site supply was assumed at 428 V which is within the +10% AS60038 requirement). Assuming a voltage loss buffer (throughout the site's system) of 2% with a target voltage of 390 V, the optimized incoming site voltage is calculated at 397.8 V, which means that the overvoltage is 30.2 V (428-397.8) which equates to a 7.1% overvoltage. Power costs savings are achieved by reducing consumption (kWh) and reducing maximum demand charges (i.e. kW, kVA and/or kVAR charges, often based upon the maximum demand for a site each month). Power quality is also improved by stabilising and balancing phase voltage supply, hence reducing motor overheating, reduced malfunctions of sensitive equipment, and reduced wear on equipment and electrical infrastructure. Reduced equipment wear is difficult to quantify hence the cost-benefit analysis presented below only considers savings from consumption and demand charges.

Percentage voltage reductions do not correlate directly to the percentage of energy (kWh) and demand (kVA / kW) savings, as the overall energy savings depend upon the type of load / equipment, the target voltage, amount of overvoltage, equipment utilization, etc. The expected savings of voltage optimisation is a 0% saving for DC equipment (LED lighting, inverter air conditioning, office IT equipment etc); approximately 3-5% for VSD driven motors; to 9-15% for motors operating at partial loading most of the time, oversized motors, HVAC and refrigeration systems. Across an entire facility, energy usage reduction of 12 to 14.4% are quoted for VO case studies[17,18,19]. A 430 kVA/600 A VO system can be purchased for $60,590[20] with estimated installation and commissioning costs of $25,000. Energy and maximum load reductions of 7%, 12% and 14% were modelled, saving $10,825, $18,558 and $21,651, and delivering paybacks of 7.9, 4.6, and 4.0 years respectively[21].

Further considerations for VO:

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[16] Energywise. Solutions for Energy Cost Reduction. Available online: http://energywise.net.au/ (accessed on 5 March 2017).

[17] https://www.captech.com.au/case-study/energy-savings-through-voltage-optimisation/

[18] https://www.environment.nsw.gov.au/resources/business/160226-voltage-optimisation-guide.pdf

[19] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/33611/pg01_10.pdf

[20] CapTech: https://www.captech.com.au/

[21] https://www.ergon.com.au/retail/business/tariffs-and-prices/large-business-tariffs, Tariff 45, accessed 30 April 2019.

- If you are the one in ten business that receives voltage within the range of 220 - 230 V single phase (approximately 400 V three phase) then the economic viability of VO will be reduced for your business.
- Sites with consistently high loads will have shorter payback periods whilst sites with short spikes then long periods of low loads will have a longer payback (as VO equipment is recommended to be sized for the high demand periods).
- The physical size of the equipment is similar to a fridge; and is defined by the electrical rating (kVA) required.
- VO should be positioned as close as possible to the main switchboard (MSB) in order to minimise the cost of cable to and from the equipment. Typically, up to about 20m away from the main switchboard is viable, beyond that the cost of cable can have a significant impact on the project.
- VO is installed in series with the electricity supply (the power is routed out of the switchboard, through VO, then back to the switchboard). Additional costs can be incurred where MSBs are very old or in poor condition[22].

For some facilities and depending upon the power reticulation infrastructure, voltage reduction could be achieved at minimal to no cost by changing the manual tap setting on the transformer (e.g. if the transformer is under the operational control of the facility or the facility has a designated transformer; or if adjustments can be made at the zone substation transformers) – this has been referred to as Conservation Voltage Reduction (CVR). A VO device allows such reduction to be achieved more accurately, because it has more tapings, enabling it to provide finer ranges of voltage output plus can be installed on-site[23].

4.3 Energy Management Systems (EMSs): Low levels of automation and reliance on manually operated plant results in slower response times, un-optimised operations, inefficient energy usage and higher power demand. An example of this is switching on all large plant at once at the beginning of a shift, leading to a very large load spike from starter current and sub-optimal matching of the plant load with the electricity costs associated with different sources of power. A more efficient method would be to automate the staging of equipment coming on- and off-line. The general function of an EMS is to monitor all power sinks and sources in a plant, logging generation and usage characteristics and aggregating this into a detailed model for automated decision making. Critical data can then be extracted to a side-wide dashboard to enable staff to make informed and meaningful decisions. When trends are defined, most processes may then be automated to bring further efficiency gains. For a commercially available, off the shelf EMS, an expectation of 5% reduction in consumption (kWh) is reasonable; with the real gains being made when integrating renewables, embedded generation, and monitoring market forces to dictate load spreading/shedding, generation, and consumption. An EMS can then be thought of as the integral component that enables the highest value to be derived from a facility.

A quote for the supply and integration of an energy management system for an edge of grid power supply, existing 380 kVA diesel generator, and planned 98 kW of solar at a 20,000 SCU feedlot was

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[22] http://energywise.net.au/voltage-optimisation/

[23] https://powerlogic.com.au/electrical-policies-and-procedures_105_2008376636.pdf, accessed 30 Apr 2019.

received at $114,300[24]. The exact savings of an EMS can be difficult to predict due to depending on many complex and interrelated factors, however there is potential for automated response significantly faster than manual control. An example of how an EMS would work is during the sunlight hours when solar is providing power at ~4 to 8 c/kWh (depending upon scale, installation costs, and solar radiation), the EMS throttles the genset (generating power at approximately 32 c/kWh) higher during the peak period where power is charged at over 50 c/kWh (e.g. in regional Queensland), and lower during the off peak period when power is charged at 19 c/kWh. With larger solar arrays, an EMS can control the time at which loads come on- and off-line to concentrate loads to match high solar generation or spread / shift loads when power is most expensive.

An example scenario run was using an EMS to control the speed of a VSD on a hay grinder, mill ventilation fan and pumping saving 25% of energy use (kWh basis); and controlling 98 kW solar generation during the peak sunshine hours[25] (assumed maximum intensity from 11am to 3pm), with predicted savings of $23,691 or 12% of a predicted bill under Ergon Tariff 45. Outside of the solar generation hours, the site kW load is under the recommended minimum throttle of a diesel engine of 40-50%. This is in line with the literature showing an average saving of approximately 10%, with greater savings to be made with a better understanding of critical/noncritical motors and automated load shedding. Thus, for the $114,300 EMS, the simple payback period was estimated at 4.8 years.

4.4 Load Shedding: turning motors speeds down, delayed starts, or turning motors / loads off via utilization of automated systems - refer EMSs above for more information.

VSDs are an example of a technology that enables motor speeds to be varied to match the output requirement (e.g. water pressure, ventilation air volumes per second, boiler combustion air, cooling requirements, tonnes per hour milling, etc). Taking fans as an example, the cube law relationship between speed and power means that reducing a fan's speed in a variable torque load application by 20% can achieve energy savings of 49%.

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[24] ComAp: https://www.comap-control.com/

[25] Assumed at 8 c/kWh

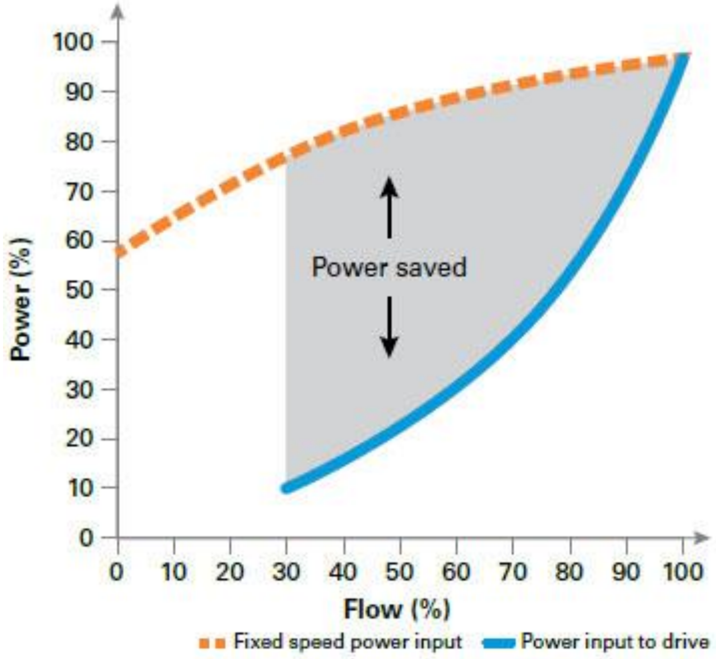

Figure 9: Flow versus power draw curve for fixed and variable speed drives. The broken line indicates the power input to a fixed-speed motor and the solid line indicates the power input to a variable frequency drive. The shaded area represents the power saved by using a variable frequency drive for a given flow.

4.5 Demand Management: Shaping the power load at a feedlot to match the availability of lower cost power such as PV solar, stored PV solar, and off-peak power. Storage options include supercapacitors and batteries e.g. Li-ion, and can be charged using excess PV solar and/or low cost off-grid power then discharged during times of high power costs to reduce kW / kVA and kWh costs. Embedded generation such as diesel gensets can also be employed. Demand management can be integrated into automated systems - refer EMSs above. Supercapacitors (supercaps) are positioned between capacitors and batteries in terms of electronic components and have the advantages of storing far more energy than a conventional capacitor, can turn on "instantaneously", very long lifetimes regardless of the number of charge cycles (e.g. hundreds of thousands of charge/discharge cycles rather than thousands). Supercaps are heavy hence not used for transport or mobile devices but are well suited to stationary power requirements. Battery options are now available at approximately 11[26] to 28[27] c/kWh over the warrantied period, depending upon scale and supplier, hence where current power prices exceed and are anticipated to be half this cost post-2020. There is an economic argument to not invest in batteries in the short term, however to ensure that feedlots are "battery ready" which includes ensuring room on a facility switch board, suitable covered / weather protected areas are available adjacent to a facility switch board and suitable data capture i.e. min data to enable associated data analytics for optimum sizing of batteries. A demand management system, utilizing embedded generation and load shedding is provided in Figure 6 below.

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[26] Solar Choice Pty Ltd

[27] 13.5 kWh Tesla Powerwall2 with 95% depth of discharge analysed over a 10 year warranty period.

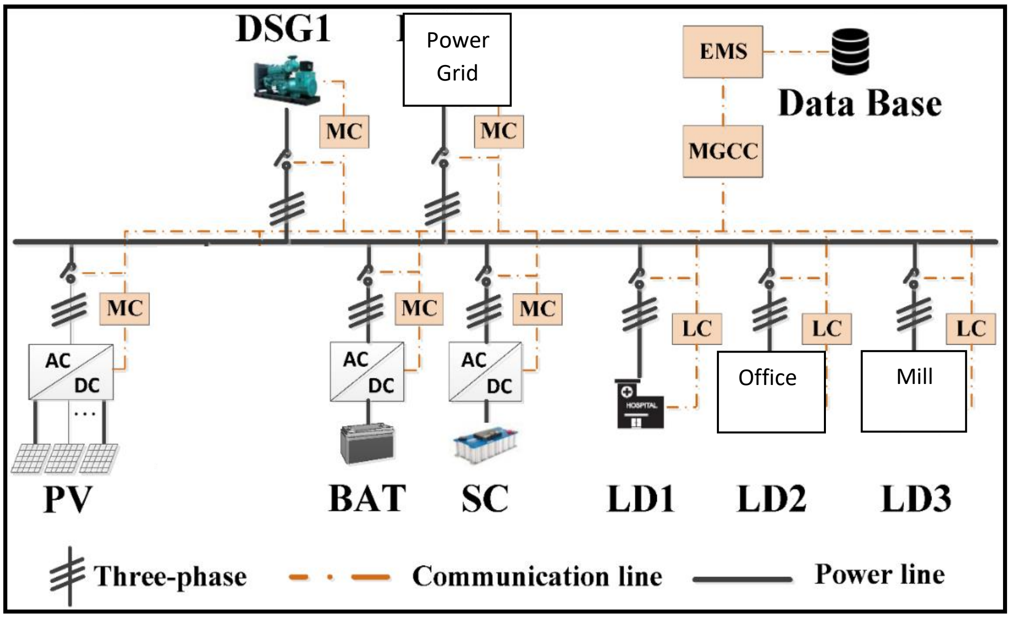

***Figure 10:** Simplified diagram of a micro-grid adapted from Chen et al.[28]. SC: super capacitor, which provides very rapid power load / power supply response and assists with synchronisation but has a smaller kWh storage than the battery bank (BAT). MGCC: microgrid control centre; LC: load control; EMS: Energy Management System; DSG: diesel gensets; LC: load control.*

4.6 Motor Variable Speed Drives (VSD): It has been observed that a large proportion of motors in a typical feedlot are direct on line (DOL) or star-delta starting (refer below). A DOL starter can draw up to ten times the normal running current during starting, which can be reduced by around 30% by a star-delta configuration, however this is relatively uncommon in Australia. DOL suits motors that need to run at full speed all of the time; if this is not required then there will be inefficiencies in power consumption, hence variable speed drives (VSD) may be used to better match motor requirements. Studies on VSDs show energy savings of 25 to 60%[29]. Brief descriptions of different motor types is as follows:

> **Direct online (DOL):** the motor is switched on in one operation, with a direct connection from the power source. The starting current can be up to ten times the normal running current of the motor. A contactor is generally used to switch power, and often a thermal or electronic overload relay is provided for motor protection. DOL is the simplest and cheapest method of motor starting, but consideration needs to be made for power supply limitations on starting current. DOL is well suited for motors that need to run at full speed all of the time.
>
> **Star-delta starting:** the motor is first connected in 'star' configuration, which allows the motor to gather speed without drawing excessive current. Once the motor is up to speed (or a pre-

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[28] www.mdpi.com/1996-1073/11/8/2150

[29] http://www.abb.co.uk/cawp/seitp202/c253ae5e6abf5817c1256feb0053baf7.aspx; https://www.designworldonline.com/how-to-calculate-compressed-air-savings; carbontrust.com

set time is elapsed) it is then connected in the normal ‘delta’ configuration. This method can reduce the starting current demand by 30%, but is only suited to applications where the motor is starting without load (e.g. where a clutched gearbox is used). Star-delta starting is relatively uncommon in Australia.

Soft starting: an electronic device which regulates the voltage flowing to the motor at start-up. By slowly ramping up the supply voltage to the motor, a smooth start without excessive current flow can be achieved. Soft starters are more expensive than DOL or star-delta, but they are widely used due to their convenience and simplicity.

VSDs; also called Variable voltage / variable frequency (VVVF): an electronic device which allows complete control of the motor speed including starting and stopping. It operates by changing the frequency of the power supplied to the motor. VVVF is extremely versatile and often used in process applications where a constant flow needs to be maintained. In addition, because the motor can be run at a slower speed and hence use less energy, use of a VVVF can facilitate significant power savings. Variable speed drives are generally the highest capex motor starting type, but their versatility means they are very widely used. When operating at near full speed, there is a crossover point where VVVFs can use more energy than a DOL motor due to efficiency losses associated with VVVFs (i.e. heat losses; temperature control requirements); this is shown in the figure below. Hence, some larger systems may have both VVVF and DOL configurations.

Motors suitable for VSDs tend to spend a significant portion of their operation unloaded or at fractional load, with examples of suitable motor types including fans, conveyors, elevators, and augers. A quote was received for the 32 kW mill fan at $7,759[30], as indicative of potential savings for other pieces of plant. Saving was conservatively estimated at 25%, saving $4,595 per annum, with simple payback 1.7 years. Additional motors identified as being suitable for VSD included the tub grinder, and bore pumping. The larger kW rating conveyor/elevator/auger motors may be suitable for VSD, but their operation schedule must be defined with greater clarity before a definitive recommendation can be made. For these loads in addition to the mill ventilation fan, VSD is predicted to save 48,474 kWh/annum, or $15,512 with a similar payback period.

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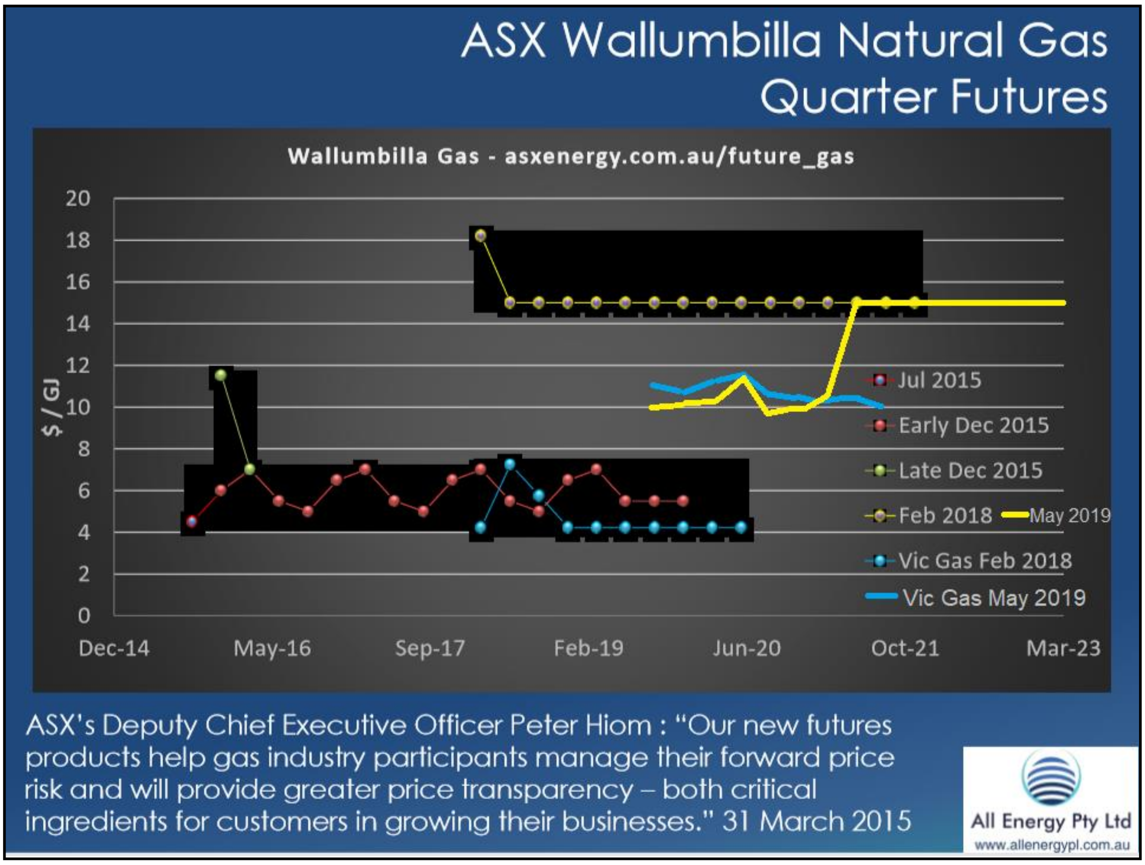
[30] Eaton (OEM): http://www.eatoncorp.com.au/Oceania/index.htm and Indratel (System Integrator): http://indratel.com.au/

5 Thermal Energy

The following opportunities related to grain wetting and steam flaking operations where hot water and / or steam are required. Thermal energy cost reduction opportunities are outlined in the following sections.

One highly disruptive element impacting eastern Australia are the unexpectedly high natural gas prices. For the approximately 40% of Australian manufacturing and up to 53% of red meat industry thermal energy exposed to natural gas prices, there is a new and very worrying trend: ASX Natural Gas Futures Contracts for Victorian Gas Q2 2019 [$10.50/GJ] are sat higher than Wallumbilla (Qld) Gas [$10.05/GJ] and remain higher the majority of the time through 2019 and 2020 until Wallumbilla (Qld) shoots up to $15/GJ in Q1 2021. As recently as early 2018, Victorian gas prices were at $4/GJ and were expected to stay this low through for as long as Futures Contracts were available (mid-2020), refer to Figure 1 below. Fast forward 1 year to now, and natural gas prices are almost triple where they were expected to be, hence there are unexpected and rapid changes in the east coast gas market resulting in much higher gas prices (ASX, 2019). This means that companies that have been sitting on a gas contract for several years will be in for a very rude shock when they go back to the market for a new gas contract. The release of gas tenements by the Queensland government for domestic gas production only is hoping to ease upward pressure on future natural gas pricing, however the ASX data does not indicate future rapid declines.



ASX's Deputy Chief Executive Officer Peter Hiom : "Our new futures products help gas industry participants manage their forward price risk and will provide greater price transparency – both critical ingredients for customers in growing their businesses." 31 March 2015

Figure 11: *ASX Natural Gas Futures data.*

5.1 Fuel shifting

Just as there have been advancements in onsite power generation such as PV solar and high efficiency gensets, so too there have been rapid advancements in "off the shelf" boilers for combusting a wide range of fuels. The table below summarizes fuels commonly available throughout Australia.

Table 4: Fuel Shifting Options

Fuel [all estimates exclude GST]	$/GJ LHV [calculated; fuel supply only]	$/GJ thermal energy fully costed 10 yrs	$/GJ thermal energy fully costed 20 yrs
LNG (Liquid natural gas)	16.65	$ 28.21	$ 26.41
LPG (Propane)	27.00	$ 30.27	$ 28.70
Natural Gas (reticulated from existing pipeline	12.00	$ 15.20	$ 13.60
Diesel	32.52	$ 45.38	$ 38.95
Heavy fuel oil (i.e. recycled lube oil)	14.47	$ 17.60	$ 16.03
Thermal Coal; Assume 370km delivery distance in B-doubles	6.84	$ 10.99	$ 8.92
Thermal Coal; Assume 370km delivery distance in B-doubles (Collie) WITH CARBON PRICE	6.84	$ 12.34	$ 10.27
Biomass: 12% moisture hardwood chip	**3.75**	**$ 14.95**	**$ 9.35**
Biomass: 30% moisture pine chip	5.16	$ 16.36	$ 10.76
Grade 3 Recycled Wood - Chipped	3.60	$ 14.80	$ 9.20
Biomass - air dried hardwood sawmill residue – chipped to 30mm	3.48	$ 14.68	$ 9.08
Refuse derived fuel [gate fee at market landfilling rates; the negative value indicates a source of revenue due to avoided landfill levy fees]	-3.98	$ 7.22	$ 1.62
Flat plate solar collectors – to raise water from ambient to approx. 60 to 70 °C			$ 2.37
Waste heat recovery heat exchanger on existing diesel genset or existing boiler without economiser			$ 1.60

The cost of typical fuels used at Australian feedlots ranges from around $15/GJ for Victorian natural gas, $20/GJ for NSW natural gas, and $25-$30/GJ for rural Queensland LPG (with $25/GJ used for estimates in this report). Over this range, the fully costed (factoring fuel and boiler purchase over life of plant) payback for hardwood chip biomass ranges from 7 – 3 years. For a 20,000 SCU feedlot, a biomass boiler would be rated to around 3 MWt and cost approximately $3.3 million. It is recommended to investigate biomass when facilities have a gas boiler that is approaching end of life, otherwise replacing a functional boiler may not deliver sufficient savings to justify the capital cost.

Routinely, up to 11 to 15% of thermal energy requirements is the specific heat of water for boiler water pre-heating (depending upon incoming water temperature and final temperature of warm water produced), hence there is a limit in the percentage of heat that can be provided via vacuum tubes and economizers generating warm water only. Concentrated solar is not limited to this percentage where an appropriate system is used (e.g. heating of a closed loop thermal oil system or where the system is suitable for raising steam such as via the use of a flash drum).

Simple payback for boiler make-up water pre-heating for flat plate collectors was estimated at 3.2, 2.4, 1.9 years (up to 80 °C, routinely 60 to 70 °C).

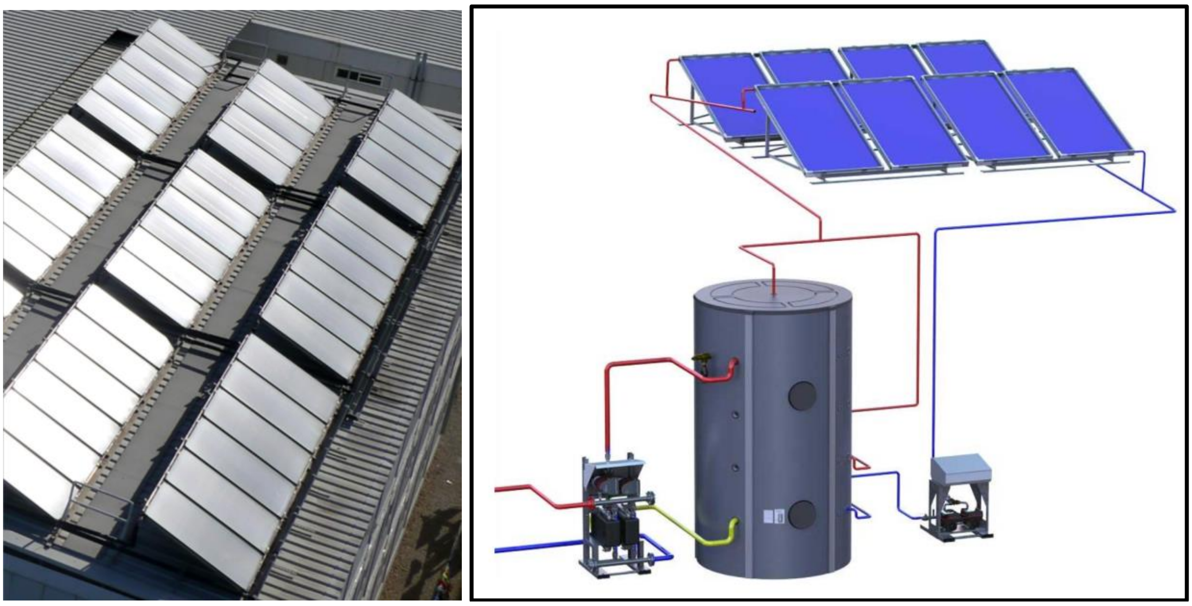


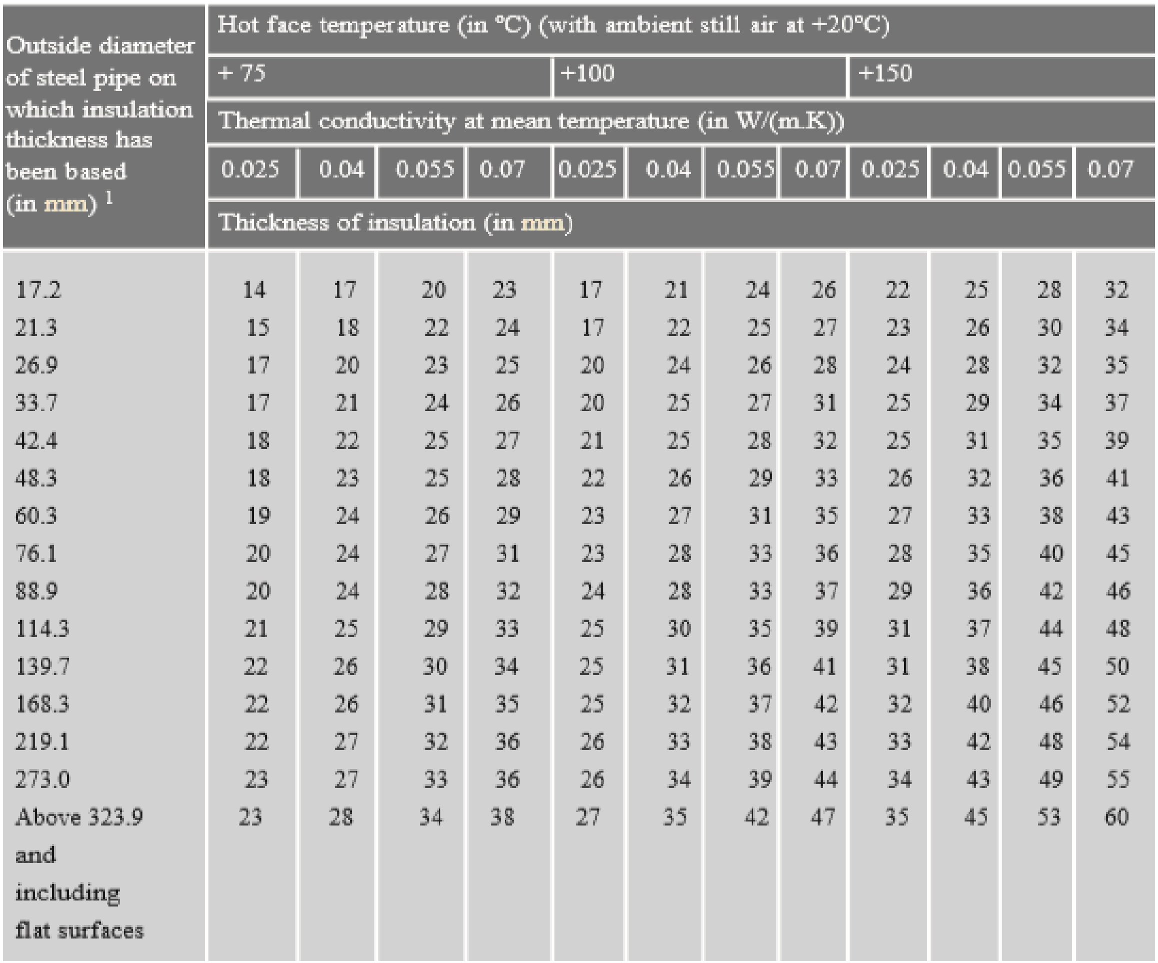
Figure 22: *Example of a commercial flat plate solar collector system showing flat plate collectors, heat storage, heat exchangers and pumps. Source: Solahart Australia Pty Ltd.*

5.2 Lagging and insulation

All equipment and pipework containing materials at elevated temperatures should be lagged for health and safety as well as energy efficiency purposes. Lagging of boilers, condensate return / deaerator vessels, steam pipes, flanges and hot water tanks will have paybacks in the period of months (routinely 1 to 6 months).

The exact lagging requirements are a function of the outside diameter of the pipe or if a flat surface, the temperature of equipment surface, the ambient temperature, the thermal conductivity of the material and the cost of the thermal fuel. The table below provides a guide on thickness of insulation, where the second column (~0.04) is pertinent for 1.5% carbon-steel with steam as the thermal transfer medium. Mineral wool (glass) is suitable for most temperatures at feedlots.

Table 5: Insulation Thickness Guide[31]



Outside diameter of steel pipe on which insulation thickness has been based (in mm) [1]	Hot face temperature (in °C) (with ambient still air at +20°C)											
	+ 75				+100				+150			
	Thermal conductivity at mean temperature (in W/(m.K))											
	0.025	0.04	0.055	0.07	0.025	0.04	0.055	0.07	0.025	0.04	0.055	0.07
	Thickness of insulation (in mm)											
17.2	14	17	20	23	17	21	24	26	22	25	28	32
21.3	15	18	22	24	17	22	25	27	23	26	30	34
26.9	17	20	23	25	20	24	26	28	24	28	32	35
33.7	17	21	24	26	20	25	27	31	25	29	34	37
42.4	18	22	25	27	21	25	28	32	25	31	35	39
48.3	18	23	25	28	22	26	29	33	26	32	36	41
60.3	19	24	26	29	23	27	31	35	27	33	38	43
76.1	20	24	27	31	23	28	33	36	28	35	40	45
88.9	20	24	28	32	24	28	33	37	29	36	42	46
114.3	21	25	29	33	25	30	35	39	31	37	44	48
139.7	22	26	30	34	25	31	36	41	31	38	45	50
168.3	22	26	31	35	25	32	37	42	32	40	46	52
219.1	22	27	32	36	26	33	38	43	33	42	48	54
273.0	23	27	33	36	26	34	39	44	34	43	49	55
Above 323.9 and including flat surfaces	23	28	34	38	27	35	42	47	35	45	53	60

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[31] https://cibse.org/getmedia/3c90596e-89e7-437c-989a-3ad5f939eab5/FEB08-Economic-Thickness-of-Insulation-for-Hot-Pipes-1993-rep-1996.pdf.aspx

5.3 Elevated temperature grain wetting and use of high quality steam

North American feedlot operations have been running high efficiency flaking facilities where via the use of wetting agents / additives and elevated tempering temperatures / preconditioning hot water to achieve a target moisture of 20 – 21% during tempering. The steam added in the steam chests then simply serves the purpose of raising the temperature to 95 – 96 oC and does not serve the purpose of moisture addition. This requires high quality / higher pressure steam (e.g. 10 barg) than what is routinely used in Australian steam flaking operations (e.g. wet / lower pressure steam at 3 barg or less). Higher pressure steam “cooks” the grain better and faster. Previous experience has found to not raise the grain during tempering above gelatinisation temperatures, which for wheat is in the range 52 to 63 ^{o}C, where barley typically gelatinizes in the 59 – 63 °C range, but various studies have documented temperatures from 52 – 68 °C.

Tempering is the process of adding water (typically 8-10% moisture increase) to whole grain with a period of storage (typically 8 - 48 hours, with approx. 24 hours being most common) to enhance water absorption (target grain moistures 20-22%) prior to processing with a roller mill. The addition of moisture to grain has the effect of dramatically reducing fines, allowing a more consistent roll and reducing the energy cost of milling.

All Energy Pty Ltd completed a mass and energy balance taking into account the thermodynamics and specific heat of grain and initial moisture of the grain, tonnage of wetting water added and water specific heat. If heated water at 95 °C from a vacuum tube is added to grain at 25 °C at the rate to achieve a final moisture of 20%, then the final mixture temperature will be 59 °C assuming an adiabatic system (e.g. no heat loss due to tempering bins being perfectly insulated). Hence, if 95 °C water is added then the grain would approach the target temperature of 59 °C. To maintain this temperature, additional water can be added however leachate could be generated. Where the tempered grain is at 21% moisture and is heated from 59 °C to 96 °C using high quality steam with no requirements for adding additional moisture, for an adiabatic system (i.e. no heat loss due to being perfectly insulated) the energy savings in reduced steam addition to the steam chests is calculated to be 75.1%. The direct injection of steam would still increase the moisture of the tempered grain, with the grain exiting the steam chests estimated to be 22.2% moisture. In an actual system the heat load would be higher due to losses from the steam supply systems and vessels. Anecdotal evidence from North America suggests 50% less steam requirements when steam flaking is operated in the described manner. Hence, there is a strong motivation, especially before the installation of a boiler, to consider heating wetting water towards 95 °C. This could be achieved economically via the use of vacuum tubes, flat plate collectors or concentrated solar thermal modules, waste heat recovery from gensets and boilers and/or vacuum tubes. This infrastructure can also be utilized for boiler water pre-heating and/or expanded as the plant increases in size. The payback period for this configuration is difficult to estimate and will depend upon whether process controls can be easily made and if the boiler can produce higher quality steam (e.g. 3 barg steam with no condensate), however the simple payback periods could be as low as 1.3 years where warm water for tempering is created via the use of an economiser or heat exchanger on a diesel genset.

All Energy Pty Ltd costed an 800 kW flat plate solar thermal collector system to raise water to approximately 60-70 °C for wetting and boiler water pre-heating. This system would reduce the load on the boiler to 0.8 MW (approximately 76% reduction from 3.3 MW) and cost $249,000. The fully costed price for thermal energy is $2.40 from flat plate collectors compared to $27/GJ for LPG, delivering a simple payback of 3.2 years for a 20,000 SCU feedlot.

Literature on corn preparation for livestock suggests that wetting grain at elevated temperatures (i.e. increasing the conditioning temperature to 77°C for 60 secs to increase gelatinization by 9.4%; 88 °C for 60 sec to increase gelatinization by 20.8%) results in a greater degree of starch gelatinization when evaluated by the modified glucoamylase method[32]. The greatest improvement has been achieved for sorghum, with lower gelatinization for barley and wheat. Anecdotal examples of wetting with warm or hot bore water in Australian feedlots has shown that elevated temperature grain wetting has worked well with white grain and hence could provide an opportunity for enhanced feed efficiency gains.

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[32] An evaluation of total starch and starch gelatinization methodologies in pelleted animal feed, L. Zhu C. Jones Q. Guo L. Lewis C. R. Stark S. Alavi, Journal of Animal Science, Volume 94, Issue 4, 1
April 2016, Pages 1501–1507, https://doi.org/10.2527/jas.2015-9822 01

6 Discussion

6.1 Emissions

Using published National Greenhouse Accounts Factors[33], the site Scope 2 emissions (emissions from purchased electricity) and effect of energy efficiency technologies on emissions intensity was modelled.

Table 6: Energy Efficiency Emissions Reduction Analysis

Scope 2 Emissions	**kWh pa**	**GJ pa**	**t CO_2 pa**	**Emission Reduction t CO2 pa**	**% Emission Reduction**	**Note**
Business as Usual	483,290	1,740	156.6	-	-	Bituminous coal-fired grid power
Power Factor Correction	483,290	1,740	156.6	-	-	No kWh saving from PFC
Voltage Optimisation	434,961	1,566	140.9	15.7	10 %	Conservative 10% saving of kWh
Energy Management System	133,978	482	43.4	113.2	72 %	Throttling VSDs, Solar + Generator during peak period
Variable Speed Drive	145,422	524	47.1	109.5	70 %	On mill ventilation fan, pumping, and tub grinder

The greatest reduction in emissions is observed as a result of implementing an EMS, as this is a comprehensive and integrated piece of plant for an efficient energy strategy. Calculating a $/t CO2 abatement can suggest some 'easy wins' for feedlots to reduce their emissions intensity and make progress towards the wider red meat industry CN30 goal.

Table 7: VO, EMS, VSD $/t Emission Reduction

	Capital Cost	**$/t CO_2 Reduced**
Voltage Optimisation	$ 85,590	$ 5,466
Energy Management System	$ 114,300	$ 1,010
Variable Speed Drive	$ 7,759	$ 570

MLA supported the creation of an online tool for feedlots to understand fuel swapping options; the tool can be found at: www.myenergy.tech

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[33] https://www.environment.gov.au/system/files/resources/5a169bfb-f417-4b00-9b70-6ba328ea8671/files/national-greenhouse-accounts-factors-july-2017.pdf

Reductions in the combustion of the amount of fuel or changing to a fuel with a lower t CO_2-e per GJ will reduce scope 1 emissions. The following table provides an example of how efficiency gains and fuel swapping can reduce scope 1 emissions.

Table 8: Thermal Fuel Switching Emissions Reduction

Scenario	Estimated t CO_2-e per annum
Coal fired boiler for a 20,000 SCU steam flaking operation	3,379
Natural gas for a 20,000 SCU steam flaking operation	1,589
Biomass fired boiler for a 20,000 SCU steam flaking operation	49
Solar thermal heating for wetting water; 50% reduction in steam from natural gas fired boiler	795

6.2 Fuel and Power Trends

Australian Bureau of Statistics data shows that in the past two years, power prices are up 14.5%, with natural gas up 11.2%, against an economy-wide CPI increase of 3.7%. Power went up 3.9 times the rate of CPI and this is not an anomaly: over 10 years, CPI is up 23% compared to power at 110%[34]. The high price of electricity has been linked to the high price of natural gas for power peaking plants.

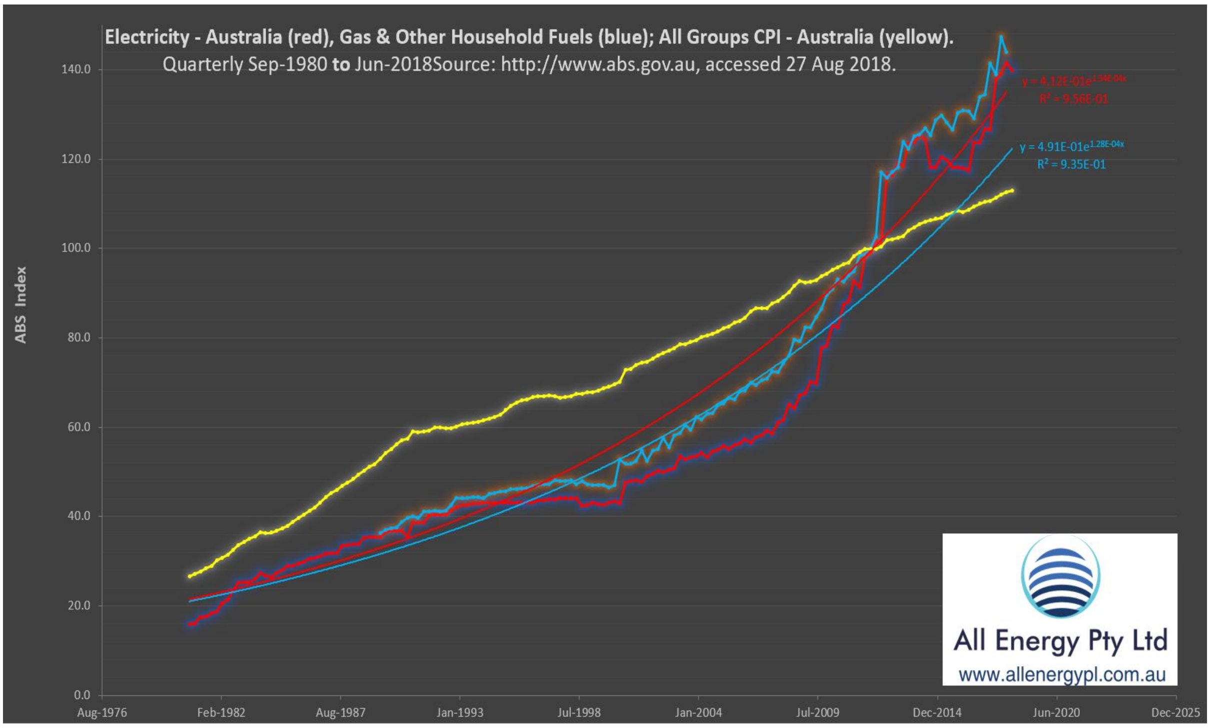

Figure 13: *Trend of Australian Electricity (Red), Gas (Blue), against CPI (Yellow), 1980-2018*

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[34] https://www.abs.gov.au/AUSSTATS, accessed 23 April 2019.

Domestic natural gas pricing is being driven upwards due to demand in Japan, China, and Korea for Australian LNG. This is bringing wholesale gas prices in Australia closer to parity with the Asian markets, resulting in significant year on year increases in the price of natural gas to consumers in the Australian red meat industry. According to the ASX Natural Gas Futures Contracts, by Q1 2021 wholesale natural gas in Queensland is anticipated to be at $15/GJ whilst in Victoria natural gas is anticipated to be at $10.95/GJ by Q3 2020[35].

As outlined above, grid power costs are increasing at a rate higher than economy wide CPI. Future changes in emissions pricing could also increase power costs. Changing tariffs means that a higher percentage of the bill is attributable to the maximum demand during the month. Due to the cyclic nature of the RMI power draws (i.e. day shifts during weekdays) the RMI will have a disproportionately higher percentage of grid power costs associated with maximum demand (kW / kVA) charges compared to industries with steady loads or loads that can be shifted to off-peak periods

When emissions pricing mechanisms are reintroduced into the Australian market, whether these take the form of broad based emissions pricing, narrower scope pricing, or emissions trading schemes, larger emitters of GHGs in the Australian RMI may be liable and vulnerable to a significant annual cost increase. Biological fuels or sources of energy, including woodchip, manure, biogas, straw etc. have around 97 - 99% less emissions than coal and natural gas. The RMI must look to energy sources from within its own supply chain or that are available at a lower cost. Options include:

- Managed forest plantations to generate biomass for boilers whilst also generating revenue via the Emissions Reduction Fund. The same land can generate revenue via the soil carbon method and can be co-grazed.
- Waste to energy: manure and processing wastes can be converted into biogas for generating power and thermal energy.
- Solid fuels such as biomass and solid wastes can be gasified to generate power and thermal energy.
- Solar radiation can be used to generate thermal energy and power.

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[35] https://www.asxenergy.com.au/futures_gas, accessed 1 May 2019.

7 Conclusions/recommendations

The electrical efficiency technologies analysed as part of this milestone included

- Power Factor Correction (PFC)
    - A 175 kVAr PFC system was estimated, via the use of the *in silico* model, to bring the average power factor from ~0.6 for a 20,000 SCU feedlot to 0.9 – 0.95, and had an estimated outlay of $9,400 (excluding GST). When there is no $/kVA charge associated with power purchased from the grid (as observed on many QLD Ergon tariffs), there is little-to-no financial incentive for PFC, however it is a requirement that consumers must maintain a PF > 0.8. For a distribution network charging $10.4 to $15/kVA, the simple payback period for the above listed PFC device increasing PF from 0.6 to 0.9 was estimated at 0.6 to 0.9 years.
    - **It is recommended that all Australian feedlots that are charged a $/kVA element as part of their bill or generate their own power investigate Power Factor Correction for their site.**

- Voltage Optimisation (VO)
    - A voltage optimization (VO) system rated to 430 kVA / 600 Amps can be purchased for $60,590 with estimated installation cost of $25,000 (excluding GST). The expected savings of voltage optimisation depend on the type of equipment, from 0% saving for DC equipment (e.g. LED lighting, inverter air conditioning, office IT equipment) to approximately 3-5% for VSD driven motors; to 9-15% for motors operated at partial load, HVAC and refrigeration systems. Energy and maximum load reductions of 7%, 12% and 14% were modelled, saving $10,825, $18,558 and $21,651, and delivering paybacks of 7.9, 4.6, and 4.0 years respectively.
    - **Voltage Optimisation may be a good fit for Australian feedlots with a high proportion of direct-on-line (DOL) motors, motors under partial loads, or feedlots receiving grid power at a higher than required voltage (e.g. at the fringe of the grid, where voltages tend to be higher than required to ensure reliable distribution).**

- Energy Management System (EMS), Load Shedding, Demand Management
    - EMS to integrate the edge of grid power supply, existing 380 kVA diesel generator, and planned 99 kW of solar was received at $114,300[36]. An example scenario run was using an EMS to control the speed of a VSD on a hay grinder, mill ventilation fan and pumping saving 25% of energy use (kWh basis); and controlling 98 kW solar generation during the peak sunshine hours[37] (assumed maximum intensity from 11am to 3pm), with predicted savings of $23,691 or 12% of a predicted bill under Ergon Tariff 45. Outside of the solar generation hours, the site kW load is under the recommended minimum throttle of a diesel engine of 40-50%. This is in line with the literature showing an average saving of approximately 10%, with greater savings to be made with a better understanding of critical/noncritical motors and automated load shedding. Thus, for the $114,300 EMS, the simple payback period was estimated at 4.8 years.
    - **All Australian feedlots are recommended to consider an EMS to incorporate their embedded generation, and allow automated energy decisions on load shedding,**

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[36] ComAp: https://www.comap-control.com/

[37] Assumed at 8 c/kWh

    spreading, and demand management. At the least, energy monitoring software should be considered in order to visualise how a site consumes power and where efficiency gains and cost savings can be made.

- Motor Variable Speed Drives (VSD)
    - Indicative quote for mill fan at $7,759, with estimated saving of 25%, $4,595 per annum, 1.7 year simple payback period. Large loads that spend a significant proportion running at fractional or unloaded demand (e.g. unloaded augers) should be investigated as likely a good fit for VSDs.
    - **It is recommended to consider VSDs for larger loads and motors that have long periods of running unloaded or partially loaded .**

Options to reduce thermal energy costs include:

- Fuel shifting. Specifically:
    - from LPG, LNG or natural gas to biomass;
    - Using solar thermal for boiler make-up water pre-heating and tempering water heating. This can be vacuum collectors for raising to 60 – 80 ^{o}C, or concentrated solar collectors for heating to higher temperatures.
    - Waste heat recovery heat exchangers on diesel genset or boilers (where an economiser is not currently used)
    - MLA supported the creation of an online tool for feedlots to understand fuel swapping options; the tool can be found at: www.myenergy.tech

Recommendations for future works include:

- Commercial pilot of an EMS for an Australian feedlot with associated reporting on kWh and maximum kW reductions, detailed reporting on the integration process and optimization of power generation / load shedding / demand management.
- Trial a concentrated solar thermal system to raise wetting water towards 95 ^{o}C for elevated grain tempering.
- Trial a concentrated solar thermal system to raise steam suitable for steam flaking.
- Disseminate knowledge about energy options from within the RMI supply chain:
    - Solar PV and solar thermal.
    - Managed forest plantations to generate biomass for boilers whilst also generating revenue via the Emissions Reduction Fund. The same land be generate revenue via the soil carbon method and can be co-grazed.
    - Waste to energy: manure and processing wastes can be converted into biogas for generating power and thermal energy.
    - Solid fuels such as biomass and solid wastes can be gasified to generate power and thermal energy.

8 Key messages

General messages from feedlot energy strategies and associated action items are

- **The red meat industry must reduce its reliance on fuels exposed to international pricing mechanisms (i.e. natural gas) and emissions intensive fossil fuels**
    - Feedlots should consider their thermal efficiency options as part of their reduction strategy.
    - Other strategies include fuel switching, and grain wetting operational changes
- **The red meat industry must reduce its reliance on the conventional power grid (where connected)**
    - Electrical energy efficiency will make a significant contribution to this goal
    - Other components of a sustainable electrical energy strategy include embedded generation, microgrids, and automation