final report

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Improving feedlot energy and water use efficiency

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Executive summary

Water and energy use efficiency are important issues for the feedlot industry. Natural resources need to be managed to secure long-term sustainability. Red meat 2030 seeks out world-leading environmental management for the Australian industry, as does the goal of being carbon neutral by 2030.

Energy and water management must be embedded with business as usual activities if these goals are to be achieved.

At a micro level, feedlots are located on fringe of grid or remote locations, often using bulk delivered fuels such as LPG that have high unit cost ($/GJ). Depending on location, LPG is two to four times more expensive per unit than pipeline natural gas. Similarly, high cost per unit electricity ($0.20/kWh and greater) is typical in the sector.

This project seeks to support the direction of red meat 2030 and reduce cost impost on Feedlot operations by:

- Determining and quantify strategies to improve efficiency for a 30,000 SCU steam flaking Feedlot.
- Leverage modern water and energy management platforms to support business excellence.
- Produce a summary factsheet to support industry.
- Provide a blueprint for Feedlot operations to reduce cost and contribute towards CN30.

24 meters were strategically located around the Feedlot and connected via communications equipment. Metering point location focused on high cost, high-value end uses to provide greater insight into boiler fuel, steam, water, and electricity cost.

Data was collected over 12 months and used to identify, develop, and quantify strategies to improve efficiency. The data confirmed a total energy balance of thermal (67%), diesel (21%) and electricity (12%).

Thermal meters (for measurement of gas and steam) were used to inform boiler productivity and strategies to reduce cost. We found tracking of simple KPIs such as MJ/Tonne grain milled, or MJ/hd/d provided valuable insight for Feedlot operators to manage thermal cost.

Diesel fuel is an important (and costly) resource for feedlot operators. 88% is attributed to feed trucks, loaders, tractors, scrapers and bobcats. While this is a major cost, economically attractive alternatives are limited. However, diesel is expected to be disrupted by low emissions alternatives such as renewable methane, hydrogen or electric vehicles over the next 5 to 15 years. It is worth keeping a watching brief on these emerging technologies.

Electrical energy is a smaller part of the total energy balance but has high unit cost ($/kWh or $/GJ), hence, projects to reduce or remove grid consumption offer attractive returns (such as lighting, controls and solar PV).

Measurement of water confirmed cattle drinking water at 75.8%. The mill plant consumes much smaller amounts (1.8% for grain wetting water and 1.6% for boiler feedwater). Water for dust suppression (6.9%) was the largest non-cattle using application.

Measurement and Verification (M&V) methodologies, in line with the International Performance Measurement and Verification Protocol (IPMVP), were used to measure and verify water and energy use improvements against the baseline.

All meter data is recorded and stored within third-party software package "Power Management Expert". This package can export data to Excel spreadsheets for further analysis and reporting.

Results

The collaborating partner facility through previous capital expenditure and energy management strategies had already demonstrated energy cost reductions of 40% and scope 2 emissions reduction of 50%. This project built off that momentum, taking efficiency to the next level through measurement and data analytics.

A total of nine strategies to improve energy use efficiency were identified and assessed for a total cost of just over $500k, returning an IRR of 23% (4.3-year simple payback).

Reduction strategies identified have the potential to:

- Reduce grid electricity by 6.1%
- Reduce gas energy (LNG) by 13.7%
- Reduce water consumption by 3.5%

Strategies range from additional solar PV at the induction shed and accommodation block, to more involved opportunities such as heat recovery and combustion control in the boiler house. Integration of high temperature heat pumps would bring a new level of innovation to further reduce boiler work and ultimately gas cost.

During the project, the collaborative partner was able to use energy dashboards to identify the benefits of increased boiler service intervals, avoiding a 20% loss in thermal performance.

Key messages for Feedlot operators wanting to measure and improve water and energy use efficiency because of this project include:

- **Know your numbers:** have a good sense of your energy and water costs, the most significant users and potential opportunities surrounding the system before selecting where to meter.
- **Goals:** set firm goals that are clear, measurable, and time-bound
- **Invest:** budget to invest 10% of your annual water and energy spend on improvements each year. It is not unreasonable to expect to reduce your costs by +50% with the right effort and focus. The introduction and expansion of renewables drive these costs closer to zero over time. Feedlots looking to implement a similar monitoring system can use the following cost estimates as a guide (includes software licences for data analytics, IT, and electrical connectivity):
    - Electrical $2,000 per point
    - Gas and steam $10,000 per point
    - Water $4000 per point (high end) to $1000 per point (low end)

Recommendations

- Embed the use of energy and water data analytics into business operations; this may include integration with the feedlot management system.

- Review the list of opportunities, test if they are attractive for your operation against your economic hurdle rates or other decision-making criteria. Perform detailed engineering and economic assessment to confirm if they are technically feasible, then plan to execute in a staged approach. Tariff reviews, Solar PV, lighting and boiler related projects offer the most attractive combination for Feedlot operations.

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1 Background

Water is an essential nutrient for feedlot cattle. Provision of water with adequate quality and quantity is critical to ensuring optimal productivity and profitability of lot feeding. Water has many uses in feedlots including drinking water, trough cleaning & evaporation, losses from troughs & pipes, cattle washing, evaporation losses from holding storages, feed preparation, staff amenities, vehicle cleaning and irrigation.

Drinking water accounts for 80-90% of total water use at feedlots. Technologies to improve water use efficiency within feedlots are important to ensure long-term sustainability in supply of water for feedlots.

Energy is generated for feedlots from combustion of hydrocarbons onsite (gas, diesel, and coal), mains electricity and renewable energy sources. Energy is utilised for multiple uses including powering trucks for cattle and commodity transportation, feed mills, water pumps, feed trucks, farming equipment, building, maintenance equipment and vehicles.

Feed-mills are typically the largest energy consumer on feedlots. With rising energy costs, feedlots are seeking to continuously improve energy efficiency.

Water and energy use efficiency are important issues for the feedlot industry. Natural resources need to be managed to secure long-term sustainability. Red meat 2030 seeks out world-leading environmental management for the Australian industry, as does the goal of being carbon neutral by 2030.

This project monitored water and energy use over a 1-year period and determined opportunities to improve efficiency at 30,000 SCU steam flaking feedlot.

The overarching aim of this project was to document practical strategies to improve water or energy use efficiency that are commercially attractive and likely to be adopted across the industry.

2 Project objectives

Project objectives include:

1) Determine strategies to improve water or energy use efficiency for a 30,000 SCU steam flaking Feedlot by:
    a) Metering water and energy use in the Feedlot over one year
    b) Identify technologies to improve water use efficiency and energy use efficiency
2) Generate the economic feasibility (cost-benefit and payback period) for at least six strategies
3) Produce MLA tips and tools factsheet summarising strategies to improve the energy efficiency of the 30,000 SCU steam-flaking feedlot

3 Methodology

Using instrumentation and IT infrastructure, energy and water use is measured in real-time (or near real-time) and connected to an energy and water management platform. Measurement of energy flow in the thermal system was somewhat challenging, requiring specific instrumentation to achieve the desired outcome. For example, metering energy flow (in and out) in the flaking plant requires an inline vortex meter (or other appropriate instrument) with pressure and temperature compensation.

It also requires a fixed heating value to be programmed so that energy use (GJ) or energy flow (GJ/hr) can be captured. The same was valid for steam, where mass flow, pressure and temperature was required to compute energy produced by the boiler (GJ).

These measurement points are critical for accurate energy management and KPI monitoring, such as thermal efficiency (energy out over energy in, or in this case, steam energy (GJ)/LNG energy (GJ)) and GJ/tonne grain milled.

The scope included the installation of 20 meters at the collaborative partner Feedlot which is a 30,000 SCU steam flaking feedlot on the Darling Downs, Queensland.

Table 1 provides 20 metering points identified for the project at the time of proposal submission. This included:

- 13 water meters
- Five electrical meters
- One gas meter
- One steam meter

Table 1: meter list - original scope

Orginal scope

Location	Water	Electrical	Gas	Steam	Totals
Bore 1	1				1
Bore 2	1				1
Bore 3	1				1
Cattle Pens	9				9
Mill Plant		1			1
Hospital		1			1
Accommodation		1			1
LNG			1		1
Steam header				1	1
Boiler make up water	1				1
Amenities		1			1
Mill plant		1			1
Total	**13**	**5**	**1**	**1**	**20**

Since undertaking the project – Smart Business Hub (SBH) worked with the collaborative partner and MLA to refine and improve metering points to be lower risk, provide higher coverage, more significant business, and industry value. The final scope is below.

Table 2: metering points - final scope

Final scope

Location	Water	Electrical	Gas	Steam	Totals	Unique identifier	NMI
Bore 1 - utility meter*	1				1	SUB0002390-2	SUB0002390-2
Bore 2 - utility meter*	1				1	SUB0002390-4	SUB0002390-4
Mill electricity - utility meter*		1			1	QFFF7000013-1	QFFF7000013-1
Solar farm electricity - utility meter*		1			1	Solarfarm	Solaredge
LNG - utility meter*			1		1	LNG main	
Turkeys nest outfeed 1 (cattle drinking water)	1				1	WM1	
Turkeys nest outfeed 2 (cattle drinking water)	1				1	WM2	
Accommodation water	1				1	WM3	
Dust suppression water	1				1	WM4	
Farm supply	1				1	WM5	
Boiler feedwater	1				1	WM6	
Grain wetting process water	1				1	WM7	
3MW boiler fuel			1		1	GM1	
Total process steam - to steam chests				1	1	SM1	
Steam supply to hot well				1	1	SM2	
Mill motor 1 electricity		1			1	EM5	
Mill motor 2 electricity		1			1	EM6	
Mill motor 3 electricity		1			1	EM7	
Mill motor 4a & 4b electricity		1			1	EM8	
Old and new workshop electricity		1			1	EM3	
Compressed air station		1			1	EM4	
Mill plant total		1			1	EM1	
Batch box switchboard		1			1	EM2	
Tub grinder		1			1	EM9	
Accomodation electricity utility meter		1			1	3051843935-1	3051843935-1
Induction shed/hospital utility meter		1			1	3051781948-1	3051781948-1
Total	**9**	**13**	**2**	**2**	**26**		

Scope improvement includes:

- **Reduced risk:** the decision was made to meter turkey's nest outfeed water to represent cattle drinking water, instead of trying to meter down to individual pen or pen row level. Due to pipe configuration, metering rows or pens would require excavation works and risk of pipe damage, an unacceptable risk for site operations.
    - After review, an alternative solution was found and involved the installation of high-quality, non-intrusive, ultrasonic meters on turkey nest outflows to pick up cattle drinking water. This negated the need to cut critical water infrastructure to install inline meters. The technology has been utilised before at other sites within the industry partners portfolio with positive feedback.
- **Communications:** several metering points within the feedlot are remote from power or IT infrastructure; hence special consideration had to be given to communications solutions.
    - After review, radio links were used with two points of data capture to avoid data loss.

Other essential improvements from the original scope:

- Connectivity of utility meters, which are covered under the industry partners own energy management planning, to the benefit of this research project.
- The capture of non-cattle drinking water such as dust suppression, grain wetting and amenities provide insightful information and support more accurate water balancing.

- The capture of hot well steam usage so that thermal system efficiency can be analysed.
- Measurement of large electrical loads such as the tub grinder, mill plant (by milling line), compressed air and workshop facilities.

3.1 Methods

Measurement and Verification (M&V) methodologies, in line with the International Performance Measurement and Verification Protocol (IPMVP), were used to measure and verify water and energy use improvements against the baseline and will be for future enhancements. Use of statistically valid regression models to monitor changes in water and energy intensity (for example, GJ/hd/d or L/hd/d) were leveraged.

All meter data is recorded and stored within third-party software package "Power Management Expert". This package can export data to Excel spreadsheets for further analysis and reporting.

3.2 Project Sequence

1) Review of annual historical baseline data (collected in 12-month blocks) – were available from the Feedlot.
2) Meters and data recording systems were commissioned over two months to measure water, electricity, gas, and steam.
3) After commissioning, data measurement occurred for a 12-month period.
4) Review of meter software outputs during the 12-month measurement period - using the software platform to demonstrate improvements in water and energy use efficiency. This used direct measurement devices installed, coupled to a software analytics package. This method provided feedback in real-time of operational changes made to reduce energy and water use and improve efficiency.
5) After the first six months of data collection, a review meeting was held between the feedlot, MLA and SBH to review opportunities for improvement in water and energy efficiency and shortlist opportunities for improvement.
6) After the 12 months, an opportunity review (energy and water productivity, renewables and storage), opportunity modelling and business case development (matched to feedlot collaborator standard) was produced to generate the economic feasibility (cost-benefit and payback period) that included at least 6 strategies to improve water and/or energy efficiency.
7) In combination with the MLA final report, an MLA tips and tools factsheet summarising six strategies to improve the energy efficiency of the 30,000 SCU steam-flaking feedlot was produced.

4 Results

4.1 Site energy and water baseline

The following data was collected and provides water and energy baseline consumption for 12 months before installing the metering system:

Table 3: energy and water baseline from 1 July 2018 to 30 June 2019

Utility type	Unit of measure	Consumption	End-use
Electricity	kWh/pa	1,435,095*	Mill plant, office, amenities, accommodation, and hospital
LNG	GJ/pa	35,864*	Boiler fuel for the flaking plant
Diesel	GJ/pa	7,622*	Feed trucks, general vehicles, and generators
Water	ML/pa	502.3224	For cattle, mill plant and amenities.

*Baseline energy figures were updated from previous milestone reports as FY19 NGER data was not available at that time. Updates include:

- Electricity from 922,822 to 1,435,095 kWh/pa to reflect NGER reporting data, solar generation, and the inclusion of accommodation consumption.
- LNG from 24,819 to 35,864 GJ/pa to reflect NGER reporting data.
- Diesel from 7,042 to 7,622 GJ/pa to include both vehicle consumption and stationary energy generation (for standby generators).

4.2 Review of renewable energy sources

Bioenergy

A basic estimate suggests 18,000 tonnes p.a of manure is generated from the facility (30,000 SCUs).

While considered a renewable energy resource, no further discussion is needed. The collection of manure without contamination and with adequate volatile solids in a typical outdoor earth pen feedlot is very challenging from a commercial perspective. We expect such a project to be economically unattractive (for example, the collection of manure as a feedstock for anaerobic digestion).

Solar PV

There is useful solar resource at the feedlot location with 1,199 to 1780 kWh/kWp per annum available. Of note is the swing in the generation between summer and winter months which can be much as 75%. The lowest month is 41 kWh/kW$_p$ and highest 159 kWh/kW$_p$.

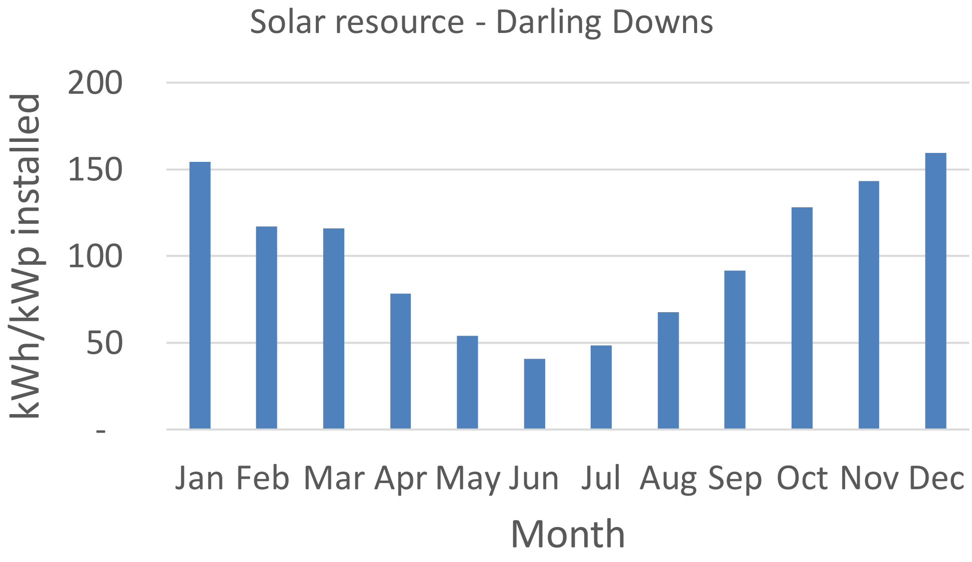

Figure 1: Darling Downs solar PV resource, source: PV watts

The Feedlot had already installed a 300kW$_p$ solar PV array (commissioned Nov 2017) when SBH started this project. A second 29kW$_p$ solar PV system for the induction shed was included in the preliminary list of opportunities, and to the feedlots credit brought forward and commissioned in September 2019.

A cost-benefit analysis for the 29 kW$_p$ system is included in Section 5.9.6.2 of this report.

Figure 2: Existing 300kW$_p$ Feedlot ground mount solar PV array

Figure 3: new 29kW$_p$ rooftop system under construction during the project period

Biomass

With respect to energy, the most useful biomass for feedlot operations is generally woodchips to fuel a biomass boiler; however, due to size of the boiler (3MW) and access to reasonably priced gas, a biomass boiler is economically and technically unattractive; hence no further investigation is warranted.

In general terms, biomass boilers start to become attractive at sizes over 5MW. This is due to the construction cost for auxiliary equipment such as biomass bunkers, material handling equipment, buildings and infrastructure required for a reliable solution.

Wind

The average wind speed in the feedlot area is 6.62m/s, which is too low to consider wind generation at this scale. Feedlot electrical demand is too small for a wind turbine to be attractive. Wind generation is more suited to utility-scale applications with average wind speeds of 10 m/s and above.

4.3 Energy and water management system scope

The majority of water and energy meters are clustered around the mill plant and associated infrastructure, with just six water meters remote from the mill plant for end uses such as cattle drinking water and accommodation.

Throughout the project, SBH has:

- Scoped, reviewed, and detailed equipment specifications and user requirements.

- Conducted site visits to confirm site build requirements to achieve project objectives and to meet/manage sub-contractors.
- Engaged and collaborated with the industry partner IT department to confirm proposed communications devices and hardware met the industry partner’s security requirements, and ensured successful integration with their systems.
- Facilitated deliverables of sub-contractors, suppliers, and auxiliary services to ensure delivery dates were executed, including weekly project meetings to drive outcomes.
- Managed technical issues surrounding physical meter installation such as gas compliance, electrical compliance, communications issues, and steam meter locations.
- Managed the install of the meter system as per the scope of works.
- Validated metering data using traditional energy management approaches.
- Developed site-specific energy and water dashboards and reports within the software package to support operational efficiency.
- Facilitated training and hand over sessions for site personnel.
- Leveraged metering data to support the development of Cost Benefit Analysis (CBA) for each efficiency opportunity.
- Engaged with contractors (where possible) to develop budget price estimates for efficiency opportunities as an input to CBAs.

4.4 Energy and water management system installation

The system network infrastructure design is provided below (Figure 4):

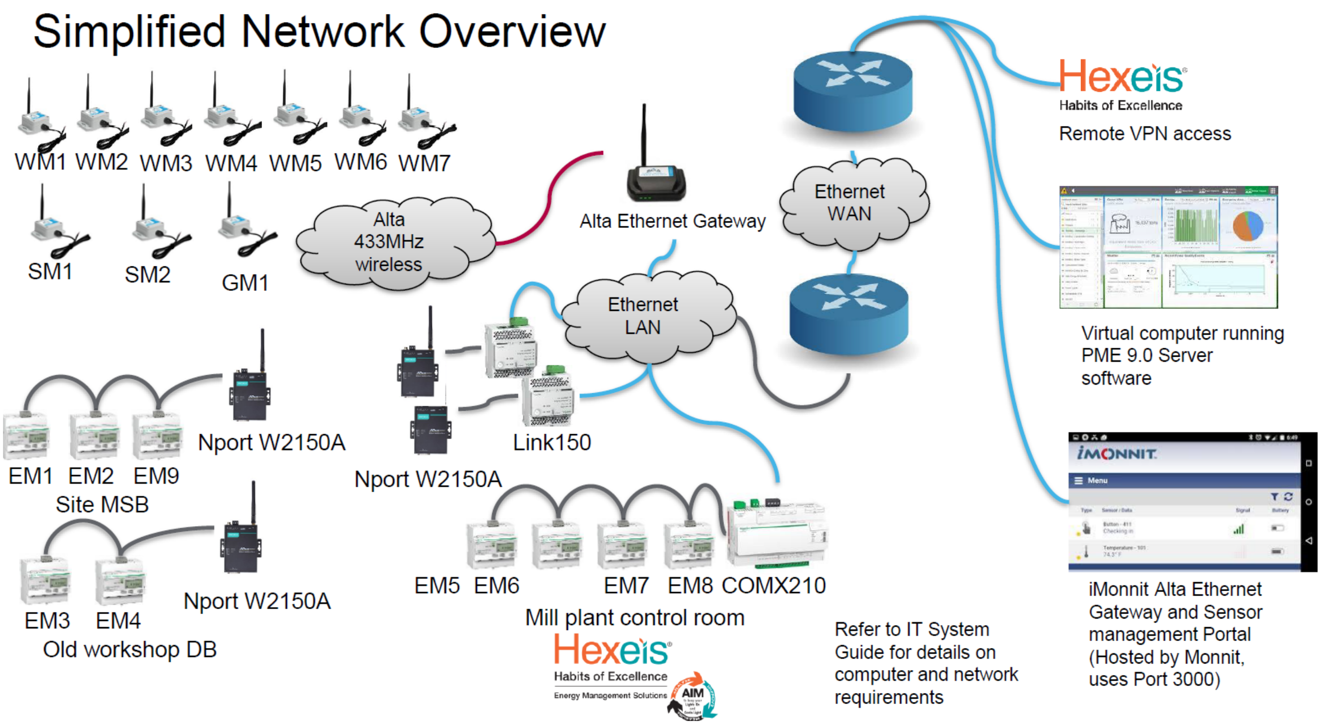

Figure 4: metering system network overview

Energy and water data are connected via a combination of radio, and industrial ethernet communications with high-quality instrumentation.

One LNG meter, two bore water meters and three electricity billing meters are connected via a National Electricity Market (NEM) approved Meter Coordinator portal, and part of the industry partners energy management strategy.

Total LNG data was validated in January 2020. These meters are not shown in Figure 4. They are revenue (billing) meters and operate under the same protocols required for the National Electricity Market (NEM).

At the end of milestone 2 (14 July 2019) all meters were installed, however some improvements where scheduled, these included:

- **Back-bore water meter:** upgraded to include a pulsing output so that it could be remotely read.
- **Solar PV output meter:** a utility grade meter was planned for installation, in addition to the existing SolarEdge meter to make it easier for the industry partner to create renewable energy certificates, however after detailed investigation it was proven to be cost-prohibitive. Data is still available via the Solaredge platform.
- **LNG meter:** a secondary output was connected so that the industry partner can remotely read this meter without having to contact their retailer. The meter was validated in January 2020.
- **Accommodation electricity meter:** the modem was upgraded early 2020 to allow for remote reading.

For new sub-meters (non-utility meters), the following technology has been used:

- Flexim ultrasonic flow meters for cattle drinking water.
- Endress and Hauser vortex meters for steam and gas flow.
- Mauflow turbine meters for low-grade water areas such as farm and accommodation water.
- Endress and Hauser prowhirl (magflow) for process water such as boiler makeup water.
- Schneider series kWh meters for electricity with Schneider gateways.
- Alta wireless radio gateways for remote communications.

All sub-meters are connected to the energy and water management platform. In contrast, the industry partner utility meters are connected to their own, internal big data analytics package and third-party metering software.

4.4.1 Installation by metering point

This section discusses and documents each metering point installation.

4.4.1.1 Bore 1 - utility meter

Bore 1 water meter is an existing turbine-style meter. However, the pulsing output from the meter had to be connected to the industry partners metering platform. Daily consumption files are transferred to their IT system in NEM12 format. The meter captures water drawn off bore number one located at the feedlot entry.

- **Location:** near the feedlot entrance, close to the RO shed.
- **Unique identifier:** bore one
- **Coverage:** bore one total water consumption

Figure 5: Bore 1 water meter

4.4.1.2 Bore 2 - utility meter

Bore 2 is a turbine-style meter that was upgraded to have a pulsing output connected to the industry partners metering platform. Bore 2 is remotely read (automatically) with daily consumption/flow data sent to their IT system. The meter captures water drawn from bore number two.

- **Location:** near the induction shed
- **Unique identifier:** bore 2
- **Coverage:** bore two total water consumption

Figure 6: Bore 2 - water meter

4.4.1.3 Mill electricity - utility meter

The Mill has a utility-grade EDMI Mk10E electricity meter with a National Meter Identifier (NMI). It has been modified to provide near real-time data.

- **Location:** main switchboard adjacent to the solar farm.
- **Unique identifier:** QFFF700013
- **Coverage:** total electricity consumption for the mill plant and all electricity around the mill plant (administration, amenities, workshops, compressed air, commodities shed)

Figure 7: Mill plant electricity meter

4.4.1.4 Solar farm electricity - utility meter

The mill solar farm has a CER approved solaredge meter to capture solar generation. It is connected to the solaredge monitoring portal and can be accessed remotely.

- **Location:** main switchboard adjacent to the solar farm
- **Unique identifier:** solar farm
- **Coverage:** solar farm output and patristic load

4.4.1.5 LNG - utility meter

The LNG meter is a utility meter located within the LNG compound managed by BOC. Via the industry partners metering partner, a PLC output has been programmed and connected to a pulse input meter so that gas consumption can be remotely read.

- **Location:** inside the LNG compound adjacent to the commodities shed loader entrance
- **Unique identifier:** LNG main
- **Coverage:** total LNG consumption

Figure 8: LNG compound and metering point

4.4.1.6 Turkeys nest outfeed 1 (cattle drinking water)

Turkeys nest outfeed 1 used high-quality ultra-sonic transducers mounted to the external pipe walls. Transducers are connected to the above-ground electrical cabinet powered by solar panel and batteries. Data is sent back to base via a radio link.

- **Location:** at the base of turkey nest one near the feedlot entrance, in the in-ground pit.
- **Unique identifier:** WM1
- **Coverage:** turkeys nest number 1 outflow that provides a portion of cattle drinking water for the older side of the feedlot (supplying drinking water for approximately 14,834 head of cattle and referred to as 100, 200 and 300 lanes by site). During this project site identified a down-stream junction; hence this meter captures part cattle drinking water for the old side (lanes 100 to 300). The site has since installed (September 2020) an additional meter to overcome this issue.

Figure 9: Turkeys nest outfeed 1 (cattle drinking water)

4.4.1.7 Turkeys nest outfeed 2 (cattle drinking water)

Turkeys nest outfeed 2 uses the same technology as Turkeys nest outfeed 1 (cattle drinking water) and captures total cattle drinking water for 400 to 600 lanes.

- **Location:** at the base of turkey nest two at the back of the Feedlot.
- **Unique identifier:** WM2
- **Coverage:** turkeys nest number 2 outflow that provides cattle drinking water for 400, 500 and 600 lanes.

Figure 10: Turkeys nest outfeed 2 (cattle drinking water)

4.4.1.8 Accommodation water

Accommodation water is an inline turbine meter with pulsing output, suitable for poly pipe connection and can handle hard water.

- **Location:** near the feedlot entrance close to the RO shed
- **Unique identifier:** WM3
- **Coverage:** Accommodation water consumption

Figure 11: Accommodation water

4.4.1.9 Dust suppression water

Dust suppression water is measured with a magnetic flow meter. The technology uses the change in magnetism to measure water flow accurately.

- **Location:** near the dust suppression truck filling station
- **Unique identifier:** WM4

- **Coverage:** dust suppression water

Figure 12: Dust suppression water

4.4.1.10 Farm supply

Farm water uses an inline turbine-style meter suitable for poly pipe connection and can handle hard water.

- **Location:** above ground, across the road from the RO water treatment shed
- **Unique identifier:** WM5
- **Coverage:** Farm water consumption

Figure 13: Farm supply

4.4.1.11 Boiler feedwater

Boiler hot well outflow or feedwater is measured using a magnetic flow meter.

- **Location:** on the outfeed from the boiler feedwater tank.
- **Unique identifier:** WM6

- **Coverage:** outflow from boiler feedwater tank to the boiler steam drum

Figure 14: boiler feedwater meter

4.4.1.12 Grain wetting process water

Grain wetting water is measured with an existing meter, connected to the industry partner mill plant PLC. SBH was able to use a secondary output from this meter and connect it to the energy and water management system.

- **Location:** at the grain wetting station on the south-east wall (outside) of the boiler house
- **Unique identifier:** WM7
- **Coverage:** process water for grain wetting

Figure 15: Grain wetting water meter

4.4.1.13 3MW boiler fuel

A corrected vortex meter was installed on the 3MW boiler gas fuel line to measure energy flow.

- **Location:** boiler house
- **Unique identifier:** GM1
- **Coverage:** 3MW gas-fired boiler fuel consumption

Figure 16: 3MW boiler fuel - energy meter

4.4.1.14 Total process steam - to steam chests

Process steam is measure with a corrected vortex meter to capture energy flow.

- **Location:** boiler house
- **Unique identifier:** SM1
- **Coverage:** total process steam from steam header to grain chests

Figure 17: process steam - energy meter

4.4.1.15 Steam supply to hot well

A vortex meter, capable of measuring energy flow, has been installed on the hot well steam supply line.

- **Location:** boiler house

- **Unique identifier:** SM2
- **Coverage:** steam supply to hot well to maintain makeup water temperature

Figure 18: hot well steam supply meter

4.4.1.16 Mill motor electricity

Mill motor electricity is captured using Schneider kWh meters with split-core Current Transformers. (CTs). The mill plant is noted as having three Benmic 18 x36” Mills and one 20 x 36” R&R Mill (four mills in total). Three 6MT steam chest (above the Benmic Mills) and one 8MT steam chest (above R&R mill).

Above the steam chests are four 30MT overhead surge bins that are also used for tempering. Dry grain is transferred from a 12,000 MT (approximate) dry grain storage area.

#	Location	Unique identifier	Coverage
1	Mill control room switchboard	EM5	Mill motor 1
2	Mill control room switchboard	EM6	Mill motor 2
3	Mill control room switchboard	EM7	Mill motor 3
4	Mill control room switchboard	EM8	Mill motor 4a and 4b

Figure 19: Mill motor electricity meters

4.4.1.17 Compressed air station

Compressed air electricity is captured with Schneider kWh meters and split-core CTs.

- **Location:** old workshop
- **Unique identifier:** EM4
- **Coverage:** workshop and process compressed air plant

4.4.1.18 Main switchboard electrical meters

Electricity for the entire mill plant, batch box switchboard, tub grinder and workshop are captured by individual Schneider kWh meters with split-core Current Transformers.

#	Location	Unique identifier	Coverage
1	Main switchboard	EM1	Mill plant - total control room
2	Main switchboard	EM2	Batch box switchboard
3	Main switchboard	EM9	Tub grinder
4	Main switchboard	EM3	Old and new workshops

Figure 20: Main switchboard electrical meters

5 Discussion

5.1 Energy and water management system - 12 months of data

This section provides a graphical and tabulated representation of meter data as well as some analysis utilising 12 months of post-commissioning data.

Extract meter data was used to fulfil MLA's reporting requirements for the project which include:

- Water consumption data recorded as L/hd/d for each month of measurement, considering climatic data and dry matter intake factors. KPIs were developed including:
  - Total site water (including all site usage and losses)
  - Cattle drinking water in isolation: cattle drinking water was accurately measured for the new section of the feedlot (referred to as 400, 500 and 600 lanes) which services approximately 14,057 head of cattle.
- Market categories of cattle present at the feedlot.
- Grain processing data collected in tonnes, considering different grain type flaked (wheat and barley)
- Roller hours since recorrugation*
- Total feed batched (tonnes feed batched)
- Occupancy of Feedlot (head days) factored into mill electrical consumption.

*The industry partner facility was unable to provide roller hours for milestone three as they have been implementing a control system upgrade. Included in the control system upgrade is the capture of Mill-run hours at the mill computer with the ability to enter "reset dates" when a roller is serviced. Included in this report is Mill run hours from 3 June 2020 till 31 July 2020.

5.2 Production data

Production data was collected and used to compute energy and water intensity KPIs for the industry partner facility. For reference, a description of the mill plant is as follows:

Steam is supplied to four steam chests: three 6Mt chests and one 8Mt chest. Above the steam chests are four 30Mt overhead surge bins that are also used for tempering. Below are four roller mills: three Benmic 18 x36" mills, and one R&R 20 x 36" mill.

Dry grain is transferred from a 12,000 Mt (approximate) dry grain storage area.

The following production data was collected:

Table 4: production data

#	Month	Head days	Total tonnes flaked (as fed)	Total tonnes flaked (DM)	Total tonnes (delivered)	Total Tonnes DM (delivered)	Barley, % flaked tonnage (as-fed)	Wheat, % flaked tonnage (as-fed)
1	Aug	31,559	9,294	7,297	12,842	10,024	100%	0%
2	Sep	32,360	9,330	7,249	12,943	10,058	92%	8%
3	Oct	32,474	9,860	7,407	13,953	10,540	46%	54%
4	Nov	31,883	8,862	7,011	13,384	10,356	0%	100%
5	Dec	31,189	9,000	7,103	13,708	10,757	0%	100%
6	Jan	29,300	9,700	7,646	12,440	9,730	26%	74%
7	Feb	24,852	6,117	4,847	9,277	7,161	32%	68%
8	Mar	24,647	7,155	5,713	9,975	7,817	70%	30%
9	Apr	27,892	7,560	5,764	10,876	8,462	94%	6%
10	May	28,310	8,790	6,835	12,327	9,401	100%	0%
11	Jun	28,306	9,747	6,557	11,489	8,721	86%	14%
12	Jul	25,814	8,290	6,491	10,620	8,126	100%	0%
Totals		**29,049**	**103,705**	**79,919**	**143,834**	**111,151**	**62% (average)**	**38% (average)**

5.3 Total Energy

The breakup of total baseline energy use across the Feedlot is:

- **Thermal (74%):** gas to fuel the boiler(s) to generate steam for the flaking plant
- **Diesel (16%):** for feedlot trucks and other vehicles
- **Electricity (10%):** for the mill plant, administration, and accommodation.

Percentages (Figure 21) derived from the 12-month baseline period 1 July 2018 to 30 June 2019 for each utility, then converted to standardised units (GJ/pa).

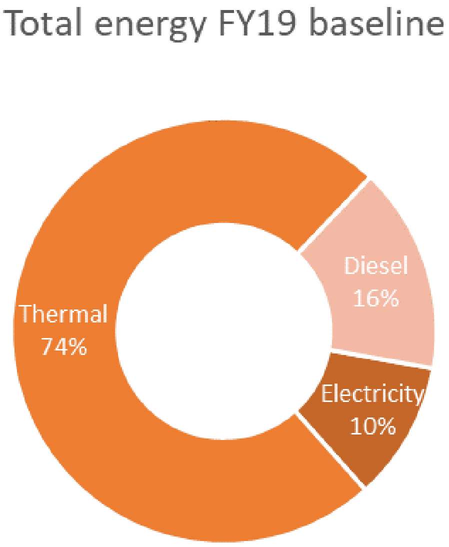

Figure 21: Total energy – baseline period

In comparison (Figure 22), data from the measurement period (1 August 2019 to 31 July 2020) indicates similar portions of thermal energy (74% vs 67% respectively).

Since completing a Type 2 energy audit in 2015, the Feedlot has progressively advanced energy management, efficiency, and renewable energy opportunities, including:

- Tariff reviews and strategic procurement.
- LED lighting rollout and lighting controls.
- Improved compressed air system performance.
- Removal of electric heating from some commodity storage vessels.
- 300kWp of solar PV.
- Improved steam management and thermal insulation.

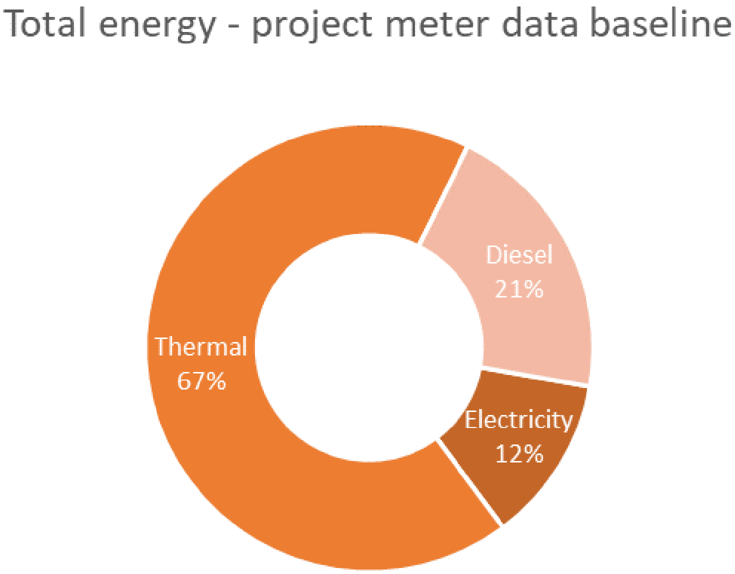

Figure 22: total energy - measurement period 1 August 2019 to 31 July 2020

Total facility energy and intensity for the measurement period is provided in the following table. This considers three measures of intensity for MJ/hd/d, MJ/Tonne delivered, and MJ/Tonne delivered Dry Matter (DM). This includes all energy sources for the feedlot operation of thermal, diesel and electricity.

Table 5: Total energy performance during the measurement period

#	Month	Days	Head days	Total energy (MJ)	Total energy intensity (MJ/hd/d)	Total energy intensity (MJ/hd/month)	Total energy intensity (MJ/tonne, delivered)	Total energy intensity (MJ/tonne delivered, DM)
1	Aug	31	31,559	3,762,142	3.85	119.21	292.96	375.33
2	Sep	30	32,360	3,149,616	3.24	97.33	243.34	313.14
3	Oct	31	32,474	3,945,933	3.92	121.51	282.80	374.38
4	Nov	30	31,883	3,476,935	3.64	109.05	259.77	335.75
5	Dec	31	31,189	3,427,798	3.55	109.91	250.06	318.67
6	Jan	31	29,300	3,008,039	3.31	102.66	241.80	309.15
7	Feb	29	24,852	2,338,577	3.24	94.10	252.08	326.59
8	Mar	31	24,647	3,062,345	4.01	124.25	307.01	391.77
9	Apr	30	27,892	3,331,227	3.98	119.43	306.29	393.65
10	May	31	28,310	3,626,185	4.13	128.09	294.17	385.73
11	Jun	30	28,306	3,457,177	4.07	122.14	300.91	396.43
12	Jul	31	25,814	3,641,784	4.55	141.08	342.93	448.17
Totals		**366**	**29,049 (average)**	**40,227,758**	**3.79 (average)**	**115.73 (average)**	**281.18 (average)**	**364.06 (average)**

5.4 Thermal Energy

Thermal energy represents the majority (67 to 74%) of energy consumption. Historically, thermal energy was estimated using baseline data and energy engineering principles. Metering of thermal energy is rarely seen at feedlots or any industrial facility as it can be difficult and expensive to implement.

This project attempts to close that gap and demonstrate the value of thermal metering when coupled to an Energy and Water Management System (EWMS).

Figure 23 is an extract of the EWMS. Boiler fuel consumption fluctuates from 3 to 8.5 GJ/hr, representing a thermal load of 800 to 2350 kW. The boiler appears to fluctuate between medium and high fire to maintain steam pressure in the steam drum. The burner has basic controls with inadequate turn-down ratios to achieve reasonable thermal efficiency. This is discussed further in Section 5.9 as an opportunity.

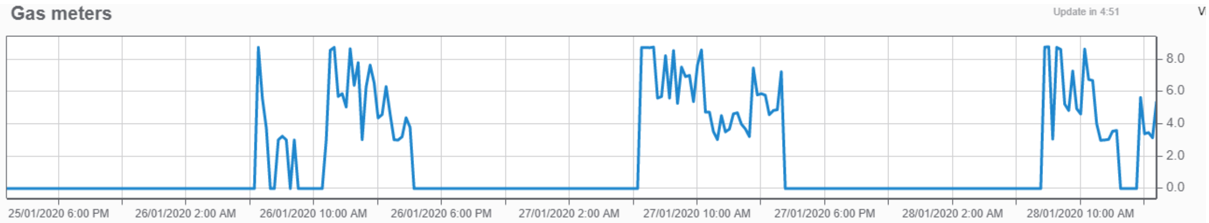

Figure 23: Boiler fuel consumption

As mentioned in the production section, steam is supplied to four steam chests: three 6Mt chests and one 8Mt chest. Above the steam chests are four 30Mt overhead surge bins that are also used for tempering. Below are four roller mills: three Benmic 18 x36” mills, and one R&R 20 x 36” mill.

Dry grain is transferred from a 12,000 Mt (approximate) dry grain storage area.

Total thermal energy and intensity for the measurement period is provided below (Table 6). This considers three measures of intensity for MJ/hd/d, MJ/Tonne flaked, and MJ/Tonne flaked Dry Matter (DM).

Table 6: Total thermal energy performance during the measurement period

#	Month	Thermal energy consumed (MJ)	Thermal energy intensity (MJ/hd/d)	Thermal energy intensity (MJ/Tonne flaked)	Thermal energy intensity (MJ/Tonne DM flaked)
1	Aug	2,716,410	2.78	292.28	372.28
2	Sep	2,125,099	2.19	227.77	293.17
3	Oct	2,881,366	2.86	292.23	388.99
4	Nov	2,297,088	2.40	259.21	327.66
5	Dec	2,186,274	2.26	242.92	307.82
6	Jan	1,841,840	2.03	189.88	240.90
7	Feb	1,392,107	1.93	227.58	287.21
8	Mar	1,935,399	2.53	270.50	338.77
9	Apr	2,200,189	2.63	291.03	381.69
10	May	2,487,142	2.83	282.95	363.87
11	Jun	2,375,771	2.80	243.75	362.31
12	Jul	2,689,000	3.36	324.37	414.26
Totals		**27,127,687**	**2.55 (average)**	**262.04 (average)**	**339.91 (average)**

The industry standard for measuring thermal energy intensity is provided graphically in MJ/hd/d on Figure 24.

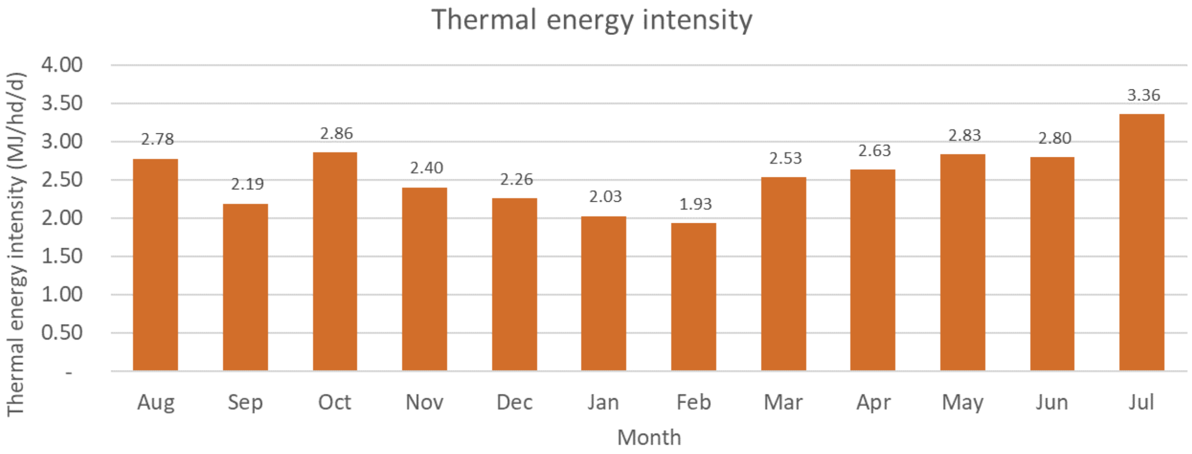

Figure 24: Total facility thermal energy intensity (MJ/hd/d)

Thermal performance does vary, and it pays to monitor intensity at a daily interval. This ensures changes in fuel cost don't go unnoticed. Going into more detail on steam, Table 7, Table 8 and Table 9 provide the work done by total, process and hot well steam. This data set will provide value when evaluating new technologies as they become commercially available, such as high temperature heat pumps for steam generation.

Table 7: total energy intensity (process steam plus hot well heating) for steam produced

#	Month	Total steam energy produced (MJ) (total process steam + hot well heating)	Total steam energy intensity (MJ/hd/d)	Total steam energy intensity (MJ/Tonne flaked)	Total steam energy intensity (MJ/Tonne DM flaked)
1	Aug	2,327,095	2.38	250.39	318.93
2	Sep	2,224,144	2.29	238.39	306.84
3	Oct	1,892,520	1.88	191.94	255.50
4	Nov	2,002,901	2.09	226.01	285.69
5	Dec	1,888,371	1.95	209.82	265.87
6	Jan	1,727,548	1.90	178.10	225.96
7	Feb	1,244,288	1.73	203.41	256.71
8	Mar	1,481,508	1.94	207.06	259.32
9	Apr	1,715,069	2.05	226.86	297.53
10	May	2,006,093	2.29	228.22	293.49
11	Jun	1,972,211	2.32	202.35	300.77
12	Jul	1,935,926	2.42	233.53	298.25
Totals		**22,417,674**	**2.10 (average)**	**216.34 (average)**	**280.40 (average)**

Table 8: thermal intensity for process steam produced

#	Month	Process steam energy produced (MJ)	Process steam energy intensity (MJ/hd/d)	Process steam energy intensity (MJ/tonne flaked)	Process steam energy intensity (MJ/tonne DM flaked)
1	Aug	2,120,020	2.17	228.11	290.55
2	Sep	2,070,810	2.13	221.95	285.68
3	Oct	1,845,900	1.83	187.21	249.20
4	Nov	1,910,778	2.00	215.61	272.55
5	Dec	1,750,745	1.81	194.53	246.50
6	Jan	1,655,590	1.82	170.68	216.54
7	Feb	1,182,920	1.64	193.38	244.05
8	Mar	1,411,500	1.85	197.27	247.07
9	Apr	1,651,150	1.97	218.41	286.45
10	May	1,929,870	2.20	219.55	282.34
11	Jun	1,851,570	2.18	189.97	282.37
12	Jul	1,773,330	2.22	213.91	273.20
Totals		**21,154,183**	**1.99** (average)	**204.22** (average)	**264.71** (average)

Table 9: thermal intensity for hot well heating steam

#	Month	Hot well steam energy produced (MJ)	Hot well steam energy intensity (MJ/hd/d)	Hot well steam energy intensity (MJ/tonne flaked)	Hot well steam energy intensity (MJ/tonne DM flaked)
1	Aug	207,075	0.21	22.28	28.38
2	Sep	153,334	0.16	16.43	21.15
3	Oct	46,620	0.05	4.73	6.29
4	Nov	92,123	0.10	10.40	13.14
5	Dec	137,626	0.14	15.29	19.38
6	Jan	71,958	0.08	7.42	9.41
7	Feb	61,368	0.09	10.03	12.66
8	Mar	70,008	0.09	9.78	12.25
9	Apr	63,919	0.08	8.45	11.09
10	May	76,223	0.09	8.67	11.15
11	Jun	120,641	0.14	12.38	18.40
12	Jul	162,596	0.20	19.61	25.05
Totals		**1,263,491**	**0.12** (average)	**12.12** (average)	**15.70** (average)

Within the project scope, steam meters were installed on the main process steam line and hot well steam line so that total steam load and intensity (Table 7) could be measured. These meters were set up to measure energy flow (in GJ/hr) as opposed to traditional approaches that look for steam flow (in kg or tonnes/hr).

A gas meter was installed on the main 3MW boiler – this boiler is utilised approximately 75% of the year.

The intent was to monitor boiler Coefficient of Performance (COP) as a proxy for efficiency using the input-output method (source; http://cleaverbrooks.com/reference-center/insights/Boiler%20Efficiency%20Guide.pdf).

Data used to estimate COP is provided in Table 10. Estimated COP is based on:

COP = Process steam energy (MJ) / Total input energy (MJ)

Where:

- Process steam energy (MJ) = direct measurement by the total process steam meter.
- Total input energy (MJ) = total gas energy (MJ) + measured volume of boiler feedwater x enthalpy (kJ/kg) of make-up water at 40°C.

Table 10: boiler performance

#	Month	3MW boiler gas consumption (MJ)	Total thermal energy (MJ)	Boiler feedwater (L)	Total energy input (MJ)	Process steam energy (MJ)	Estimated thermal efficiency/COP (%)
1	Aug	1,916,250	2,716,410	958,450	2,878,197	2,120,020	74%
2	Sep	1,824,090	2,125,099	848,850	2,268,385	2,070,810	91%
3	Oct	1,404,030	2,881,366	715,660	3,002,170	1,845,900	61%
4	Nov	1,729,000	2,297,088	703,270	2,415,800	1,910,778	79%
5	Dec	1,729,025	2,186,274	821,880	2,325,008	1,750,745	75%
6	Jan	1,471,880	1,841,840	708,490	1,961,433	1,655,590	84%
7	Feb	928,590	1,392,107	542,300	1,483,647	1,182,920	80%
8	Mar	1,366,000	1,935,399	612,220	2,038,742	1,411,500	69%
9	Apr	1,790,610	2,200,189	696,750	2,317,801	1,651,150	71%
10	May	2,183,390	2,487,142	826,120	2,626,591	1,929,870	73%
11	Jun	1,994,960	2,375,771	900,410	2,527,760	1,851,570	73%
12	Jul	1,730,380	2,689,000	995,850	2,857,099	1,773,330	62%
Total		**20,068,205**	**27,127,687**	**9,330,250**	**28,702,633**	**21,154,183**	**74% (average)**

When reviewing this data down to an individual boiler level at 30min intervals, the thermal lag between fuel burn and steam generation became clear, this is expected but may appear odd to the untrained eye as there are times when interval data (30min and hourly) suggests a COP or efficiency greater than 1 or 100% which isn't technically possible. The better way of using this data is looking at total daily or monthly energy produced, divided by total daily or monthly energy added to the system. In the example above, we have estimated total input energy using the measured gas energy, plus enthalpy of make-up water at 40°C and the measured volume of boiler feedwater.

We have not included condensate return in this calculation as flow is not measured, and volumes are very small. Condensate is returned from steam traps (only), hence it is insignificant. COP is then calculated by dividing process steam energy by total energy added to the system.

This method isn't perfect as can be seen in September when the estimated COP is 91% which is unlikely. In reality, a COP of 65% to 75% is expect for the site-specific set up. However, the measurement does provide significant value when used as an indicator of thermal efficiency by observing daily trends over time, in combination with monitoring stack temperature and flaking intensity.

We also used the data to calculate if the boiler was running in an optimal configuration, considering things like:

- Efficiency at running load
- The ratio of process steam to parasitic load (for example, to heat feedwater). Very useful in an open-ended system with almost 100% makeup water.

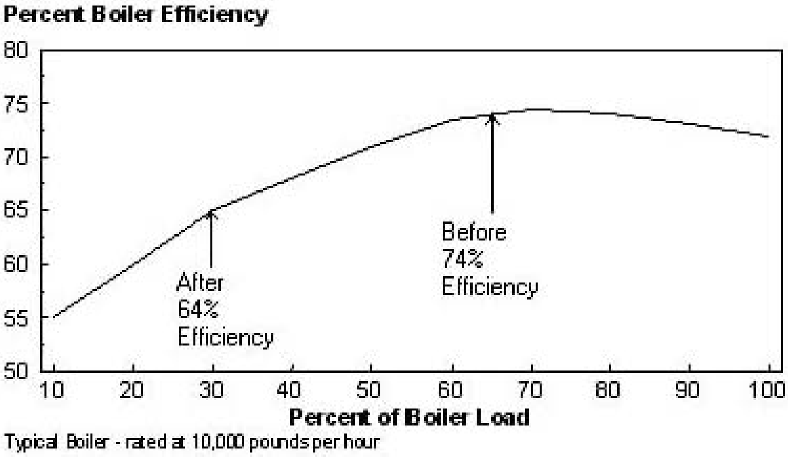

Figure 25: typical efficiency to load curve for a steam boiler; source https://c03.apogee.net/mvc/home/hes/land/el?utilityname=peco&spc=cel&id=19026

If more accurate COP measurement is desired, there are systems available that can take care of thermal lag and blow down losses like this one from Spirax Sarco:

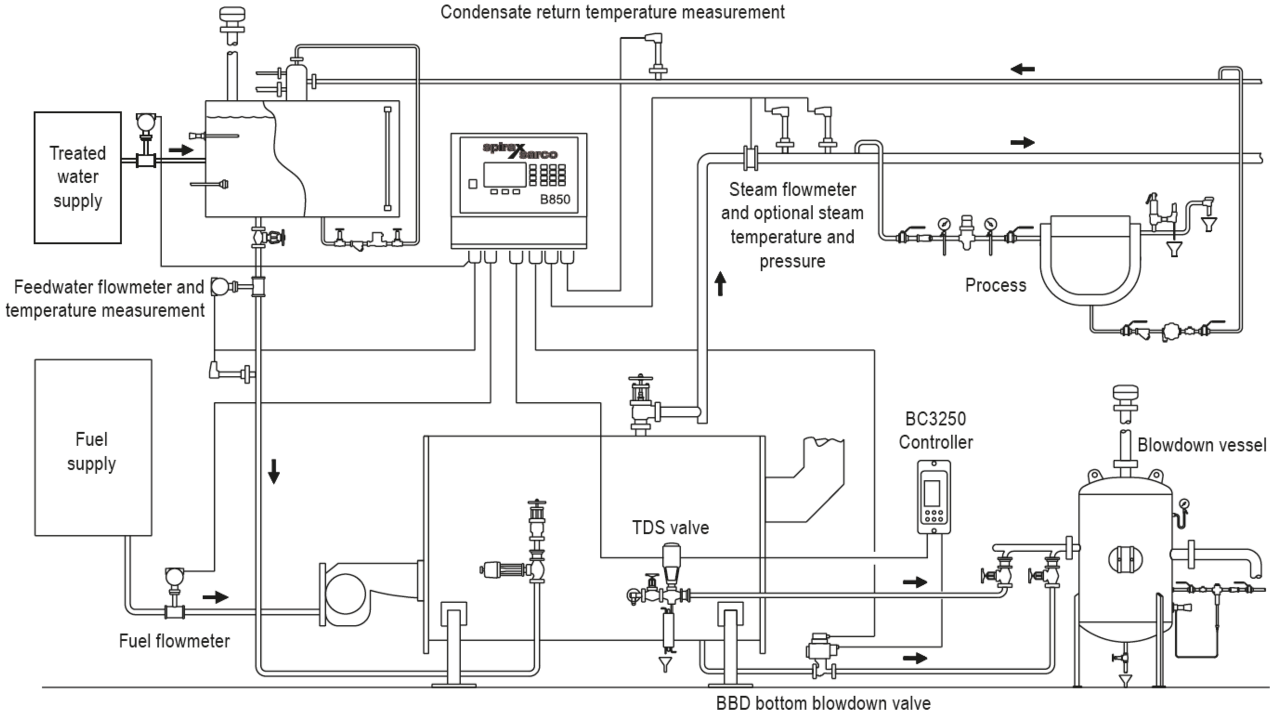

Figure 26: boiler efficiency measurement, typical boiler house application, source; Spirax Sarco

5.5 Diesel fuel energy

Diesel is an important energy resource for feedlot operators (21% of total energy use) and used to power feedlot trucks, loaders, tractors and pen scrapers, generators and many other vehicles and machines. In this example, diesel consumption at the industry partners facility is recorded by a fuel management system and represented as follows:

Table 11: monthly diesel use and intensity

#	Month	Diesel energy (Litres)	Diesel energy (MJ)	Diesel intensity (L/hd/d)	Diesel intensity (L/Tonne) as fed	Diesel intensity (L/Tonne) DM
1	Aug	16,447	634,855	0.02	1.28	1.64
2	Sep	15,696	605,872	0.02	1.21	1.56
3	Oct	16,664	643,228	0.02	1.19	1.51
4	Nov	19,963	770,561	0.02	1.49	1.93
5	Dec	20,278	782,728	0.02	1.48	1.89
6	Jan	18,348	708,225	0.02	1.47	1.89
7	Feb	13,914	537,073	0.02	1.50	1.94
8	Mar	19,578	755,714	0.03	1.96	2.50
9	Apr	19,092	736,942	0.02	1.76	2.26
10	May	19,378	747,975	0.02	1.57	2.06
11	Jun	18,618	718,673	0.02	1.62	2.13
12	Jul	15,822	610,743	0.02	1.49	1.95
Totals		**213,798**	**8,252,591**	**0.02 (average)**	**1.50 (average)**	**1.94 (average)**

Splitting consumption across categories, it is no surprise that feedlot trucks have the highest consumption (39%) operating around eight hours a day, seven days a week. This is followed by loaders (28%) and tractors, scrapers and bobcats (21%).

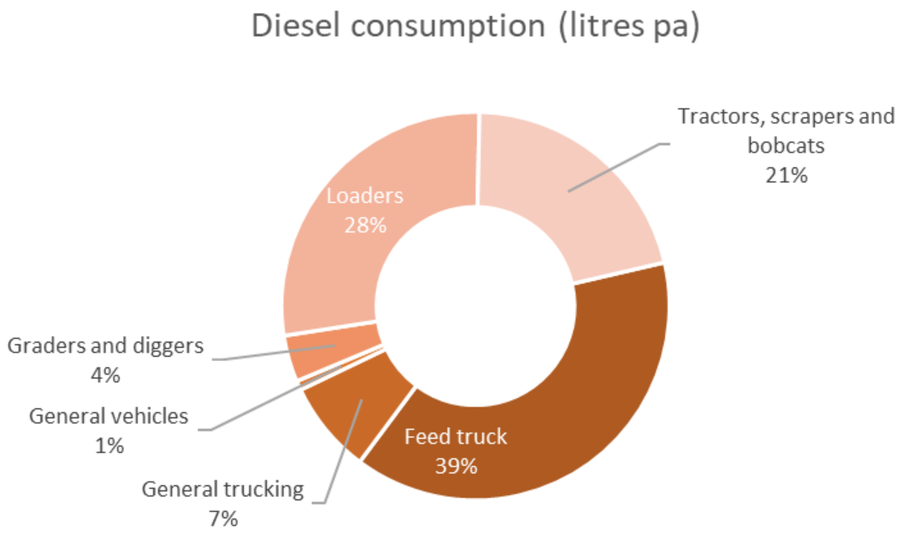

Figure 27:diesel use by category (%)

Vehicles quantities are provided in the following table:

Table 12: quantity of vehicles

Category	Quantity
Feed truck	6
General trucks	3
General purposes vehicles (utes, 4x4's)	11
Graders and diggers	2
Loaders	6
Tractors, scrapers and bobcats	7
Telehandler	1
Total	**37**

Diesel is expected to be disrupted by low emissions alternatives such as renewable methane, hydrogen or electric vehicles over the next 5 to 15 years. While commercially attractive alternatives are limited today, it is worth keeping a watching brief on these emerging technologies.

5.6 Electrical Energy

Electrical energy is another crucial input for feedlot operators, in most cases, feedlots experience high unit rates ($/kWh) as they are in fringe of grid or remote locations or have limited options to procure energy strategically.

At the industry partner facility, there are three electricity billing (or utility) meters of:

- **NMI QFFF700013-1:** this supplies electricity to the mill plant, amenities, workshop, commodities shed, tub grinder, administration, workshop(s), compressed air, front bore pump, water treatment and boiler house electricity. 87% of electrical energy is associated with this meter.
- **NMI: 3051781948-1:** this meter's electricity for the Induction shed, hospital, back bore pump electricity meter and equates to 9% of total site electricity.
- **NMI 3051843535-1:** this meter's staff accommodation electricity which is 4% of total site electricity consumption.

Data from all three meters were used to capture total energy needs. Baseline electricity consumption was 1,435,095 kWh/pa in FY19 (see Table 3: energy and water baseline from 1 July 2018 to 30 June 2019) with 38% of that coming from onsite renewable solar generation.

When we compare total electricity consumption in the baseline year (1 July 2018 to 30 June 2019) to the measurement period (1 August 2018 to 31 July 2020), it was slightly less at 1,346,522 kWh. A difference of 6.2%.

A better comparison is kWh/hd/d – and note the site is working on integrating head data with the EWMS so the KPI can be tracked and reported.

Table 13: Metered electricity consumption data (August 2019 to July 2020)

#	Month	Mill plant (kWh)	Solar generation (kWh)	Total Mill (kWh)	Induction/ hospital (kWh)	Accommodation (kWh)	Total site (kWh)	Renewable (%)
1	Aug	60,938	41,038	101,975	7,610	4,547	114,132	36%
2	Sep	57,136	44,241	101,377	10,934	3,979	116,290	38%
3	Oct	56,565	44,075	96,075	12,479	3,919	117,039	38%
4	Nov	51,011	49,096	95,126	9,278	4,305	113,691	43%
5	Dec	56,911	55,957	107,674	8,157	6,419	127,443	44%
6	Jan	58,232	54,882	108,019	7,803	6,298	127,215	43%
7	Feb	55,229	49,268	99,911	4,794	4,430	113,721	43%
8	Mar	48,990	44,327	89,062	5,506	4,298	103,120	43%
9	Apr	58,940	38,854	94,266	7,636	4,040	109,471	35%
10	May	67,671	32,361	97,188	4,617	3,981	108,630	30%
11	Jun	63,847	30,010	91,430	2,581	4,321	100,759	30%
12	Jul	54,050	33,551	84,955	2,910	4,500	95,011	35%
Totals		**689,518**	**517,661**	**1,167,058**	**84,306**	**55,037**	**1,346,522**	**38% (average)**

Using data from Table 13, the following is provided for the 12-month measurement period (1 July 2019 to 31 August 2020):

- **Mill plant (grid):** 689,518kWh
- **Solar generation:** 517,661kWh
- **Total mill plant:** 1,167,058 kWh
- **Induction/hospital:** 84,306kWh

- **Accommodation:** 55,037 kWh
- **Total site electricity:** 1,346,522kWh
- **Average Percentage of renewable electricity:** 38%

Table 14: electrical intensities based on kWh's

#	Month	Head count	Total tonnes (delivered)	Total Tonnes DM (delivered)	Electrical intensity (kWh/hd/d)	Electrical intensity (kWh/tonne fed)	Electrical intensity (kWh/Tonne DM)
1	Aug	31,559	12,842	10,024	0.12	8.9	11.4
2	Sep	32,360	12,943	10,058	0.12	9.0	11.6
3	Oct	32,474	13,953	11,033	0.12	8.4	10.6
4	Nov	31,883	13,384	10,356	0.12	8.5	11.0
5	Dec	31,189	13,708	10,757	0.13	9.3	11.8
6	Jan	29,300	12,440	9,730	0.14	10.2	13.1
7	Feb	24,852	9,277	7,161	0.16	12.3	15.9
8	Mar	24,647	9,975	7,817	0.13	10.3	13.2
9	Apr	27,892	10,876	8,462	0.13	10.1	12.9
10	May	28,310	12,327	9,401	0.12	8.8	11.6
11	Jun	28,306	11,489	8,721	0.12	8.8	11.6
12	Jul	25,814	10,620	8,126	0.12	8.9	11.7
Totals		**29,049**	**143,834**	**111,644**	**0.13 (average)**	**9.4 (average)**	**12.1 (average)**

Table 15: electrical intensities based on MJ's

#	Month	Head count	Total tonnes (delivered)	Total Tonnes DM (delivered)	Electrical intensity (MJ/hd/d)	Electrical intensity (MJ/tonne fed)	Electrical intensity (MJ/Tonne DM)
1	Aug	31,559	12,842	10,024	0.42	32.00	40.99
2	Sep	32,360	12,943	10,058	0.43	32.34	41.62
3	Oct	32,474	13,953	11,033	0.42	30.20	39.98
4	Nov	31,883	13,384	10,356	0.43	30.58	39.52
5	Dec	31,189	13,708	10,757	0.47	33.47	42.65
6	Jan	29,300	12,440	9,730	0.50	36.81	47.07
7	Feb	24,852	9,277	7,161	0.57	44.13	57.17
8	Mar	24,647	9,975	7,817	0.49	37.22	47.49
9	Apr	27,892	10,876	8,462	0.47	36.23	46.57
10	May	28,310	12,327	9,401	0.45	31.72	41.60
11	Jun	28,306	11,489	8,721	0.43	31.57	41.59
12	Jul	25,814	10,620	8,126	0.43	32.21	42.09
Totals		**29,049**	**143,834**	**111,644**	**0.46 (average)**	**34.04 (average)**	**44.03 (average)**

Using the same data set, Figure 28 presents the electricity breakup using measured electrical energy in kWh as the unit of measure to derive percentage breakup:

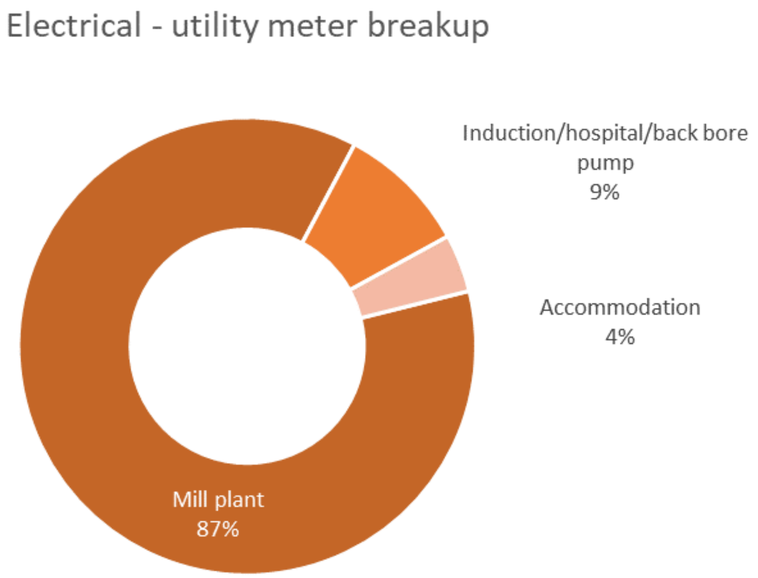

Figure 28: utility meter - electricity break up for the first 12-month measurement period (1 July 2019 to 31 August 2020)

Utilising the new EWMS, the following commentary is provided to drill down into electrical energy use (Figure 29: electricity balance):

- 27% of electricity is attributed to mill auxiliary plant loads such as transfer augers, after-hours lighting, controls, boiler equipment and pumps, some of which can run through the night.
- Roller mill motors represent 23% and run 6 to 9 hours a day, however, are by far the most significant electrical demand (kW/kVA) onsite.
- Other significant loads include the Induction and hospital shed (9%), administration and amenities (7%) and the tub grinder (2%) used to separate hay bales.

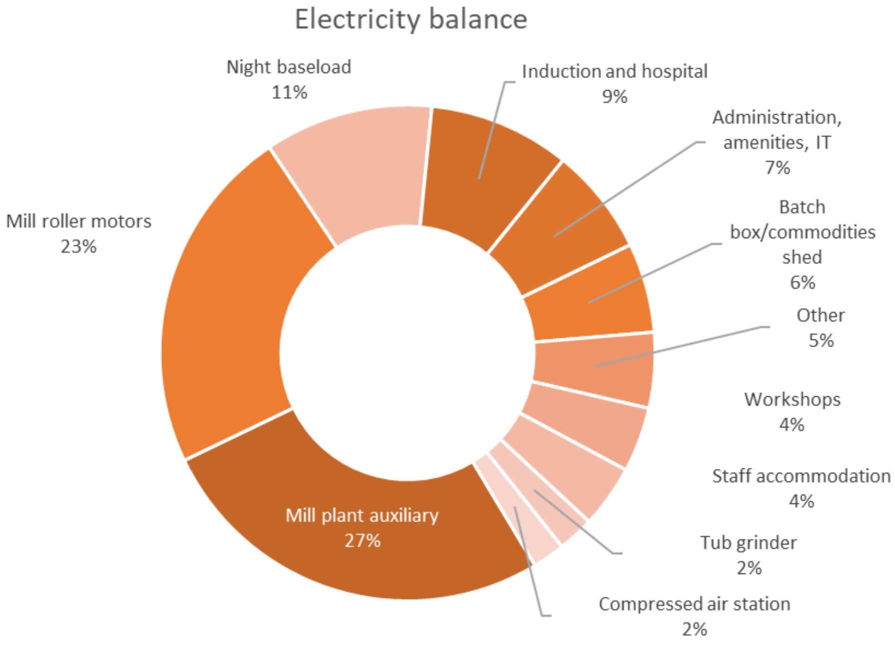

Figure 29: electricity balance for the 12 month measurement period from 1 August 2019 to 31 July 2020 using electrical energy in kWh as a proxy for percentage balance.

Going into more detail we can assess the performance of the mill on an intensity basis for mixtures of white cereal grains such as wheat and barley (Table 16). The best way to use these KPIs is by comparing either annual or daily intensity. The Feedlot operator will be able to compare daily intensity using the EWMS and Feedlot management system.

Table 16: mill electrical intensity

Month	Mill electrical energy (kWh) (x4)	Total tonnes flaked (as fed)	Total tonnes flaked (DM)	Barley, % flaked tonnage (as fed)	Wheat, % flaked tonnage (as-fed)	Mill electricity intensity (kWh/tonne flaked, as fed)	Mill electricity intensity (kWh/tonne flaked, DM)	Tonnes flaked per mill hour (as fed) *
Aug	24,210	9,294	7,297	100%	0%	2.60	3.32	NA
Sep	23,692	9,330	7,249	92%	8%	2.54	3.27	NA
Oct	23,546	9,860	7,407	46%	54%	2.39	3.18	NA
Nov	23,016	8,862	7,011	0%	100%	2.60	3.28	NA
Dec	23,813	9,000	7,103	0%	100%	2.65	3.35	NA
Jan	28,994	9,700	7,646	26%	74%	2.99	3.79	NA
Feb	26,433	6,117	4,847	32%	68%	4.32	5.45	NA
Mar	17,899	7,155	5,713	70%	30%	2.50	3.13	NA
Apr	23,507	7,560	5,764	94%	6%	3.11	4.08	NA
May	30,080	8,790	6,835	100%	0%	3.42	4.40	NA
Jun	28,690	9,747	6,557	86%	14%	2.94	4.38	8.82
Jul	28,351	8,290	6,491	100%	0%	3.42	4.37	8.65
Totals	**302,230**	**103,705**	**79,919**	**62% (average)**	**38% (average)**	**2.96 (average)**	**3.83 (average)**	**NA**

*due to a PLC issue, mill roller hours were not available till June 2020.

The EWMS has many features to support optimal use of utilities, below are some example dashboards that have been set up to monitor electricity consumption:

Figure 30 shows a day on day comparison of electrical demand so that operators can see how the different combination of mill motors compare and how the profile looks compared to the day before. This has many other features, such as comparing the same day of the week or days in the month or year. This allows the operators to analyse production data to drive the lowest energy intensity per tonne milled or identify issues such as the reduction in roller performance.

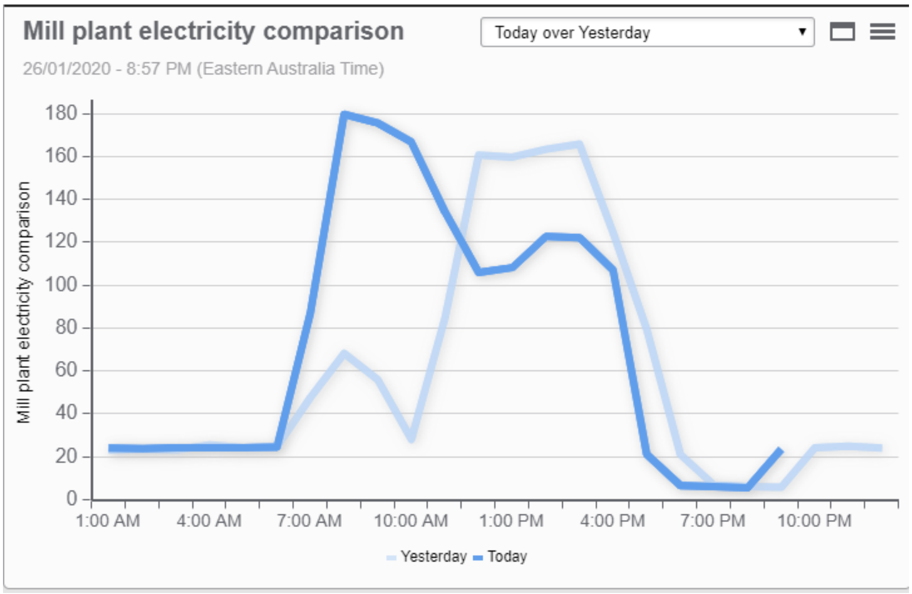

Figure 30: day over day comparison - electrical demand

Figure 31 is monthly electricity consumption for the mill plant with a target line introduced, which again can be used to drive operator behaviours.

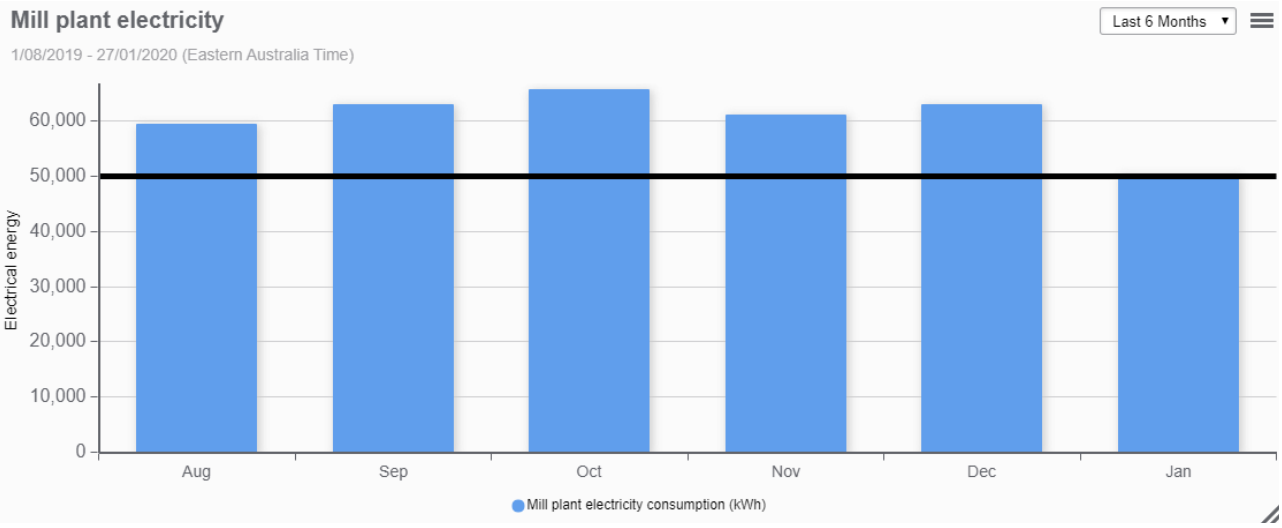

Figure 31: monthly electricity consumption with the target line

Figure 32 is an example of the real-time trend feature in the EWMS, using this feature operators can quickly check what the load is in real-time and monitor the impact of any changes, particularly useful for changes in roller pressure or after boiler services.

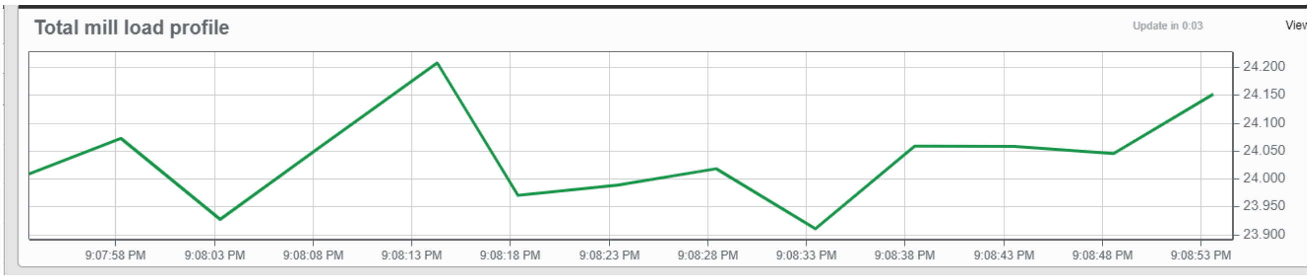

Figure 32: a real-time trend of mill plant demand

5.7 Water Consumption

Water is a critical resource for Feedlot operators, industry benchmarks suggest cattle need anywhere from 30 to 70 L/hd/d. Total water intensity at the industry partner facility ranged from 43 to 64 L/hd/d. This was calculated using meter data from the two bore water meters that supply the whole facility. The KPI includes evaporation at the turkey's nests and other water system losses.

Table 17: water KPIs

#	Month	Days in the month	Water consumption (kL)	Average MAX Heat Load Index HLU	Headcount	Water consumption (L/hd/d)
1	Aug	31	44,804	68.72	31,559	45.80
2	Sep	30	51,231	74.16	32,360	52.77
3	Oct	31	57,735	80.83	32,474	57.35
4	Nov	30	56,527	79.97	31,883	59.10
5	Dec	31	58,042	85.81	31,189	60.03
6	Jan	31	58,539	89.60	29,300	64.45
7	Feb	29	40,986	91.92	24,852	56.87
8	Mar	31	45,561	85.48	24,647	59.63
9	Apr	30	51,256	82.08	27,892	61.26
10	May	31	44,150	65.17	28,310	50.31
11	Jun	30	37,264	69.15	28,306	43.88
12	Jul	31	34,795	65.10	25,814	43.48
Totals		**366**	**580,890**	**78.17**	**29,049**	**54.58**

Improving water use efficiency is somewhat challenging at the collaborative partner facility as there is no volume charge for water, even though the aquifer is a finite resource. Hence there is no cost benefit when water savings are made. While water conservation is very important for the collaborative feedlot partner from a sustainability perspective. The points above were taken into consideration, and greater focus placed on energy efficiency and GHG emissions for the purpose of this report and the ability to add value to industry.

However, it is insightful to report the measured facility water breakup (Figure 33). Approximately 75.8% of total water is used for cattle drinking water.

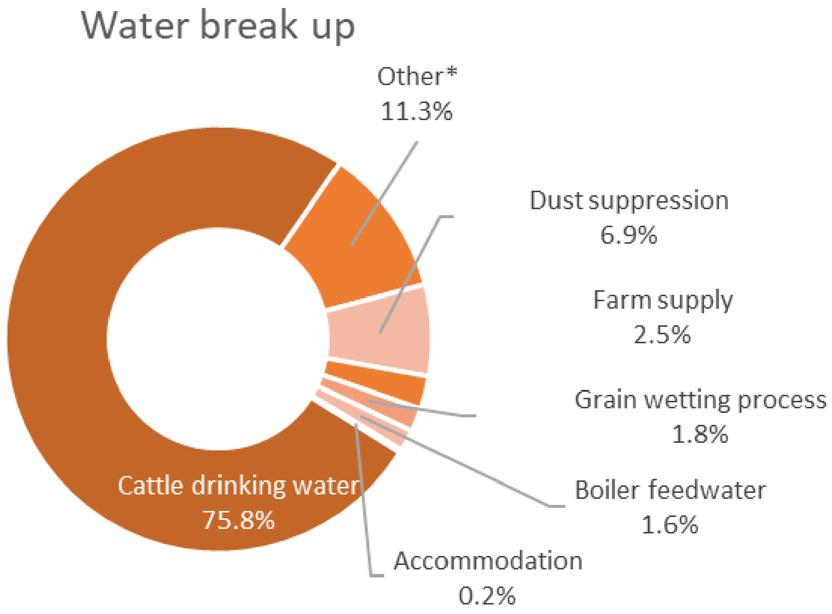

Figure 33: water break up

Cattle drinking water was accurately measured for the new section of the feedlot (referred to as 400, 500 and 600 lanes) which services approximately 14,057 head of cattle. Total feedlot cattle drinking water was then calculated by extrapolating the total number of cattle on fed for each month, multiplied by the measured water intensity.

While cattle drinking water dominates water consumption, it is followed by other (11.3%) which includes unmetered end uses such as offices, amenities, workshops and turkeys nest evaporation. Dust suppression accounts for 6.9% and may be an area for potential water savings, for example by using engineered spray nozzles on the dust suppression truck (see section 5.9.11).

Then much smaller water consumers follow, such as the farm supply (2.5%), grain wetting water (1.8%) and boiler feedwater (1.6%).

Drilling down into grain wetting water (Table 18) and boiler feedwater (Table 19) the following intensities were observed:

Table 18: grain wetting water intensities

#	Month	Days in the month	Grain wetting process water (L)	Grain wetting water intensity (L/tonne flaked)	Grain wetting water intensity (L/tonne flaked) DM
1	Aug	31	813,262	87.50	111.46
2	Sep	30	882,339	94.57	121.72
3	Oct	31	999,570	101.38	134.94
4	Nov	30	965,247	108.92	137.68
5	Dec	31	986,502	109.61	138.89
6	Jan	31	933,991	96.29	122.16
7	Feb	29	673,467	110.10	138.94
8	Mar	31	732,204	102.33	128.16
9	Apr	30	784,070	103.71	136.02
10	May	31	916,552	104.27	134.09
11	Jun	30	870,709	89.34	132.79
12	Jul	31	735,292	88.70	113.28
	Totals	**366**	**10,293,205**	**99.73**	**129.18**

Table 19: boiler feedwater intensities

#	Month	Days in the month	Boiler make up water (L)	Boiler make up water intensity (L/tonne flaked)	Boiler make up water intensity (L/tonne flaked) DM
1	Aug	31	958,450	103.13	131.36
2	Sep	30	848,850	90.98	117.10
3	Oct	31	715,660	72.58	96.62
4	Nov	30	703,270	79.36	100.31
5	Dec	31	821,880	91.32	115.72
6	Jan	31	708,490	73.04	92.67
7	Feb	29	542,300	88.65	111.88
8	Mar	31	612,220	85.57	107.16
9	Apr	30	696,750	92.16	120.87
10	May	31	826,120	93.98	120.86
11	Jun	30	900,410	92.38	137.32
12	Jul	31	995,850	120.13	153.42
	Totals	**366**	**9,330,250**	**90.27**	**117.11**

There is an interesting correlation between boiler make up water in the months of June and July 2020. This is also when lower boiler performance was observed. As mentioned earlier in the report, the site used their EWMS dashboards to pick up increased gas consumption and had the boiler serviced, bring it back to acceptable performance and making a good fuel saving.

5.8 Preliminary list of opportunities

The following water and energy use efficiency opportunities have been reviewed with MLA and the collaborating feedlot. As mentioned in Section 5.3, the Feedlot has made a significant reduction in energy use over the last three to four years. Feedlots that are starting out with resource efficiency, will have greater opportunities to reduce cost, energy, and emissions.

In 2015 the collaborating partner feedlot participated in the Ergon Energy, Energy Savers Plus project and received a subsidised type two energy audit. The audit supported a reduction in the cost of 40% by the implementation of LED lighting, boiler improvements, tariff review, fuel switching and solar PV. Hence, SBH had to go much deeper than a typical feedlot operation for this project to identify opportunities (Table 20: Preliminary Opportunity list).

Table 20: Preliminary Opportunity list

#	Energy or water System	Opportunity name	How energy, water or costs will be saved	What is needed
1	Thermal	Boiler hot-well temperature control and pre-heating	Feedlot flaking systems are "open circuit" with live steam used to heat the grain in steam chests; hence there is minimal condensate return (only from the steam traps). This type of system requires almost 100% make up water volume in the hot well that enters at ambient temperature. Live steam is then used to keep the hot water temperature up. We noted the hot well temperature at 60°C. The downside of this is it needs to be up around 100°C to drive off oxygen; otherwise, it can result in corrosion inside the boiler and reduces the Maximum Continue Rating (MCR) or "from and at rating". It is prudent to have an automatic valve to maintain the hot well temperature instead of having a manually "cracked" hand valve. Observations from the site visit suggest that a control system has been attempted, lifting the water temperature to around 70°C. In addition, we investigated the value of pre-heating the water with a solar thermal system or other technology.	Temperature controlled valve and a low-cost means of heating make up water.
2	Thermal	Commodity shed hot water	Vegetable oil is a supplement mixed with other grains as part of the cattle ration. The supplement needs to be kept warm so that	A heat pump or solar hot water system.

			it can be pumped and does not solidify. An electric hot water system has been installed to heat water and pump it through a coil inside the storage tank. For this opportunity, we assessed alternative heating with a heat pump and solar thermal. Energy will be saving by switching from a commercial-style electric hot water system to alternative technology.	
3	Thermal	Boiler economiser	Energy will be saved by using boiler exhaust heat to pre-heat makeup water before it enters the boiler steam drum. This is particularly advantageous in an open circuit system but sometimes not practical on small boilers (>5MW).	Shell and tube heat exchanger.
4	Thermal	Boiler combustion control	By ensuring fuel to air, the ratio is automatically adjusted to ensure near-complete combustion is achieved throughout the load cycle.	Combustion control system.
5	Thermal	Boiler make up water control	The flow of makeup water is controlled using a VSD to modulate pump speed instead of throttling valves.	Pump controls integrated with boiler controls and safeties
6	Power systems	Induction shed solar PV	By generating electricity onsite.	Solar PV system.
7	Power system	Mill shed demand management.	By controlling the switching of non-critical loads to minimise peak demand.	Specialise demand management system or additional PLC infrastructure and programming.
8	Compressed air	Compressed air auto shut down	Automatic shutdown of compressed units or isolation of compressed air loads outside of business hours.	PLC controls or compressed management system.
9	*Fuel switching/renewables	Hydrogen fuel supply	By switching from diesel to hydrogen as the fuel for feed trucks.	Additional solar PV capacity, electrolyser plant, fuel handling and truck modifications.

10	Water	Water leak detection	By setting up benchmarks in the energy and water management system, it may be possible to alert staff to water leaks faster than manual processes.	Data analytics must be set up in the EWMS with automatic alerts to staff. This will require some testing to ensure that staff do not receive nonsense alerts. We will attempt to test this feature by setting up benchmark water consumption on varying water submeters across the Feedlot and the day before difference.
11	Water	Sundry water efficiency	It may be possible to reduce the water consumption of sundry processes through improved water efficiency, for example, engineered spray nozzles on dust suppression trucks or recovery of RO reject water.	SBH investigated the efficiency of sundry equipment to see if water consumption can be reduced, this included things like replacement of water nozzles to an engineered solution, recovery of RO reject water, covering of turkey's nests to avoid evaporation.

*Detailed assessment of this opportunity would go outside the scope of this project.

5.9 Opportunity analysis and economic feasibility

Analysis and economic feasibility of opportunities are based on the following inputs and assumptions:

- Project costs are based on either:
    - Solution provider budget estimates; or
    - Previous experience; or
    - If not available, estimates using Rawlinson construction handbook pricing
- 10% project contingency
- 10% discount rate
- Current energy rates with 0% growth rate.

SBH took the preliminary list of opportunities and refined these down to projects that are likely to be progressed via the collaborative partners capital program. Following sections detail the cost-benefit of these initiatives.

5.9.1 Boiler hot-well temperature control and pre-heating (economiser)

Feedlot flaking systems are "open circuit" with live steam used to raise grain temperature in the steam chest(s). There is minimal condensate return (only from steam traps). This system requires almost 100% make up water volume in the hot well that enters at ambient temperature, and in the case of this site comes from a RO (Reverse Osmosis) plant.

The main/lead 3MW water tube boiler was observed as having a stack temperature of 360°C during the site visit. High stack temperature is a sure sign of poor efficiency with excess waste heat going up the stack. The E&WMS dashboards were used to monitor gas consumption, and the site has since doubled service intervals and saving on gas. Using the system, we compared monthly gas intensity based on MJ/hd/d and MJ/tonne flaked. This showed a 10% to 20% reduction in monthly gas consumption just by having the boiler serviced more regularly and keeping the stack temperatures at a reasonable level. A great outcome because of the monitoring system, and proactive management of the feedlot General Manager.

Figure 34: Boiler stack temperature

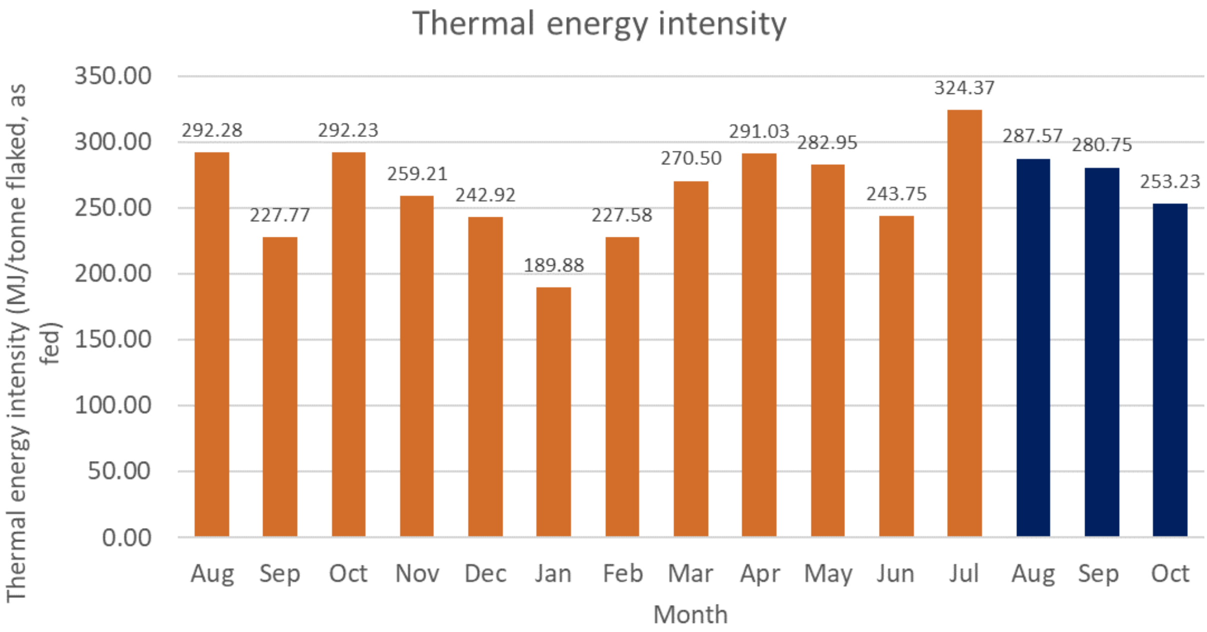

Figure 35: Total monthly thermal energy intensity (MJ/Tonne flaked As-Fed basis)

Figure 35: Total monthly thermal energy intensity (MJ/Tonne flaked As-Fed basis), helps to articulate the difference at this site between a tuned and untuned boiler. With thermal intensity (MJ/tonne flaked, as fed) coming back after being serviced during the month of August, even though the feedlot was running at reduce capacity (down to 51% head capacity in some months). We will continue to monitor this KPI but expect it to fall back to January levels (189.88 MJ/tonne flaked, as fed) as performance is monitored and actions taken.

Following on with the opportunity assessment - the following is based off an average working stack temperature of 240°C at high fire.

As mentioned in previous sections, the system design is "open-ended" and requires almost 100% make up water; this needs to be heated quickly from ambient temperature to 60°C - 80°C in the feedwater tank/hot well. Then, raised to steam once inside the steam drum.

Ideally, the feedwater temperature would be as close to 95°C as possible without the feedwater pumps cavitating. This ensures as much of the incondensable gases are removed before entering the boiler.

Currently, live steam is used to keep the hot well temperature up, which is vital for oxygen removal.

While there have been some improvements made with the hot well temperature and steam injection control over the last few years, including raising the boiler operating pressure closer to design pressure, we noted the hot well temperature at 65°C and recommend implementing the Spirax Sarco example in Figure 36 along with an economiser.

Expected benefits:

- Increased boiler capacity - the From and At rating will be much closer to the design rating.
- Better heat transfer because of less oxygen in the boiler feedwater.

- Less chance of pitting in the economiser.
- Better steam quality and less risk of carry-over; for example, more oxygen in the boiler (which is the case when the feedwater temperature is >85°C) generates bubbles and surface tension increasing the likely hood of water droplets being pulled into the steam header, increasing the likely hood of water hammer and reduced steam quality (higher wetness factor) and therefore less enthalpy.

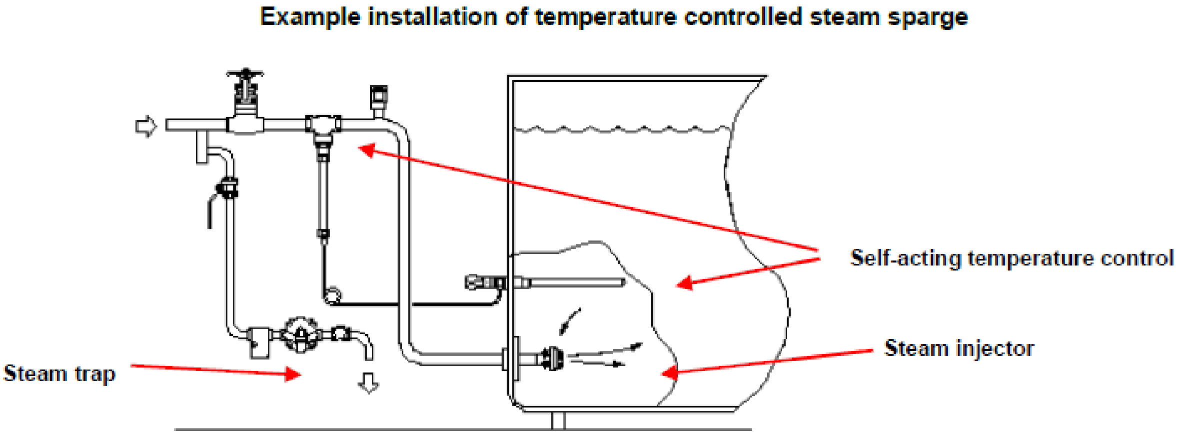

Figure 36: example installation of temperature-controlled steam sparge in a hot well (source: https://www.spiraxsarco.com/)

As there is minimal condensate return, this opportunity considers recovering waste heat from the exhaust flue at 240°C. The recovered energy will be used it lift the feedwater temperature after the hot well. The reason it needs to be after the hot well is if the temperature is lifted above 100°C the makeup water pump will cavitate. If we can get feedwater entering the boiler higher than 100°C (say 130°C) it will further lift boiler capacity (from and at rating).

In Australia, it is unusual for boilers of 5MW and below to have an economiser due to capital cost, historically low gas prices (sub $4/GJ), space and maintenance considerations.

However, most feedlots with gas fired boilers use LPG or LNG as fuel and likely to be paying more than $15/GJ. In this situation, it is worth reviewing the business case for an economiser and hot well heating control.

The following business case outputs are provided and consider the following cost estimates:

- Based on Spirax Sarco budget price estimates
    - Hot well heating system - $5,000
    - Re-circ system to reduce tank stratification - $2,500
- Economiser (based on previous estimate from boiler service provider) - $50,000
- Additional building works, approvals, and project management (estimate only) – $14,500
- Contingency 7,200

Overall, this is expected to lift thermal efficiency by 5% to 7%.

Table 21: Boiler hot-well temperature control and pre-heating feasibility

Item	Unit	Value
Estimated Energy saving	GJ/annum	968
Estimated Greenhouse Gas emission reduction	T CO_2-e/annum	50
Estimated Operating Cost savings	$/annum	17,065
Maintenance Cost Savings	$/annum	-
The estimated cost to implement	$	79,200
Estimated Demand reduction	kW	-
Payback period	Years	4.6
Internal rate of return	%	15

5.9.2 Commodity shed solar hot water with heat pump

Oils are used as a supplement to mix with grains as part of the cattle ration. The supplement needs to be kept warm so that it can be pumped and does not solidify. An electric hot water system has been installed to heat water and pump it through a coil inside the storage tank to avoid solidification.

The system costs around $6k per year and contributes 8kW to peak demand.

Energy savings of around 70% to 80% can be achieved with a solar hot water system, boosted with a hot water heat pump. A solar hot water system has been estimated at approximately $20k as there are several unknowns, such as structural integrity of the roof, correct aspect, bracketing, and distance between the collector and storage vessels.

Table 22: Commodity shed solar hot water with heat pump feasibility

Item	Unit	Value
Estimated Energy saving	kWh/annum	18,243 (66 GJ)
Estimated Greenhouse Gas emission reduction	T CO_2-e/annum	15
Estimated Operating Cost savings	$/annum	4,122
Maintenance Cost Savings	$/annum	-
The estimated cost to implement	$	19,500
Estimated Demand reduction	kW	8
Payback period	Years	4.7
Internal rate of return	%	17

5.9.3 Boiler combustion control

The facility has two boilers, one 3MW Tomlinson water tube unit that is used as the lead steam boiler, and a second 2MW Cleaver Brooks' fire tube boiler.

Boiler controls are basic and control to a head pressure setpoint of 930 to 950kPA (9.3bar to 9.5bar). Fuel and air are supplied to the burner using a throttled mechanical air damper.

The site boiler service technician has previously quoted this opportunity and provided the option to either fully replace the burner or add a new burner control system so that O_2 could be modulated.

The cost to do so is much higher than expected for this type of retrofit due to the inclusion of a new burner. However, this has the added benefit of much better turn-down leading to greater savings.

In summary, energy is saved by ensuring the fuel to air mix is always optimised based on stack measurement. Most boiler service technicians like to set the control system to 3% O_2 to ensure efficient and save operation. A VSD is installed to modulate fan speed, instead of modulating a throttling valve or air damper, this will save a small amount of electrical energy.

Project costs are based on a historic quote from the service technician that has a generous allowance for completing the project with new replacement burner and control system. Overall, this is expected to lift boiler performance by 5% to 7%.

Table 23: Boiler combustion control feasibility

Item	Unit	Value
Estimated Energy saving	GJ/annum	1,288
Estimated Greenhouse Gas emission reduction	T CO_2-e/annum	71
Estimated Operating Cost savings	$/annum	23,038
Maintenance Cost Savings	$/annum	-
The estimated cost to implement	$	95,671
Estimated Demand reduction	kW	2
Payback period	Years	4.2
Internal rate of return	%	20

5.9.4 Makeup water pre-heating (heat pump)

This opportunity considers options to offset the steam used to heat the incoming make up water from ambient to 90°C before entering an economiser to lift it to 130°C. In this instance, we have based the opportunity to use a high-temperature heat pump as 50% of the shaft energy would be supplied by the existing solar PV system.

Based on measurement from the EWMS – steam energy used to raise the hot well temperature is just over 1,200 GJ/pa, once boiler efficiency is applied (70% used in this example), this translates to almost $30k/pa in LNG costs.

A heat pump could be used to do this work, or a heat pump with solar thermal for pre-heating, using renewable electricity to power the compressor. The following business case is provided – noting that it is yet to be quoted and pre-engineering and detailed design works are required to ensure correct integration.

The example below is based on a high temperature heat pump costed at $189,416 (installed). The heat pump has a life expectancy of 15 years and needs to meet an average flow rate of 0.69 l/s.

Table 24: Makeup water pre-heating (heat pump) feasibility

Item	Unit	Value
Estimated Energy saving	GJ/annum	1,471
Estimated Greenhouse Gas emission reduction	T CO_2-e/annum	38
Estimated Operating Cost savings	$/annum	28,060
Maintenance Cost Savings	$/annum	-
The estimated cost to implement	$	189,416
Estimated Demand reduction	kW	-
Payback period	Years	6.8
Internal rate of return	%	9

5.9.5 Boiler makeup water flow control

The thermal system is an open circuit system where live steam is used to heat the product. Thus, consuming a lot of makeup water. Dosing of makeup water into the steam drum is controlled by a fixed speed, vertical multistage pump, with modulating valve to control flow, based on the steam drum level.

There is an opportunity to save electrical energy by installing a VSD to control the flow instead of the modulating (throttling) valve.

Making use of the affinity law means that reducing the speed by 10%, will result in a 20% reduction in electrical load. The following cost-benefit analysis is provided:

Table 25: Boiler makeup water flow control feasibility

Item	Unit	Value
Estimated Energy saving	kWh/annum	3,162 (11 JG)
Estimated Greenhouse Gas emission reduction	T CO_2-e/annum	3
Estimated Operating Cost savings	$/annum	900
Maintenance Cost Savings	$/annum	-
The estimated cost to implement	$	4,708
Estimated Demand reduction	kW	2
Payback period	Years	5.2
Internal rate of return	%	14

5.9.6 Solar PV

Section 4.2 discussions the solar arrays that are installed at the facility; this includes:

- A 300kW$_p$/269kW$_{ac}$ hybrid system that is connected to the mill plant NMI. This system was commissioned in November 2017.
- A 29kW$_p$/30kW$_{ac}$ roof-mounted system that is installed on the Induction shed. This system was commissioned in July 2019.

The following assessment runs updated models to check if additional capacity is attractive, and to check if energy use patterns have changed.

5.9.6.1 Mill plant solar PV expansion

SBH used the Beam.solar platform to re-model mill plant solar to test if additional capacity is attractive. Summary:

- The site recently upgraded the office facility, extending potential roof space that could be used for solar PV. Clear and up to date Nearmap (or other platform) aerial images are not available, making it impossible to map the roof for mechanical layouts. However, the image in Figure 37 shows 10kW$_p$ on the old roof space, we estimate a total of 30kW$_p$ could fit in the new roof space. The business case is based on this capacity.
- As a large system is already installed on the mill plant NMI, additional 30kW$_p$ would not be eligible for Small Scale Technology certificates which extends the payback period.

Figure 37: 10kWp concept mechanical layout on the feedlot admin building, pre-renovation

Table 26: Mill plant solar PV expansion feasibility

Item	Unit	Value
Estimated Energy saving	kWh/annum	43,824
Estimated Greenhouse Gas emission reduction	T CO_2-e/annum	35
Estimated Operating Cost savings	$/annum	5,113
Maintenance Cost savings	$/annum	Marginal
The estimated cost to implement	$	45,000
Estimated Demand reduction	kW	Marginal
Payback period	Years	8.8
Internal rate of return	%	11.3

The long payback period suggests the existing 300kW$_p$ system is still suitable for Feedlot demand.

Finally, we suspect the inverters throttle back before full capacity is delivered, to ensure there is no network export. This requires more investigation with the network and outside the scope of this project.

5.9.6.2 Induction shed solar PV

This project was included in the list of opportunities, and we commend the site for already implementing the project. A key benefit is it allows the site to operate the back-bore water pump during sunlight hours, effectively providing free water pumping for cattle drinking water.

Worth noting this system has slightly higher yield than admin office extension due to the orientation of the Induction shed roof space. The tariff is also much higher and hence has an attractive return.

Outputs from the project business case are provided below:

Table 27: Induction shed solar PV feasibility

Item	Unit	Value
Estimated Energy saving	kWh/annum	48,000
Estimated Greenhouse Gas emission reduction	T CO_2-e/annum	38
Estimated Operating Cost savings	$/annum	11,040
Maintenance Cost savings	$/annum	Marginal
The estimated cost to implement	$	26,500
Estimated Demand reduction	kW	5.8
Payback period	Years	2.4
Internal rate of return	%	38

5.9.6.3 Feedlot accommodation solar PV

The Feedlot has accommodation for workers across the road. While the electrical load is low during the daytime when staff are at the Feedlot, there are still auxiliary services such as hot water, refrigerators and general power that could be offset by a small solar PV system.

Figure 38 shows solar PV generation for $10kW_p$ overlayed with the existing load profile.

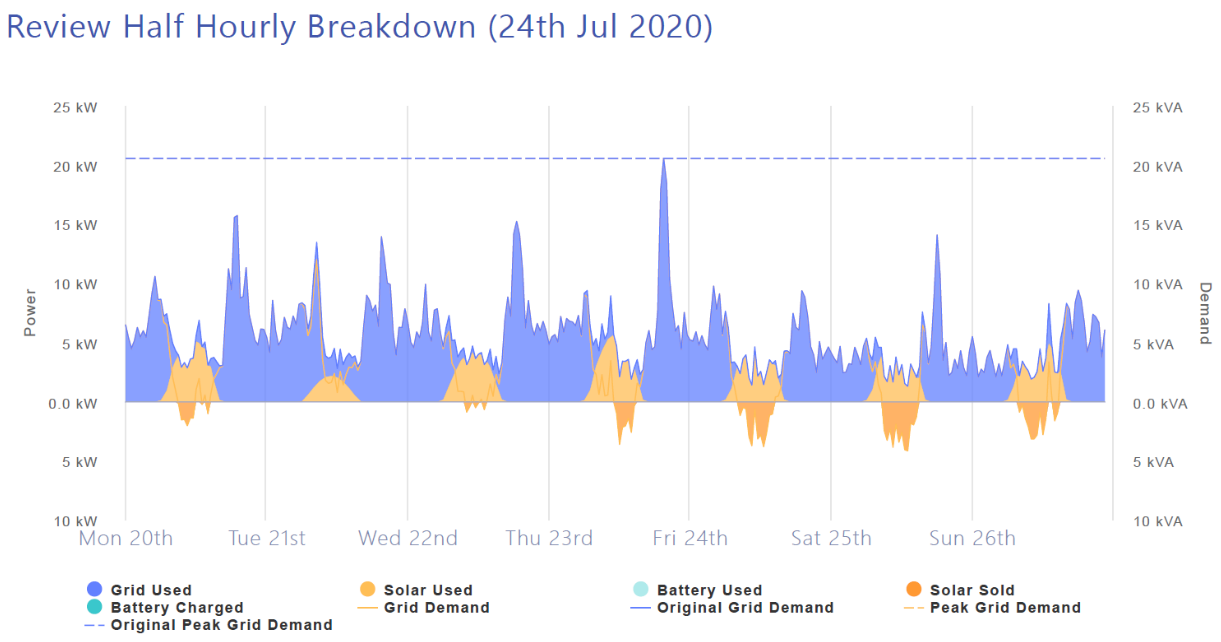

Figure 38: modelled outputs from the Beam.solar platform.

The following business case outputs are provided:

*no Nearmaps image is available to show mechanical layout.

Table 28: Feedlot accommodation solar PV feasibility

Item	Unit	Value
Estimated Energy saving	kWh/annum	13,202
Estimated Greenhouse Gas emission reduction	T CO_2-e/annum	11
Estimated Operating Cost savings	$/annum	2,196
Maintenance Cost savings	$/annum	Marginal
The estimated cost to implement	$	9,400
Estimated Demand reduction	kW	Marginal
Payback period	Years	4.3
Internal rate of return	%	23

5.9.7 Mill shed demand management

A demand management system was considered for the feedlot as the demand portion of the tariff is relatively high at $20/kVA. It would be useful to control or turn downloads in line with solar production.

However, after review, we recommend focusing on the energy efficiency opportunities outlined in the first instance. Once all systems are working efficiently, it may make sense to have an overarching control system to manipulate load, so that, demand can be reduced.

No further discussion is needed on this preliminary idea.

5.9.8 Compressed air auto shut down

An auto-shutdown of the compressed air system was reviewed. The review looked at automatically shutting the compressed air system down outside of milling hours. However, the feedlot has three systems, one for the workshop, one for the commodities shed and one for the mill plant.

At the time of review, the site was in the process of consolidating the airlines and installing a screw compressor (on a VSD). Once this project is complete and there are minimal air leaks, the site is going to review and consider an after-hours timer. A key consideration is the position of control valves across the mill plant, and whether they will hold with the compressor off, therefore the system will need to auto-start if low pressure is detected.

No further discussion is warranted at this point.

5.9.9 Hydrogen fuel supply

Hydrogen is an emerging technology and likely to play a key role in feedlot operations. One potential scenario is the use of hydrogen in feed trucks as an alternative to diesel or an alternative to gas for boilers.

However, this technology is a long way from becoming commercially viable at the collaborating feedlot economic hurdle rates. For context, diesel costs are around $40/GJ, a recent report commissioned by the Australian Renewable Energy Agency (ARENA) priced the leverlised cost of hydrogen at $155.62/GJ (source: https://arena.gov.au/assets/2016/05/Assessment-of-the-cost-of-hydrogen-from-PV.pdf).

Hence, it was agreed to focus on traditional energy manager opportunities while the technology matures.

5.9.10 Water leak detection

By setting up benchmarks in the energy and water management system, there is potential to alert staff to water leaks.

While this feature is possible with the new system, the Feedlot management system needs to be integrated, so that, water intensity can be measured, and an alert created against a benchmark.

This has been raised with the collaborating feedlot partner IT department as it requires the integration of production data that may be considered sensitive.

In the short term - site continues to monitor daily water consumption trends for cattle drinking water, as a proxy for leak detection.

We note the Feedlot does not incur a volume charge for water, hence a cost-benefit analysis could not be developed.

5.9.11 Sundry water efficiency

There are opportunities to reduce water consumption across the Feedlot. However, and unsurprisingly, cattle drinking water is the largest consumer at 75-90%. This has been covered extensively by MLA as well as other areas for savings in:

- Factsheets for feedlots, A framework for water and energy monitoring and efficiency in feedlots (Davis R, 2009).
- Quantifying the water and energy usage of individual activities with Australian feedlots; part A report, water usage at Australian feedlots (Davis R, May 2008).
- Quantifying the water and energy usage of individual activities with Australian feedlots; part B report, Energy usage at Australian feedlots (Davis R, November 2011).

To build off, and complement this work, we focused on metering and monitor of high-cost energy uses, plus selected sundry water uses, as agreed with the Feedlot General Manager. Seven water meters were installed in the following locations:

- WM1_Turkeys nest outfeed 1 (cattle drinking water)
- WM2_Turkeys nest outfeed 2 (cattle drinking water)
- WM3_Accommodation water
- WM4_Dust suppression water
- WM5_Farm supply

- WM6_Boiler feedwater
- WM7_Grain wetting process water

Discounting cattle drinking water and grain wetting process water. The following water savings are estimated for sundry applications:

Table 29: Sundry water efficiency savings estimates

Meter number	Coverage	Water saving measure	Estimated savings (kL/pa)
WM3	Accommodation water	Water savings fittings and fixture	377
WM4	Dust suppression water	Engineered spray nozzles on water tankers and dust suppression polymer. Mixed with water, dust suppression polymers are used in the mining industry. They are is sprayed onto road surfaces binding fine dust particles and preventing them from becoming airborne dust	28,125
Total			**20,467 or 3.5%**

The feedlot does not incur a volume charge for water. Hence a cost-benefit analysis could not be developed. Water efficiency measures may be implemented for water scarcity and sustainability reasons saving 3.5% of site totals.

5.9.12 Power factor correction

Until recently, there was no commercial benefit for improving power factor at the collaborative partner Feedlot. The site is on Ergon Energy tariff 45 which recently (from 1 July 2020) transitioned from a $/kW/month to $/kVA/month peak demand charge.

There is now an attractive business case for power factor corrector technology.

SBH used 12 months of historical NMI meter data to size a power factor correction unit. The unit will offset kVA charges by switching banks of capacitors to balance out reactive power (kVAr). This summary on the Ergon Energy website explains how it works: https://www.ergon.com.au/network/manage-your-energy/business-resources/understanding-power-factor#:~:text=Power%20factor%20is%20a%20measure,greater%20than%20the%20real%20power.

We recommend a 250 kVAr unit installed at the main switchboard. Of all the opportunities discussed in this report, we recommend implementing this one as soon as practical.

Table 30: Power factor correction feasibility

Item	Unit	Value
Estimated Energy saving	kWh/annum	-
Estimated Greenhouse Gas emission reduction	T CO_2-e/annum	-
Estimated Operating Cost savings	\$/annum	25,382
Maintenance Cost Savings	\$/annum	-
The estimated cost to implement	\$	33,000
Estimated Demand reduction	kVA	113
Payback period	Years	1.3
Internal rate of return	%	77

5.10 Review of project objectives

This project builds off previous work commissioned by MLA in partnership with ALFA. In 2008 a detailed study called "Quantifying the Water and Energy Usage of Individual Activities within Australian Feedlots" (Daivs et al., 2008) was completed.

We aimed to advance this work, leveraging developments in cloud computing and software analytics, specific to energy and water management.

Key objectives

1) Determine strategies to improve water or energy use efficiency for a 30,000 SCU steam flaking Feedlot by:
    a. Metering water and energy use in the Feedlot over one year: a total of 24 metering points was installed and connected or connected if there was an existing meter. All metering points now come back to a remotely read portals that can be accessed for data analytics. Data was captured for 12 months and continues to be.
    b. Identify technologies to improve water use efficiency and energy use efficiency: a total of nine technology opportunities are identified with CBAs developed. Technologies include thermal efficiency and heat recovery, steam control, data analytics, solar PV, high- temperature heat pumps, variable speed drives and power factor correction.
2) Generate the economic feasibility (cost-benefit and payback period) at least six strategies: as mentioned above, nine technology opportunities are identified with CBAs developed. In aggregation, these provide a 23% IRR for a capital investment of $502,895. The opportunity for feedlots yet to focus on energy and water management will be far greater. The collaborative feedlot partner site had already reduced scope 2 emissions by 50% and energy costs by 40% before we started this project. However, a significant challenge was water efficiency projects, while there are opportunities to save water, there is no volume-based water charge, only a small access fee. For this reason, water efficiency projects do not provide commercial returns and would be reliant on sustainability drivers or Government support to be funded. MLA has done lots of good work in this area that is worth pursuing.

3) Produce MLA tips and tools factsheet summarising strategies to improve the energy efficiency of the 30,000 SCU steam-flaking feedlot: a tips and tools factsheet accompanies this report and is based on the collaborative partners, 30,000 SCU steam flaking feedlot.

Project insights confirm that the most attractive commercial returns lie within in the thermal system. Feedlots are located on fringe of grid or remote locations, often using bulk delivered fuels such as LPG that have very high unit costs ($/GJ). For context, bulk delivered fuels such as LPG are 2 to 4 times more expensive per unit than pipeline natural gas.

Mill plant rollers operate 6 to 10 hrs per day, 7 days per week, making them a near-perfect match for solar PV technology. If your feedlot does not have solar PV, it is worth investigating.

Additional research is recommended in the following area:

- Optimal technology integration and pilot of boiler water pre-heating for open-ended steam systems. This may include (but not limited to) to high-temperature heat pumps integrated with solar thermal collectors.
- The cost-benefit of solar PV panel cleaning in dusty environments
- Further development of data analytics and integration with feedlot management systems for advance utility management.

6 Conclusions/recommendations

The value of metering and data analytics to aid Feedlots has been demonstrated by this project. Already, the collaborative feedlot partner has been able to leverage data analytics to track and quantify boiler performance, and the benefit of increased service intervals.

A system with these capabilities reduces the cost of future auditing and value creation that can be derived through professional support. More importantly, it draws in the attention and focus of operational staff through qualitative measurement.

Good data drives good results.

Project learning includes:

- **IT communications:** due to the remote location of metering points around the Feedlot (in particular, water meters), hardwired connections were cost prohibitive. As an alternative radio wireless communication were used (for remote meters only). With this came communications faults and regular signal dropouts. These create data gaps when faults go unnoticed. To overcome this challenge, automated reporting via email was set up to notify system users. This is still problematic, as skilled resources are remote from the site and may be required to repair faults.
- **Software:** the software package used is compelling and well suited to the application. However, it is not overly intuitive and suited to resources skilled in energy management or engineering.
- **Thermal efficiency:** it is difficult to measure thermal efficiency in real-time due to the thermal lag between energy in, in the form of gas, to energy out, in the form of steam. To overcome this problem boiler performance is assessed over more extended periods (days and months, not hours). There are alternative technologies on the market that address this problem, such as the B850 boiler house energy monitor from Spirax Sarco. While the measurement of thermal performance is technically challenging and expensive, fuel unit costs are high justifying the effort.
- **Meter selection and location:** it is easy to over-specify meters and metering points. In some instances, low-cost water meters with basic pulsing counter may be sufficient for the

application. For example, we installed a mag flow meter for dust suppression water when a turbine meter would have been sufficient.
- **Installation:** some metering points are intrusive and require cut-ins, for example, gas and steam meters. Feedlots mill 365 days a year. Hence cut ins need to be planned outside of these times.

Overall, it is pleasing to have a robust data set available for the facility. This allows for detailed analysis of energy and water consumption to support innovate and new ways of monitoring and improving efficiency.

6.1 Recommendations

The following recommendations are provided

- **Know your numbers:** have a good sense of your energy and water costs, the biggest users and potential opportunities surrounding the system before selecting to meter it.
- **Metering points:** start with the high cost, high-value end uses and put in expandable IT infrastructure from day one. Invest in good communications and software but be critical of each metering point and the accuracy required. Low costs meters are sufficient for some applications.
    - Only use high-end meters where it is justified.
    - Match meter quality to accuracy requirements.
    - Focus on metering points that are expected to derive commercial or environmental value.
- **Connectivity:** connect metering points to a software package that is easy to use, robust and insightful. Do not stop at manually read meters; the value they provide is limited.
- **Opportunities:** start with traditional energy and water management approaches before investing time in emerging technologies or R&D. Traditional approaches include:
    - Strategic energy procurement.
    - Energy auditing and baselining.
    - Tracking and reporting of KPIs/intensities (GJ/T grain milled, GJ/hd/d, boiler stack temperatures should 160°C to 220° C and O_2 levels – target 3%).
    - Good maintenance practices.
    - Ensure staff are accountable.

6.2 Additional research

Building from this activity, and previously MLA projects, SBH recommends additional research in the following areas:

- **Boiler make up water pre-heating:** optimal technology integration and pilot of boiler water pre-heating for open-ended steam systems. This may include (but not limited to) to high-temperature heat pumps integrated with solar thermal collectors.
- **Solar PV dust management:** a cost-benefit analysis of solar PV panel cleaning in dusty environments. When should panels be cleaned and what is the benefit?
- **Go deeper with data analytics:** further development of data analytics and integration with Feedlot management systems for advanced utility management.

7 Key messages

Key messages for Feedlot operators wanting to measure and improve water and energy use efficiency:

- **Know your numbers:** have a good sense of your energy and water costs, the biggest users and potential opportunities surrounding the system before selecting where to meter.
- **Goals:** set firm goals that are clear, measurable, and time-bound
- **Invest:** budget to invest 10% of your annual water and energy spend on improvements each year. It is not unreasonable to expect to reduce your costs by +50% with the right effort and focus. The introduction and expansion of renewables will drive these costs closer to zero over time. The following is a guide for metering costs (includes software licences for data analytics, IT, and electrical connectivity):
    - Electrical $2,000 per point
    - Gas and steam $10,000 per point
    - Water
        - High-end meter $4000 per point
        - Low-end meter $1000 per point

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