FINAL REPORT
ENERGY SUFFICIENT MEAT PROCESSING FACILITY

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1.0 EXECUTIVE SUMMARY

The Australian economy has been exposed to a rapid escalation of energy prices over the past decade, primarily for electricity and natural gas. Both have an impact on high volume, low margin businesses within the red meat industry. Energy price escalation is a complex issue attributed to several events and market failures.

To help combat this changing environment and better position the industry, Smart Business Hub was engaged by AMPC to research and develop options for a meat processing facility to become energy sufficient.

The objective was to demonstrate that a “real-world” processing facility can be energy sufficient using a range of technologies that are commercially available, reliable and supported in Australia. With a focus on technologies that are deployable, scalable and flexible to suit the range of operators in Australia.

Approach

Our holistic approach focused on construction cost associated with renewable energy technologies that are mature in the Australian market, including biomass boilers, biogas cogeneration, tank style anaerobic digestion, solar PV and battery storage.

We engaged a specialist panel of solution providers with the capacity to design and construct each technology. We also engaged an industry partner and used their facility to develop technology specific business cases.

This approach allowed us to focus on site-specific needs and construction methods using cost estimates from experienced integrators, as opposed to basing the capital cost on desktop research. The specialist panel was referred to as the Energy Sufficiency Panel or ESP and included Beam Energy Labs, Evo Energy, Finnbiogas, GEM Energy and Justsen Pacific, with Smart Business Hub as the lead researcher.

Outcomes

The outcome of the research demonstrates there are insufficient waste products at the industry partner facility to be energy sufficient without importing other materials or fuels; however, it is technically feasible to significantly reduce energy risk through uptake of renewable technologies, as well as enhance sustainability and increase social license to operate.

Using the industry partner site as an example, the objectives can be achieved by sourcing alternative fuels such as biomass to service most of the steam load, integration of biogas cogeneration, solid waste digestion, solar PV, and energy storage to get the plant to 100% energy sufficient at the cost of just over $44m at an IRR of 6%.

Conclusion

A key focus of this research and development project has been to review the construction costs associated with embedded renewable energy generation and to collaborate with turn-key solution providers so that practical aspects of embedded generation are disseminated to industry.

This approach coupled with the traditional energy management skills of Smart Business Hub and powerful software developed by Beam Energy Labs allowed for the development of an energy self-sufficiency business case based on a working beef processing facility.

Technical and financial modelling developed for the project confirmed that it is technically feasible for the industry partner facility to become **100%** energy sufficient using a combination of technologies.

To achieve this outcome requires an investment of over $44m with an internal rate of return less than 10% (6%). While this will be an unattractive proposition to most red meat processors, we would encourage members to investigate:

- which specific technologies are attractive at their specific facility/facilities; and
- leverage alternative funding models to source energy that is both lower cost than the grid and lower emissions.

Recommendations

- **Start with energy productivity**: Before investing in becoming energy sufficient, processors should have a clear understanding of energy and water productivity opportunities. Energy productivity directly reduces manufacturing cost and provides attractive return (typically 15% to 100% IRR).
- **Project risk:** Processors should consider the risk profile of each technology before moving forward. Operation and maintenance of renewable energy assets vary broadly between each technology. For example, a solar PV asset is a relatively low risk, while bioenergy assets such as anaerobic digestion tanks and biogas cogeneration are more complex and require third-party support.
- **Interfacing:** Consideration needs to be given to the interactive effects between embedded generation assets, existing plant load, and the grid. Therefore, earlier engagement and collaboration with the local network provider is recommended.

2.0 INTRODUCTION

Problem summary

Over the past decade, the Australian economy has been exposed to a rapid escalation of energy pricing, primarily for electricity and natural gas. Both have had a significant impact on margins within the red meat processing sector. The rapid escalation of energy prices is attributed to many complex issues which can become magnified for red meat processors due to:

- **Location:** Processing facilities are typically located in regional or fringe of grid locations whereby electricity and natural gas network costs are higher than metropolitan areas (even with cross-subsidies in place).

/ **Capacity and resources:** Meat processors have limited internal energy and water management resources, as utility costs have historically represented a small portion of manufacturing cost. Furthermore, is it not related to core business.

/ **Cyclical:** The cyclical nature of the industry means that processors experience boom/bust cycles, making it challenging to keep pace with advances in energy efficiency and best practice asset management.

The rapid escalation of electricity prices can be seen in Figure 1. Over the last decade, electricity price escalation has far out-paced other goods and services in the economy. This is a complex issue that has many layers including aging infrastructure assets, lack of clear and consistent government policy around energy and climate, investment uncertainty, and regulatory settings lagging technology and commercial advancements.

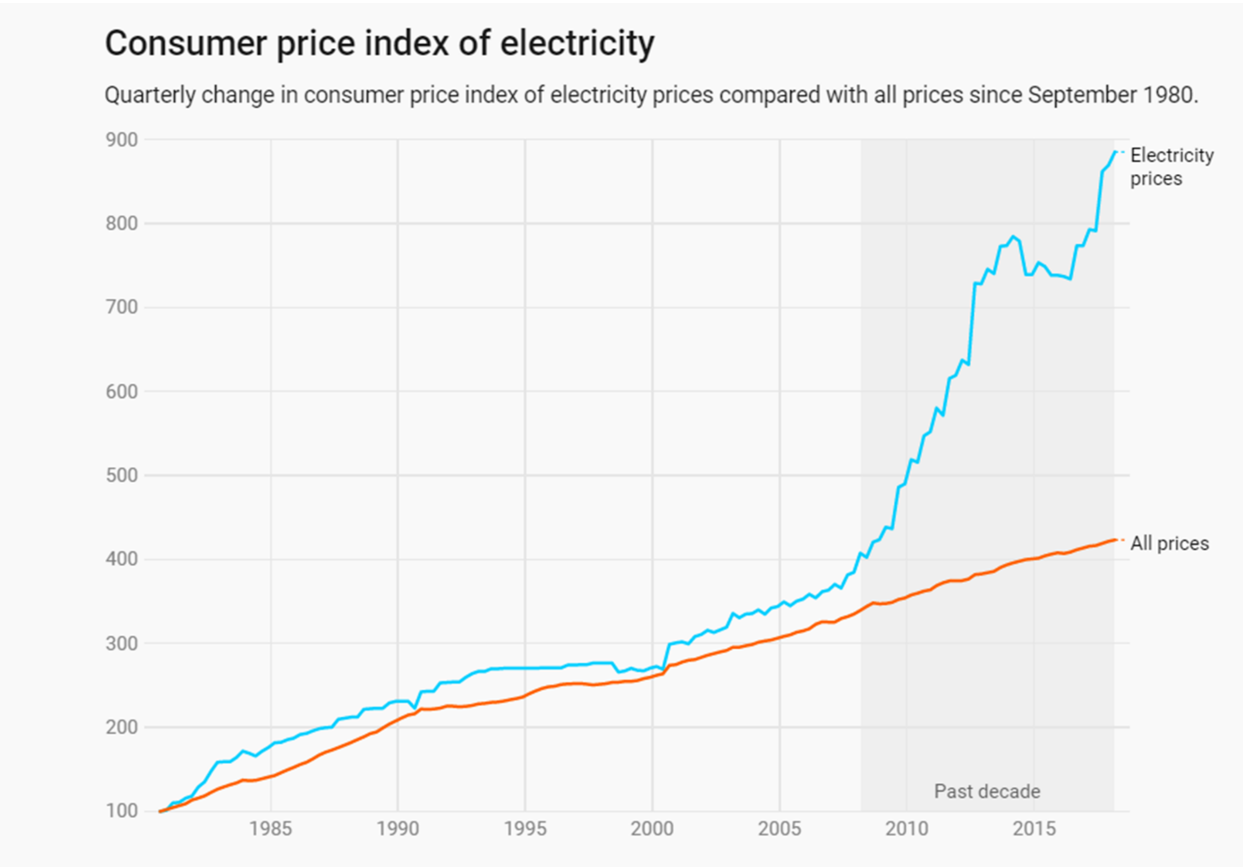


Figure 1: source https://www.abc.net.au/news/2018-07-18/electricity-price-rises-chart-of-the-day/9985300 based on Australian Bureau of Statistics data

Also, east coast natural gas markets have experienced a doubling, and in some instances trebling, of the natural gas price. Market failures, gaming, and the absence of a domestic gas reservation policy to combat LNG exports have all contributed to high domestic natural gas prices. Market conditions are often opaque, and there is a lack of competition in the industry.

Using Short Term Trading Market (STTM) ex-Ante[1] prices for all east coast markets (source: Australian Energy Market Operator [AEMO] website https://www.aemo.com.au/Gas/Short-Term-Trading-Market-STTM/Data) data (Figure 2) we can see the average gas price in the calendar year 2015 was $4.00/GJ. However, in 2018 the average price surged ahead to $8.74/GJ. This is a price escalation of 119% and does not include any retail margin, network, environment or ancillary charges.

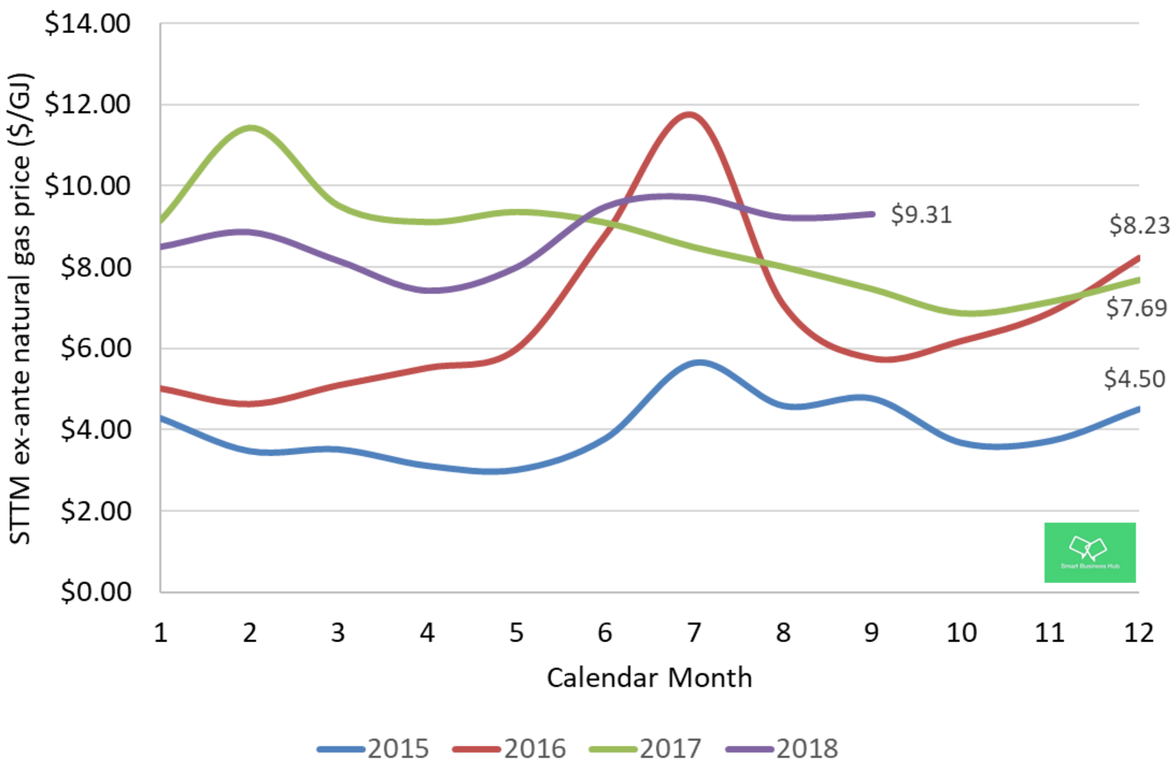


Figure 2: Average monthly STTM ex-Ante gas price, source AEMO

Electricity and natural gas are key resources for meat processors, with natural gas being used for the processing of bi-products (render) and hot water generation. Electricity is used for refrigeration systems, compressed air, pumps and fans, large process motors and machinery; hence, energy market price escalation remains a key issue for processors.

[1] The ex-ante price can be thought of as the “day ahead” price base on forecast.

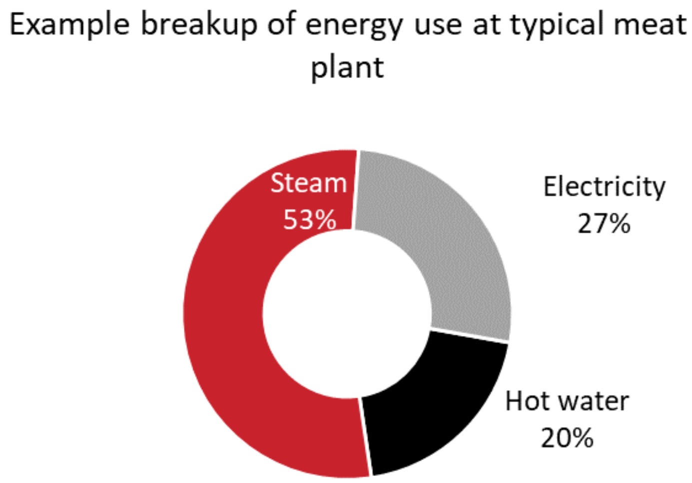


Figure 3: Source, Eco-Efficiency Meat Manual for Meat Processing, page 57, table 3.1

The purpose of this project was to review the energy needs of a working red meat processing facility and develop a site-specific case study for that facility to become partially or fully energy self-sufficient.

In this specific example, it was agreed with AMPC that some energy sources (such as biomass) could be imported to the facility, as there are insufficient bi-products or low-value material volume to meet 100% of the site's energy demand[2].

The primary objective was to demonstrate that a working red meat processing plant can become energy sufficient. This is covered in more detail in section 3.0.

We note that project objectives are in alignment with AMPCs program goal of:

/ reducing energy consumption and greenhouse gas emissions;

/ improving industry awareness, capabilities and attitudes to adapt to climate change;

/ improving waste-water management and examine technologies, practices, and procedures that could capture value from the waste product; and

/ explore options to improve industry infrastructure and maintain efficient food safety and product integrity controls.

For this RD&E activity, Smart Business Hub leveraged its technology solution provider member base to form a specific panel to meet the needs of AMPC. The panel was referred to as the Energy Sufficiency Panel or ESP.

Panel members include:

Table 1: ESP members

Organisation	Description

[2] This applies to the industry partner facility which has high steam demand due to onsite rendering.

Smart Business Hub	**Smart Business Hub:** Specialises in demonstrating whole-of-business benefits for innovative solutions and services to the business community. **Project responsibilities:** Principle investigator; project management and lead; panel mobilisation and facilitation; energy baselining, including adjustment for energy productivity potential; technology selection; sub-system due diligence; review technology selection, reliability and flexibility; sustainability review; scalability review; implementation roadmap development; gap analysis to confirm further research and development areas; holistic energy and renewable energy.
BEAM ENERGY LABS	**Beam Energy Labs:** Renewable energy software intelligence and consulting. The Beam commercial platform helps businesses assess and procure solar and batteries. **Project responsibilities:** Responsible for whole-of-system integration, optimisation and modelling; whole-of-system business case development; marginal 'energy self-sufficiency' cost curve; financial and scenario modelling for the demonstration site.
EVO energy technologies	**Evo Energy:** Turn-key cogeneration, trigeneration and heat recovery solutions provider. As an authorised 2G Partner, Evo's cogeneration plants are electrically and thermodynamically superior. They are guaranteed to be more efficient than anything else on the market. Evo 2G Cogeneration systems are a clean, low-emission and commercially attractive way to generate heat and power for a myriad of commercial applications. **Project responsibilities:** Provide cogeneration and biogas conditioning system feasibility, high-level design, specification, integration and costing (using reciprocating engine technology) for the demonstration site.
FinnBiogas	**Finn Biogas:** Biogas design and optimisation consultant. Finn Biogas is a dedicated, passionate and driven group of professionals who are focused on delivering realistic, sustainable solutions for businesses within the Australian waste-to-energy sector. **Project responsibilities:** Integration and optimisation of multiple biogas supplies such as operating covered anaerobic lagoons and biodigesters. This included technical feasibility

	of additional feedstocks or substrates as well as mechanical CAL modifications to lift biogas yield for the demonstration site.
GEMENERGY	**GEM Energy:** Australia's leading provider of turn-key solar energy solutions. Experts in renewable energy consultancy and implementation, photovoltaic engineering, electrical engineering and energy efficiency. **Project responsibilities:** Providing solar PV and battery storage feasibility, high-level design, specification, integration, and cost for the demonstration site.
JUSTSEN PACIFIC	**Justsen Pacific:** Turn-key biomass boiler solution provider, typically operating BOOM or PPA business models. **Project responsibilities:** Responsible for biomass boiler technical feasibility, high-level design, specification, integration and cost for the demonstration site.

Project limitations

Project limitations are noted as:

- **Site-specific:** While there is significant discovery benefit around construction details, we point out that technical and financial modelling for the project is based on the industry partner processing facility which:
  - processes 1000 to 1250 beef cattle five days per week;
  - has onsite rendering facilities;
  - has a Covered Anaerobic Lagoon producing biogas;
  - has site-specific energy tariffs which apply to the business case; and
  - assumes zero value for any potential export energy or value-add service that could be derived from having large-scale, 'behind the meter' embedded generation (electrical or thermal).
- **Community benefits:** Again, while beneficial to understand construction and integration detail, the project focus was on site-specific needs and does not consider broader community benefits; for example, the potential for a centralised waste-to-energy facility that may be able to provide waste solutions for businesses within the community.
- **Commercial models:** Our analysis assumes a "self-funded" model whereby a processor fully funds, builds and operates the embedded energy plant. We do not consider (in detail) the

range of alternative commercial models[3] that are available for a project of this nature. We do, however, provide comment in section 6.0.

- **Integration:** We have attempted to overlay and assess technology interactions not only with each other but with the grid and natural gas network. In reality, centralised control software and intelligence will be needed to ensure embedded generation can operate efficiently and in synergy. There are solutions available to manage this interaction. However, the cost has not been included in our modelling.
- **Technology selection:** In this project, we have been deliberate in our selection of technologies to meet AMPC's objective of energy sufficiency using technologies that are reliable, available, deployable, scalable and applicable to red meat processors. Technologies included in the industry partner business case were viewed as meeting these criteria and are more likely to be implemented by red meat processors in isolation (as a standalone project). Factors for our selection include:
  - **Attractiveness:** Technologies that are economically attractive under a self-funded scenario or are expected to significantly reduce in cost over the medium term;
  - **Availability:** Technologies that have an Australian based distributor coupled with service agent or agents;
  - **Proven:** Is proven technology within Australia and has been implemented successfully in Australia (multiple times); and
  - **Flexibility and scalable:** Ability to be scaled up or down depending on the size of the processor, noting that the industry partner facility is considered a large size processor by industry standards. There are many other great technologies such as concentrated solar thermal and solar cogeneration that are fast becoming competitive but had to be excluded from our research for many reasons[4].

3.0 PROJECT OBJECTIVES

Project objectives include:

- Demonstrate that meat processing plants can become energy self-sufficient.
- Identify technologies that are reliable and available as well as identifying gaps and further research required.
- Ensure deploy-ability to varying sizes of processing plants through demonstrated flexibility.
- Determine a roadmap for implementation accompanied by a full business case, including ROI.
- Reduce and eliminate reliance on volatile energy markets.

[3] Alternative commercial models available to processors include (but not limited to); Building Own Operate Manager (BOOM), Build Own Operate Transfer (BOOT), Power Purchase Agreement (PPA)

[4] Reasons include; limited number of installations in Australia, more suited to service based commercial models, or yet to set up a service network.

- Enhance industry sustainability while also increasing its social license to operate.
- Include a case study to demonstrate feasibility, scalability and application to the red meat industry.

4.0 METHODOLOGY

This section describes project tasks, including experimental design, measurements, analysis and methodology:

Table 2: Project tasks and methodology

Tasks	Methodology
Task 1: Develop an energy baseline for the industry partner facility and review available renewable energy resources at that facility.	Collect industry partner energy data. Analyse and present in graphical format. Review site waste and weather station data, then use engineering calculations to review renewable energy resources available to the facility. Estimate the levelised costs for each resource.
Task 2: Demonstration of the path to energy self-sufficiency.	Quantify energy requirements, overlay energy productivity projects and match to available renewable energy resources and technologies.
Task 3: Assessment of technology options.	Consult the project panel to understand technology cost, availability, flexibility and deployability. Facilitate a site tour so that the solution provider panel could review construction and integration requirements of specific technologies.
Task 4: Roadmap for implementation.	Develop visual representation (infographic) of the stages of implementation so that processors can see how technology implementation can be phased. IRR and technical risk used as a proxy to prioritise projects.
Task 5: Business case development completed.	Aggregate technical feasibility, high-level design, specifications, integration and costing developed by each turn-key solution provider for their specific technology and combine into one business case.
Task 6: Remove energy market reliance.	Review wholesale, network and LGC electricity market forecast and demonstrate if energy market exposure can be reduced.
Task 7: Sustainability and social license improvements.	Review energy, water, waste, and community impacts of the project(s).
Task 8: Finalise energy self-sufficiency	Aggregate all the individual technology business cases into

business case study.	one to demonstrate the feasibility, scalability, application and return on investment for the red meat processing site to become either fully or partially energy sufficient.
Task 9: Reporting	Compile the R&D project in the following formats: AMPC final report, overall project SnapShot, a roadmap for implementation infographic, technology fact sheets, and an explainer video.
Task 10: Final presentation and industry briefs	Build and extend industry capacity via AMPC approved events.

5.0 PROJECT OUTCOMES

This section outlines project outcomes and supporting data analysis

5.1 Industry partner facility: energy needs and available resource

The industry partner facility is a beef processing plant that processes 1000 to 1250 head of beef cattle five days per week. There is onsite rendering that processes offal, blood and tallow. There is also Covered Anaerobic Lagoon that produces biogas.

Thermal energy

At the time of assessment, the site was in the process of upgrading their natural gas meter. Hourly interval data was not available. Therefore, daily billing data was used for this project.

To better understand site steam load, the following description was provided by the industry partner:

"Steam boilers start around 10 pm on a Sunday night to ensure steam is up to pressure and there is enough hot water for Monday production. Rendering load comes online around 6.30am on a production day, with constant steam demand till 9 pm. At this point, the boiler turns down to medium or low fire to service any make up hot water required. This cycle is typical across the production week with natural gas consumption very low or zero for most of the weekend. In addition to the steam boiler, there is a dryer that accounts for a very small portion of natural gas demand.

Table 3: Average site thermal load

#	Day	Production day (Y/N)	Average hourly energy thermal energy consumption (GJ)	Average hourly energy thermal energy consumption (kW_{th})
1	**Monday**	**Y**	**33**	**9,217**
2	**Tuesday**	**Y**	**33**	**9,220**
3	**Wednesday**	**Y**	**32**	**8,978**
4	**Thursday**	**Y**	**33**	**9,103**

5	**Friday**	**Y**	**28**	**7,804**

We note that data in the table above accounts for natural gas and biogas energy consumption.

Electrical energy

The electrical load profile (Figure 4) for the week surrounding the peak demand event has been extracted from interval meter data.

The profile presented is typical of a large red meat processing facility and has the following attributes:

- Overnight, weekday baseload of 2200 to 3200 kVA
- Daytime production demand of 5000 to 6200 kVA
- Weekend demand of 2000 to 2500 kVA

Table 4: electrical load profile, week surrounding the peak demand event.

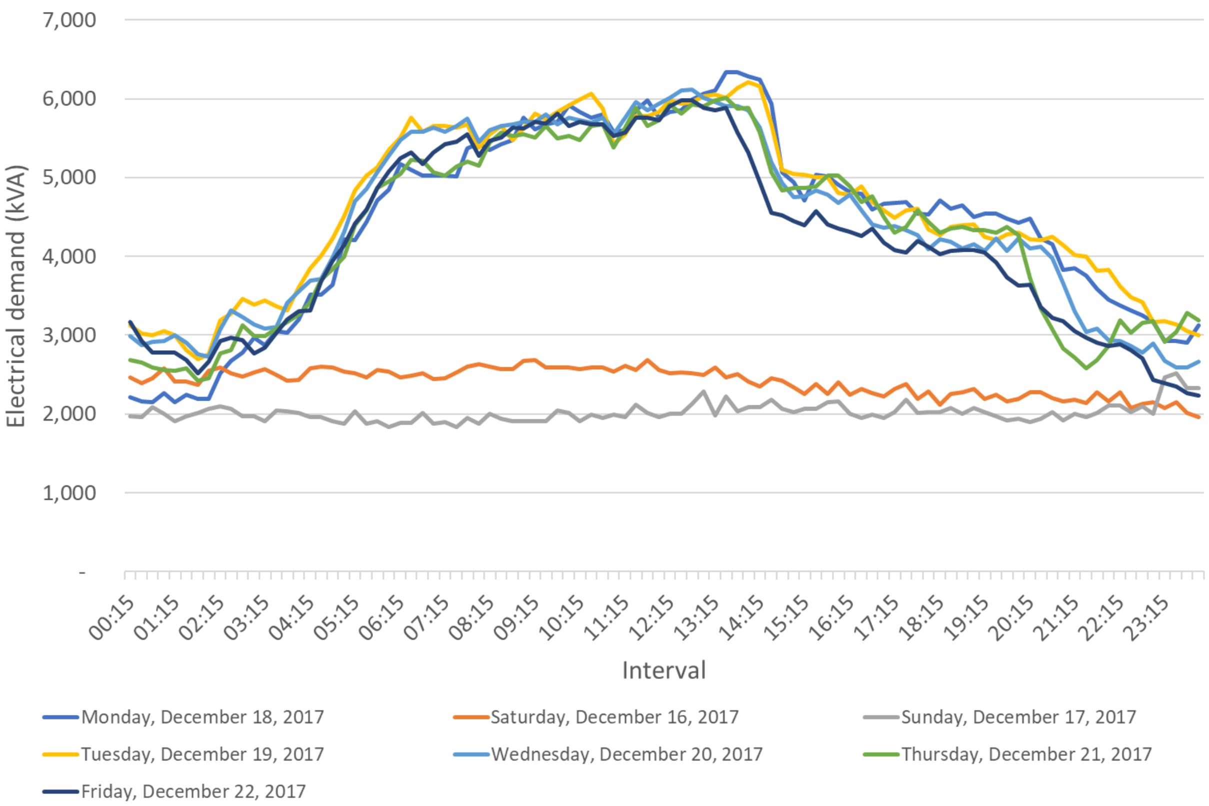


Figure 4: electrical load profile, week surrounding the peak demand event.

Annual peak demand happens in the middle of a hot summer's day when the ambient temperature is at its highest, carcass chillers are full and working hard to remove heat from the rooms.

Table 5: Peak demand events as extracted from site interval meter

Demand events	Event date	Event time	Demand value (kVA)	Demand value (kW)	Power factor @ peak demand
Max event	Monday, December 18, 2017	13:30	6,334	5720	0.90
Weekday	Monday, December 18, 2017	13:30	6,334	5720	0.90
Weekend	Wednesday, January 11, 2017	22:30	3,202	3000	0.94

While there are other fuels used onsite, such as LPG for forklifts and diesel for vehicles, these are insignificant compared to electricity and thermal load, and therefore not a focus of this study, at the request of the industry partner.

Renewable energy generation profiles

A number of technologies were reviewed for this project, including the variability of generation and how they would interact with site demand profiles. From this research, we found the main generation profiles that needed consideration were solar and wind. All other technologies can be controlled by the processor. For example, the generation of biogas is relatively constant and controlled by either the amount of wastewater flowing in the CAL or the feed rate of solid waste entering a tank style digestor. Both can be controlled by the processor and typically align with production schedules.

Table 6: summary of technology attributes

#	Technology name	Fuel source	Generation profile	Availability, flexibility and deployability
1	Biogas cogeneration	Biogas/methane	Controllable	Most equipment is shipped from Europe or the US within a 16 to 20-week lead time. Reciprocating engines have a 50% turn-down and microturbines 10%.

2	Solar PV	Solar radiation	Variable, but can be coupled with battery storage	Booming marketplace in Australia which is readily available and deployable. Inverters have good control and provide the ability to load follow with a high degree of accuracy; however, the output is subject to solar resource, which is uncontrollable. Electricity networks experienced in assessing network connection applications for solar PV
3	Concentrated solar thermal (no storage)	Solar radiation	Variable, but can be coupled with storage	Typically done at utility scale but rapidly changing and reducing in cost. Capital intensive (at the time of writing) and involves long lead times. Has the potential to be a lead technology for red meat processing with the generation of steam and electricity possible.
4	Wind turbines	Wind resource	Variable, but can be coupled with battery storage	Better suited to utility scale. Capital intensive at small scale. Requires lots of pre-engineering.
5	Biomass steam boilers	Can be a variety of organic materials such as wood chips, straw, agricultural waste, crop residues etc.	Controllable	Usually imported from Asia or Europe with long lead times (10 months), but available. Will operate better with constant steam demand (similar to coal-fired boilers). Best suited to 5MW and above with 100+ operating hours per week.
6	Anaerobic digestion	Can be a wide variety of organic material such as bi-products and other substrates.	Controllable	Available, but capital intensive. Will operate better on an optimal variety of fuel. Able to be scaled.

Please refer to the technology fact sheets that accompany this report for more detailed information on each technology.

The two main variable technologies are wind and solar. Wind generation has been discounted from the results, as capital cost (Table 7) versus benefit for wind generate is not well suited to the industry partner facility.

While wind generation is a solid technology, it is best suited to large scale utility projects. We note that large scale wind generation projects provide some of the lowest cost generation available in the market today (from an LCOE standpoint, see Figure 8: IRENA Renewable Energy Costs 2017, LCOE)

Therefore, the solar generation profile is the only one that needs more consideration.

We specifically reviewed the solar PV generation profile for the week surrounding site peak demand to see the system impact. An extract of generation data for a 7MW solar PV array is presented below:

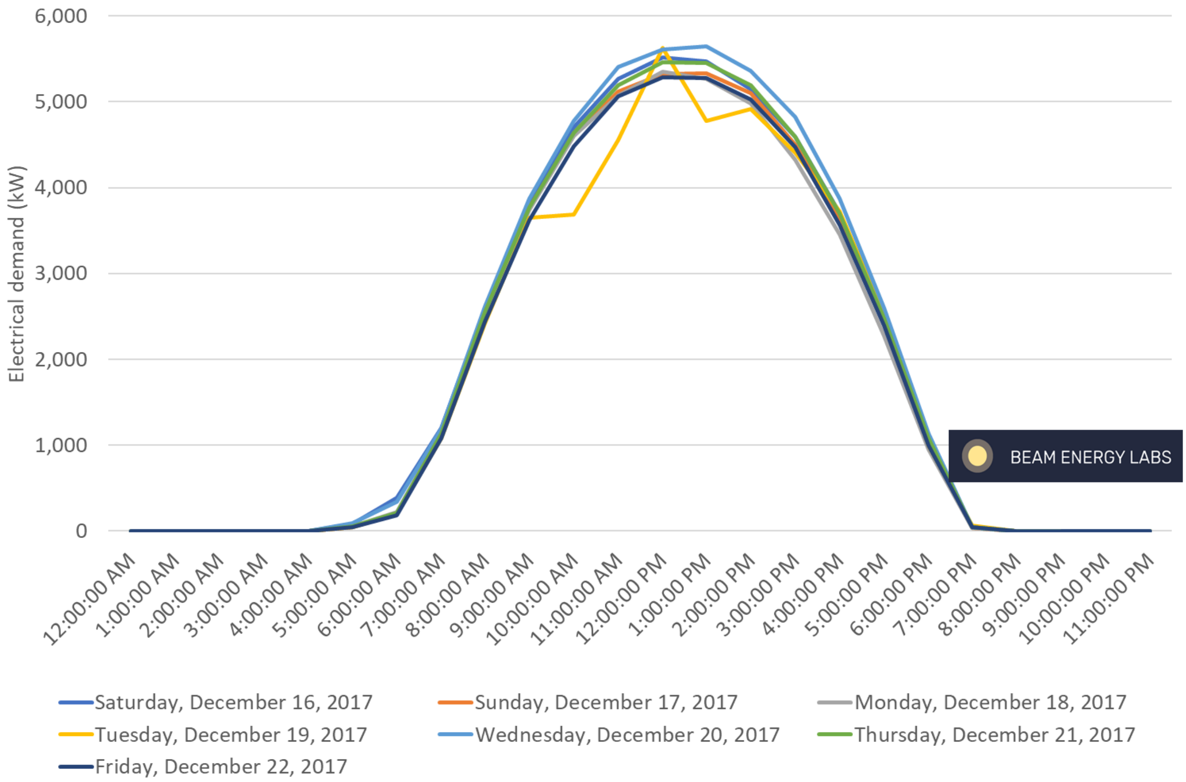


Figure 5: 7,000kWe solar PV generation profile during site peak demand, source: data extracted from Beam Energy Labs, commercial solar platform.

The following is observed:

- Large scale solar PV is well placed to offset or displace high-cost peak grid power which coincides with the industry partner peak demand.
- The monthly peak demand event occurs when carcass chillers are full and have maximum heat load, plus ambient temperatures are highest.
- Without storage, there is a risk of cloud cover during the time of site peak demand, hence the business case allows for a small peak demand offset (in this case around 20% peak demand saving, based on generation data overlaid with site peak demand data).

Using Beam Energy Labs' Beam Commerical software, we were able to run up to 100 different system capacities and scenarios in one day.

The following is an extract of the same 7,000kWe solar PV system (demonstrated above) and how NMI data would look with the solar system installed.

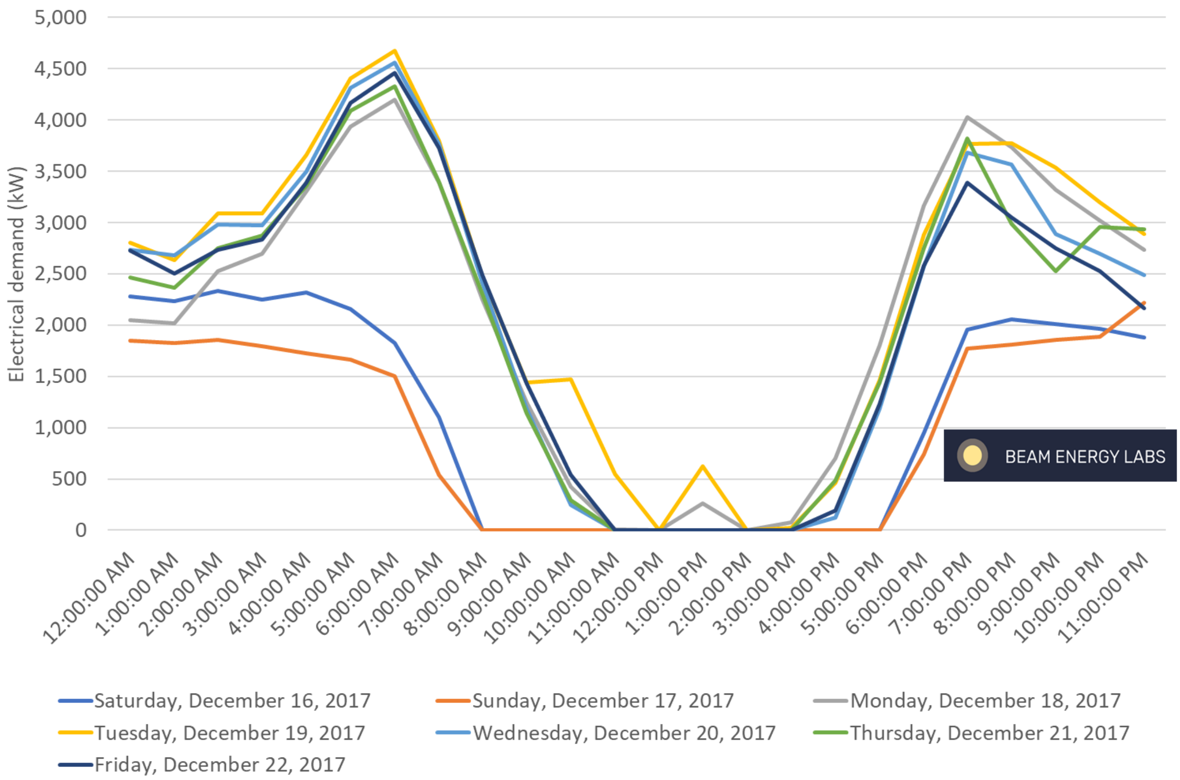


Figure 6: New site load profile with 7,000kW solar PV system

7,000 kW is the example used here as it would be suitable for the site if solar PV were installed in isolation, obviously the optimal solar capacity will change with the introduction of other “behind the meter” technologies such as cogeneration and batteries.

5.2 Technology capital cost, assessment and options

As mentioned in the section above, this R&D project focused on technologies that are available today and are more likely to be adopted by processors under a self-funded business model. The following table articulates these technologies:

Table 7: Technology capital cost

#	Technology name	Fuel source	Estimated capital cost ($)	Adoption commentary
1	Cogeneration	Natural gas/ biogas/methane	$1800 - $2500/kW	Most equipment is shipped from Europe or the US in 16 to 20 weeks. Gas conditioning for biogas units is critical. Ensure future maintenance costs are included in the business

				case.
2	Solar PV	Solar radiation	$1500 to 2,200/kW	Inverters have good control and provide the ability to load follow with a high degree of accuracy; however, the output is subject to solar resource, which is uncontrollable. Installers need to consider the interactive effects of solar PV and power quality (specifically power factor[5] and ramping)
3	Concentrated solar thermal (with storage)	Solar radiation	$8000 to 14000/kW	Typically, only done at utility scale. Capital intensive and involves long construction times. Has not been included in the industry partner business case.
4	Wind turbines	Wind resource	$3000 to $5000/kW	Typically, only done at utility scale. Capital intensive at small scale. Requires lots of pre-engineering. Has not been included in the industry partner business case.
5	Biomass steam boilers	Can be a variety of organic materials such as wood chips, straw, agricultural waste, crop residues etc.	$500 to $700/kW	Imported from Asia or Europe with long lead times, but available. Will operate better on constant steam loads (like a coal-fired boiler). Better suited to 5MW and above. Requires lots of space for fuel handling equipment and storage. Needs to be backed with a strong supply agreement.

[5] Solar PV inverters generate "true power" or kW without any reactive power which can reduce site power factor. This can be detrimental to energy costs if it impacts the magnitude of peak demand (kVA) (depending on the site-specific network tariff). However this problem can be easily solved using either kVAr capable inverter technology or with power factor correction.

6	Anaerobic digestion	Can be a wide variety of organic material such as bi-products and other substrates.	800 to 1500/m3	Available, but capital intensive. Will operate better on an optimal variety of fuel. Able to be scaled. The business case needs to consider operating cost of patristic loads, such as screens and pumps.

5.3 Technology options and assessment

Using the industry partner facility as the example, the following section provides insight into each technology. This assessment considers:

- Return on investment
- Implementation challenges
- Operational challenges
- Capital costs
- Construction challenges

Table 8: technology options and assessment summary

Technology name	Technology description
Biogas cogeneration (operating off CAL biogas)	The assessment is based on an Avus 1000c biogas cogeneration facility manufactured by 2G in Germany, supplied and installed by the Australia distributor, Evo Energy. Running on 100% CAL biogas that has been conditioned with a biological scrubber(s). Max electrical output of 1,200 kW at an electrical efficiency of 42.5%, 1,178 kW thermal output at an efficiency of 41.7%.
Biomass boiler	The assessment is based on a Justsen 15 t/hr steam biomass boiler with an MCR of 9,752 kW. Capital costs include semi-automated, fuel handling system, stoker, ash removal, bag filter, electrical, and civils.
Anaerobic tank style digestor with biogas cogeneration	Anaerobic digestion (tank style) to increase biogas to the boiler (using all by-products of blood, red solids, paunch, green stream solids, and third-grade tallow).

Solar PV (of varying sizes and configurations)	Large scale solar PV ranging from 1.6MWe roof mount, all the way up to 10.00 MW_e ground mount.
AD to boiler (all products)	Anaerobic digestion (tank style) to supply an additional 1.2 MW_e cogeneration engine (using all by-products)
AD to boiler (some products)	Anaerobic digestion (tank style) to increase biogas to boiler (using some by-products: paunch, green stream solids, and third-grade tallow)
10.0 MW solar +10MWh_e Battery	10.0 MW_e ground-mount solar PV with 10 MWh_e battery energy storage

5.4 Full business case

This section articulates the full business case for selected technologies as a package, to achieve full energy sufficiency for the industry partner facility.

This includes:

- 1.2 MW_e biogas powered cogeneration operating off existing CAL biogas
- 1.2 MW_e biogas powered cogeneration unit operating off biogas generated from a new tank style anaerobic digester, using some bi-products as feedstock
- 10.9 MW_{th} biomass boiler operating on straw
- 10MW_e solar PV array couple with 10MWh battery storage farm

Description	Capacity (kW or *GJ p.a.*)	Turn-key capital cost	Energy self-sufficiency (%)	IRR (%)	Simple payback (years)
Full sufficiency scenario	Thermal capacity = 10.9MW_{th} Electrical capacity = 12.4MW_e + 10MWh storage	$44,130,000	100% but grid connected	6%	11.9

Key assumptions

The following assumptions have been used when developing the business case(s):

- **Discount rate:** 10%
- **Project life expectancy:** 20 years
- **Maintenance costs:** Based on solution provider service level agreements or estimated parts and labour.

/ **Natural gas pricing:** Based on site-specific costs in alignment with current agreements or contracts for the first two years, then a flat forecast for future pricing (as reviewed by Beam Energy Labs).

/ **Retail electricity pricing and forecast:** Based on site-specific contract pricing for the first three years, then flat rate after that. The rationale for this approach is that while network prices may increase in future years, retail pricing is expected to have downward pressure applied as the percentage of renewable energy increases within the wholesale electricity market. Also, recent volatility in the entire electricity market means that a flat forecast is prudent to ensure business case projections remain conservative (also reviewed by Beam Energy Labs). As mentioned above, this study focused on the accuracy of project capital cost estimates to which the business case is highly sensitive.

/ **Network electricity pricing and forecast:** Escalated by CPI for future years due to the link between network business operating costs and CPI.

/ **Large scale Generation Certificates (LGCs):** The following certificate prices are used:

- 2019: $40/certificate
- 2020: $25/certificate
- 2021 to 2030: $10/certificate

/ **Project risk premiums:**

- Project management: 3%
- Management reserve: 5%
- Project contingency: 10%

/ **Export energy:** A value of $60/MWh has been assumed for export energy.

/ **Value add services:** we have assumed zero value for any other value add service such as organic fertilisers or energy network ancillary services.

5.5 Business case by technology

This section articulates the business case for each specific technology. It is important to view each technology in isolation so that individual red meat processors can see which technologies they may invest in, versus technologies better suited to alternative commercial models such as:

- Power Purchase Agreements (PPA)
- Build Own Operate Transfer (BOOT)
- Build Own Operate Manage (BOOM)
- Lease agreement

Technology name	Capacity (kW or *GJ p.a.*)	Turn-key capital cost ($)	Capital intensity ($/kW or $/GJ)	IRR (%)	Simple payback (years)
Biogas cogeneration (1 x $1.2MW_e$)	1,200 kWe	2,923,332	2,436	31%	2.9
Biomass boiler	10,998 kWth	6,409,034	583	21%	4.7
Tank based biogas plant with $1.2MW_e$ cogeneration	73,369 GJ/pa	9,121,492	7601	12%	7.3
Solar PV 7.5 MW_e	7,465 kWe	14,411,530	1,931	7%	9.1
Tank based biogas plant to existing boiler (all product)	88,835 GJ/pa	6,198,160	70	6%	9.6
Roof top solar PV 1.6 MW_e	1,558 kWe	3,654,629	2,346	6%	9.6
AD to boiler (some product)	48,359 GJ/pa	6,198,160	128	4%	14.2
Solar + battery storage	9,953 kWe and 10MWh	25,675,172	2,579	3%	12.0

6.0 DISCUSSION

Processors should start by understanding site-specific energy needs and resource productivity improvements, as these will vary from site to site. For example, there is a big difference in thermal energy requirements for processors with and without rendering facilities. Those with rendering should have a good look at biomass boilers, as natural gas pricing has reached $10 to $20/GJ. Switch to biomass to service your steam load for $4 to $7/GJ.

Processors without rendering might be able to generate hot water needs with solar cogeneration, or solar thermal plus process heat recovery, although this has not been modelled.

If processors have a working CAL producing biogas, then biogas cogeneration is likely to be an attractive option. With this, we suggest including high-quality gas conditioning equipment, as the prime mover will set you back $1800 to $2500/kWe and needs to be supplied with biogas sulphur of 80 ppm or lower.

Commercial solar is a low-risk technology that will provide low cost (7 to 12 c/kWh) daytime power that typically coincides with processor weekday peak demand. We suggest choosing a commercial model that suits your business and moving forward with that. Capital costs range from $1500 to $2000/kW.

Tank style anaerobic digestion enables processors to convert solid waste such as paunch, green stream solids, and third-grade tallow into energy. To extract value, couple with biogas cogeneration to provide baseload renewable energy. Be aware that construction costs are capital intensive at $800 to $1500/m3 + cogeneration plant.

Energy storage will play a key role in managing power quality issues such as voltage and frequency fluctuations, as well as solar PV and grid interactions during cloud cover events. However, energy storage using batteries is still capital intensive at up to $750/kWh (turn-key).

Energy management software to control the interaction between embedded generation (see Figure 7), grid and site demand will be critical to ensure smooth plant operation and avoid nuisance tripping.

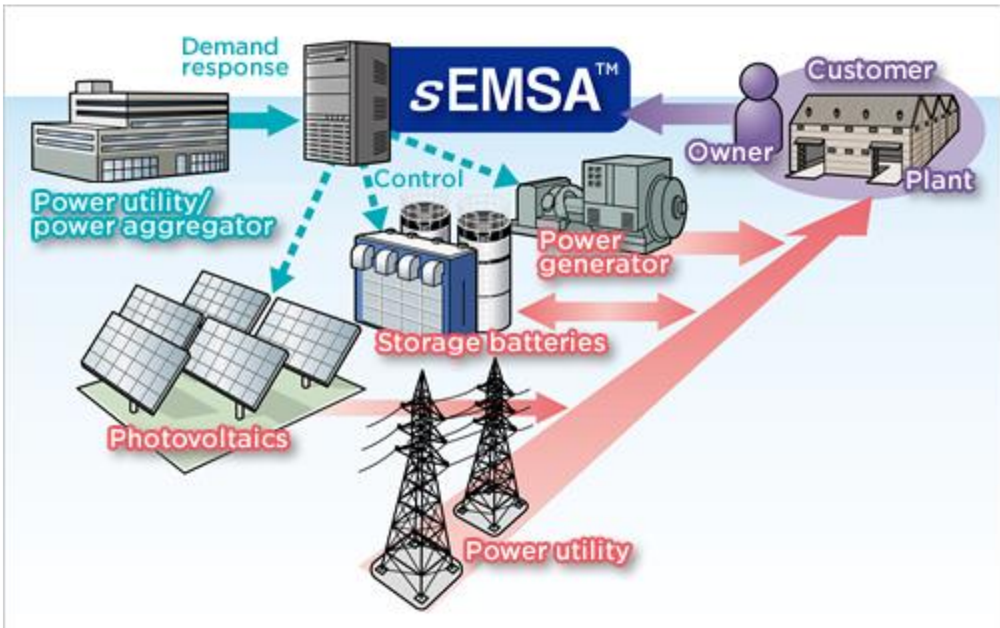


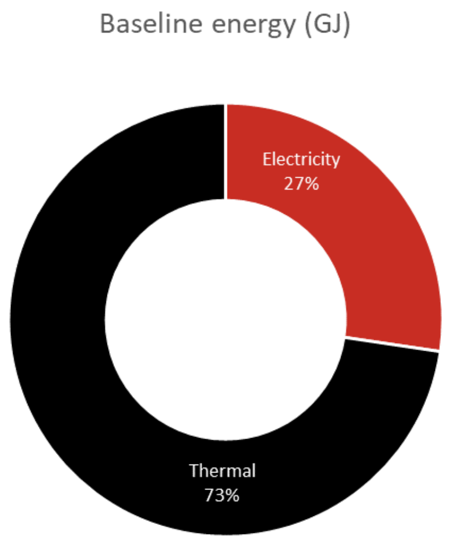
Figure 7: an infographic of interaction between grid, generation, storage and customer load, source https://global-sei.com/products/semsa/

Overall, becoming energy sufficient is technically possible for red meat processors, and can be achieved using a range of reliable technologies such as cogeneration, anaerobic digestion, solar PV, energy storage, and biomass boilers. While there is insufficient waste material available to service all of a processor's energy needs, importing fuels such as biomass reduces market exposure.

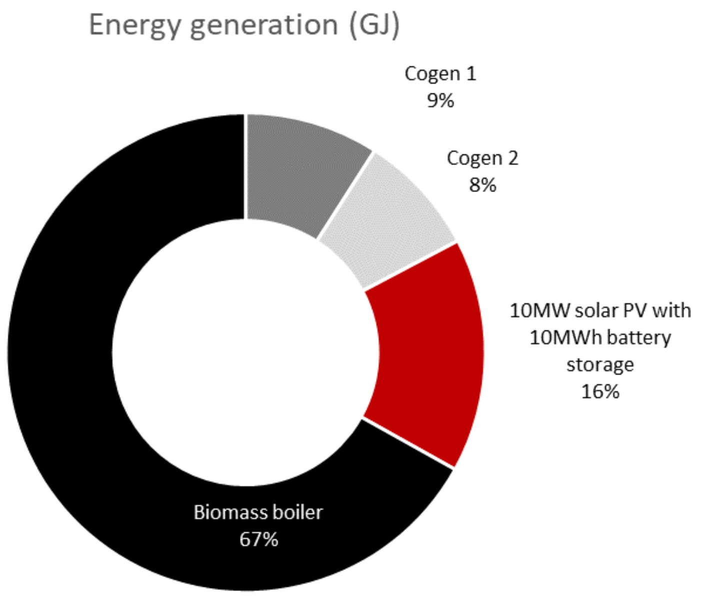
While the goal of being completely energy sufficient is capital intensive and economically unattractive, there is a range of commercial models available that can be tailored to suit.

Processors are well placed to source part of their energy needs (today) from renewable generation at a lower cost than the grid.

The industry partner facility currently sources 27% of their energy needs from the electricity grid and 73% (in the form of thermal energy) from the natural gas network.



Under the energy sufficiency scenario, 67% would be supplied from biomass, 17% from biogas powered cogeneration engines and the remaining 16% from the 10MW solar PV system couple to a 10MW battery so that energy could be time-shifted to suit production.



6.1 Technical challenges

The following technical challenges are notes as project learnings:

- **Biogas cogeneration from CAL gas:** The 1.2MW_e biogas cogeneration project operating off existing CAL gas has the advantage of sourcing fuel from a sunk asset, which we assume has a cost of zero. If the project included the cost of a new CAL, it would be economically unattractive (from an energy cost perspective).
- **Cogeneration thermal energy:** Making good use of the thermal energy generated by the cogeneration unit is difficult. As the industry partner facility has a rendering plant with heat recovery for hot water generation, it is difficult to find a good use for low-grade heat (less than 100°C). Most (approximately 70%) of plant hot water needs are generated through heat recovery of render vapours; therefore, the value of cogeneration thermal energy is reduced.
- **Commercial models:** In the absence of high LGC pricing and relatively low grid electricity pricing, it becomes difficult to achieve an IRR that would be attractive to the average meat processor (less than 3-year payback). However, technologies used are capable of generating energy at a cost lower than grid (on an LCOE basis) and therefore better suited to alternative commercial models such as power purchase agreements. Under these agreements, processors receive the technology benefits, while the solution provider is incentivised to keep the plant running at optimal levels.
- **Large scale solar PV:** Achieving attractive economic returns for large scale solar PV (without storage) sized to daytime production load becomes challenging as the industry partner facility operates five days per week and has relatively low electricity rates. This means that approximately 20% of the solar energy generated on weekends would be exported. Even if the local Distribution Network Service Provider (DNSP) approves an export connection agreement with the processor, export energy is unlikely to attract anything higher than $0.06/kWh, which is lower than the LCOE of the project.

6.2 Removal of energy market reliance

As an outcome of this project, we found the simplest way of removing energy market reliance was through fuel switching from natural gas to biomass for steam generation.

Using the industry partner facility as an example, this would remove around 96% of the natural gas load and save the facility almost $1M/pa. The challenge comes with reliable sourcing of biomass.

It is typical for meat processing facilities to have enough redundancy to ensure they can still operate when there is a major breakdown; hence, there are often two or more boilers installed.

In this example, where we fuel switch from natural gas to a biomass boiler, the existing gas fired boiler would stay in service to provide a low-cost form of redundancy, and a gas connection would be maintained. The implication of this is that fixed gas network costs cannot be removed.

Another issue remains with the blood ring dryer, which requires a small amount of natural gas to operate. If tank style AD was implemented, blood could be diverted to these tanks, however, at current market rates (around $1,000/tonne) blood has more value as a saleable product.

Electricity is slightly more complicated, as it needs to be supplied by multiple technologies. There is potential to significantly reduce market exposure, even if the processor were to adopt the biogas cogeneration (1.2MW_e) only. This would provide 27% of their electricity needs and hedge against market volatility. At the upper end, the site could generate 100% of their electricity consumption by adopting 2.4MW$_e$ of cogeneration (powered by both CAL and solid waste anaerobic digestion) and 10 MW$_e$ of solar PV and a 10MWh battery. Note that this will generate 100% of their annual electricity, but not at the same time as it is consumed. This is why a grid-connected battery system with export capability is ideal.

Together, these technologies will remove energy market exposure, with the processor generating all of their energy and exporting any spill.

6.3 Sustainability and social license to operate

The Australian beef industry has identified a number of opportunities to meet the changing expectations of customers, investors and other stakeholders. The industry has been proactive in addressing these changes by developing the Australian Beef Sustainability Framework. The framework defines sustainable beef production and tracks performance over a series of indicators annually.

Also, Meat and Livestock Australia (MLA) have identified and committed to CN30, which will see the industry become carbon neutral by 2030. Emissions profiling from this activity confirms that the most significant proportion of emissions relates to primary producers. Work is currently underway to address emissions up to the farm gate.

While less emission intensive, processors also have a role to play by ensuring emissions are reduced post farm gate. This is certainly more achievable for the processing sector, given technologies are commercially available and some are now economically attractive. With the understanding that such change is technically feasible comes the opportunity to improve sustainability and social license to operate through active community engagement and brand management.

The following opportunities are noted for processors as a result of becoming fully or partly energy sufficient:

- **People and community:** Adoption of renewable energy technologies will attract new skill sets to regional communities while supporting the plant and community through lower cost of production. Processors should engage the community when renewable energy technologies are adopted, by holding open days and educating the community on the benefits of renewable energy. Suggested activities that processors could take on when adopting renewable energy projects include:
    - Seek community approval when an investment decision is being made.
    - Hold an open day post-implementation.
    - Get local businesses involved in the servicing and maintenance of the project.
    - Engage with members of local, state and federal government so that the community benefits are understood and supported.
    - Participate in the promotion and marketing of the project through industry events and via technology suppliers.
- **Emissions reduction:** Significantly reduced (or even carbon neutral) scope one and two emissions[6] associated with processing.
- **Branding reputations:** Improved corporate image and brand reputation through environmental stewardship and economic resilience.

Consumer concerns around red meat consumption should be managed by having a proactive approach

[6] As defined by National Greenhouse Accounts Factors

to greenhouse gas emissions and renewable energy. The latest Lowy Institute survey provides some insights into public opinion toward climate change and renewable energy:

"In 2018, 59% of Australians (up five points) say 'global warming is a serious and pressing problem' about which 'we should begin taking steps now even if this involves significant costs'. Almost all Australians (84%, up three points) say 'the government should focus on renewables, even if this means we may need to invest more in infrastructure to make the system more reliable'. Only 14% say 'the government should focus on traditional energy sources such as coal and gas, even if this means the environment may suffer to some extent'." Source: 2018 Lowy Institute Poll, https://www.lowyinstitute.org/publications/2018-lowy-institute-poll

6.4 Project achievements

The following achievements are noted as a result of this R&D project:

- The site-specific business case developed using "real" data provided by the industry partner and "real" project costings provided by organisations with the capacity to design and construct turn-key solutions.
- Impact of energy productivity improvements is understood, specific to the industry partner facility.
- Technology order of priority is understood using IRR and LCOE as a proxy for decision making.
- The industry is provided with a true reflection of capital requirements to achieve energy sufficiency (or part sufficiency).
- It is demonstrated that energy sufficiency or part energy sufficiency can be achieved in a phased approach that complements broader business activity and investments.

6.5 Benefits to industry

The R&D project and associated findings demonstrate the benefit to meat processors by capturing capital requirements, commercially available technology options, and how they can be implemented in a phased approach to complement broader business activity and investments.

Other benefits include an improved social license to operate, sustainability credentials, and brand positioning. Additional tangible benefits related to the adoption of new technology (in addition to energy and carbon savings) such as reduced operating and maintenance costs, improved reliability, and improved control will be realised: "an efficient plant is a reliable plant".

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusion

A key focus of this Research and Development project has been to review the construction costs associated with embedded renewable energy generation and to collaborate with turn-key solution providers to capture practical aspects of embedded generation and disseminated to industry.

This approach, coupled with traditional energy management skills of Smart Business Hub and Beam Energy Labs, allowed for the development of an energy sufficiency business case based on a working beef processing facility.

Technical and financial modelling developed for the project confirmed that it is technically feasible for the industry partner facility to become **100%** energy sufficient. This could be made possible by using a combination of technologies including a biomass boiler, biogas cogeneration, solar PV, battery storage, and solid waste anaerobic digestion (tank style).

However, to achieve this outcome requires an investment of over $44m and has an internal rate of return less than 10%. While this will be an unattractive proposition to most red meat processors, we encourage members to:

- Investigate technologies that may be attractive for their specific facility; and
- Explore alternative funding models to source energy that is both lower cost than the grid and lower emissions.

While there has been a wave of negative media around energy, processors have more choice than ever with the development of low-cost renewable energy technology and commercial solutions.

7.2 Recommendations

- **Start with energy productivity**: Before investing in becoming energy self-sufficient, we recommend processors have a clear understanding of energy and water productivity opportunities. We also recommend it remain a key area of focus for all processors. Not only will it directly reduce manufacturing costs, but also provide attractive returns (typically 15% to 100% IRR). Also, improving energy and water efficiencies will lower future capital investment in renewables. There is no benefit in installing renewables to fuel inefficiencies.
- **Project risk:** Processors should consider the risk profile of each technology in isolation, and then in aggregation. Operation and maintenance of renewable energy assets vary broadly between technologies; for example, a solar PV asset is relatively straightforward to operate. If good quality equipment and a monitoring system are installed from day one, the asset will operate with relatively low maintenance for most of its useful life. However, bioenergy assets such as anaerobic digestion tanks and biogas cogeneration are more complex and will require third party support over the life of the asset. Processors that have experience operating CAL's, for example, will understand that it's like operating a real-life human stomach; if it gets out of balance, things go wrong.
- **Interfacing:** Consideration should be given to interactive effects between embedded generation assets, the existing plant, and the grid. The process of connecting large embedded generation can be lengthy and should be allowed in the project scope.
- **Stay grid connected:** A key objective of this project was to reduce or eliminate reliance on volatile energy markets. This does not mean disconnecting from the grid. The grid is by far the cheapest form of redundancy and reliability available to most businesses; hence, a grid connect system will be best suited to most red meat processors.

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9.0 APPENDICES

This section includes supporting documentation that has been referenced in this report.

9.1 Appendix 1 – IREAN Renewable Energy Costs 2017

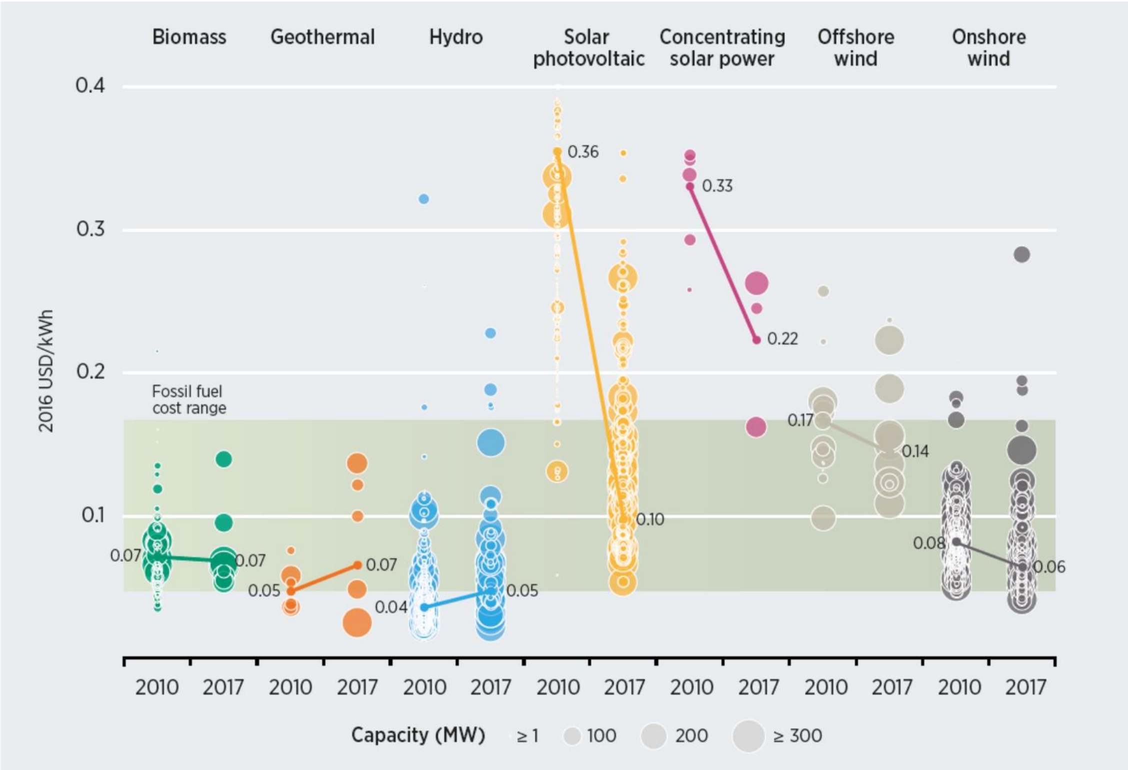

Figure 8: IRENA Renewable Energy Costs 2017, LCOE

9.2 Appendix 2 – Industry partner baseline data

Table 9: industry partner baseline information

Utility type	FY17	FY18
Electricity (kWh/pa)	28,709,586	25,354,301
LPG (GJ/pa)	1,988	1,444
Thermal energy (natural gas and biogas) (GJ/pa)	250,100	227,655
Waste water (kL)	646,484	544,626
Potable water (kl)	745,676	634,343