



Exploring the potential for primary industries to improve energy productivity



A research report for
New South Wales Department of Primary Industries
January 2019



AUTHORSHIP OF THIS REPORT

This report has been prepared by the Australian Alliance for Energy Productivity (A2EP) for the NSW Department of Primary Industries (NSW DPI). A2EP is an independent, not-for profit coalition of business, government and environmental leaders promoting a more energy productive and less carbon intensive economy.

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Citation: Jutsen, J., Westmore, T., Pears, A., Hutton, L. (2019). Exploring the potential for primary industries to improve energy productivity. Sydney: Australian Alliance for Energy Productivity.

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Executive Summary

The purpose of this study was to examine energy productivity in the NSW agricultural sector and to determine which sub-sectors had the most potential to create more value by applying energy more effectively and efficiently. Findings from this report will be used as the basis of further project planning and to guide investment in the pilot component of the Energy Efficiency Solutions Project, funded as part of the NSW Primary Industries Climate Change Research Strategy. DPI support for pilots under the project, aims to reduce investment risk, demonstrate potential and promote the application of energy productive technologies and approaches to benefit farmers.

Improvements in energy productivity are achieved through increasing the value of output per unit primary energy input deployed. This can be achieved by utilising energy more effectively to derive greater value and reduce energy waste, and/or by generating on-site energy from wastes or renewable energy sources to reduce primary fossil energy consumed. Commercial benefits for farmers can also be gained by improving the energy productivity of the energy supply system through managing the timing of consumption and utilizing energy storage.

A systematic assessment process, using the six criteria listed below, was used to prioritise those sub-sectors in NSW for coverage in this initial study based on their expected potential to benefit from pilot investment in energy productivity improvement:

1. Contribution of sector to NSW Gross Value of Production (GVP)
2. Sector growth
3. Value chain benefits
4. Reliance on energy
5. Energy intensity trends
6. Potential for opportunities

Priority sectors for energy productivity investment

Using these criteria, the sub-sectors selected for focus in this study were:

- Cattle feedlots
- Dairy farming/on-farm processing
- Horticulture, with a focus on more intensive operations
- Chicken meat and egg production
- Piggeries.

While some extensive sectors, such as extensive cropping and cattle (on pasture), have high economic impact and high levels of energy use, they are not included in the list above of priority sectors for energy productivity investment. These sectors are more suited to conventional energy efficiency initiatives delivered through training and education programs and will be dealt with separately under another component of the Energy Efficiency Solutions Project .

This study is primarily concerned with identifying transformative opportunities for improving energy productivity in agriculture beyond conventional energy efficiency opportunities. However, it is important to note that conventional energy efficiency measures, which are not covered in detail in this report as they are already the subject of many other reports, are well suited to the extensive sub-sectors with high levels of diesel use.

Extensive sub-sectors, such as broadacre farming, generally use a higher proportion of diesel, compared to electricity and gas, than intensive sub-sectors. These extensive sectors with high levels of diesel consumption have significant potential to benefit from a conventional energy efficiency approach by improving the use-efficiency of existing equipment or by updating equipment.

This study identified some important trends impacting on energy productivity in agriculture:

- Animal welfare/consumer expectations are impacting on energy application in farms. For example, the rapid trend to free range production of eggs and chickens has led to producers making modifications to existing sheds which has reduced energy productivity, at least until plant and equipment can be optimised for this new style of operation.
- License to operate and compliance with health regulations is combining with improvements in anaerobic processing technology to drive far greater interest in converting wastes to biogas for heat and/or electricity and, potentially, to supplement or replace diesel fuel (after cleaning and compression). There are large amounts of unutilised waste which can be converted to energy, in particular manure but also agricultural crop waste. Converting wastes to energy through anaerobic digestion to biogas can transform energy from a cost to an income stream and source of competitive advantage. The pork industry, for example, has a strong focus on biogas production, reflecting a combination of taking control of energy costs, reducing carbon emissions, creating new revenue streams, and dealing with a waste and odour problem that costs money and also affects their license to operate.
- There is a big drive towards using solar PV on farms, but often a poor understanding of how to best utilise it, and a mistrust of vendors approaching farmers aiming to sell hardware without concern about the best application of this technology and integration with the farm and the electricity grid. Opportunities exist to apply different solar technologies including single axis tracking, smarter demand management and storage (in many forms including hot and cold water, as well as batteries), and to optimise energy supply/production and integration with grid. This (as well as from power generation from biogas mentioned above) is particularly relevant for farms located at the edge of electricity grid, where there may be potential for micro-grids and use of on-site generation for network support.
- There is a division in many sectors between the leaders who are using advanced technologies such as Internet of Things and international best practices in energy productivity, and the others which use traditional methods. In the egg sector, for example, there are high volume state of the art operations operating on small margins and striving for small increases in productivity, and smaller farms which achieve premium pricing based on their traditional methods, and who may have little incentive (or capacity) to change present technologies and practices.
- There is a trend to increasing intensification of agriculture in many sectors. Intensification generally has the benefit of reduced water use but often increases energy use (for pumping, fans, space conditioning etc). But there is the potential to increase energy productivity

overall if there are sufficient yield increases and innovative practice and technology changes. Further work is required to fully understand these trade-offs, and the opportunities for improving energy use to maximise business benefit in intensive agriculture.

- The shift towards intensification also involves fragmentation of activities and potentially shifting of activities between traditionally defined segments. For example, intensive piggeries and feedlots rely on separate suppliers for much of their animal feed. Feed then becomes an input cost that replaces land, pasture management, cropping and processing. Consequently, operators lose direct control and must rely on contracts, monitoring, accountability etc. There are likely to be common opportunities for energy productivity innovation in feed production across many sectors, which should be further explored.
- Outside irrigation pumping, shifting from traditional fuels for heat, vehicles and other activities to electrification has yet to greatly penetrate agriculture, but there are many emerging opportunities for electrification such as adoption of heat pumps, and ultimately electric driven farm vehicles.
- The advent of the Internet of Things (IoT) is providing opportunities for process level and value chain optimisation e.g. real time tracking of the location and temperature of perishable food from farm (ideally immediately after picking) to shelf, to improve food quality, reduce waste and through better application of refrigeration, optimise energy productivity.
- There remains a big potential opportunity for agriculture to improve energy productivity beyond options addressed in this limited study: for example, will farms be able to benefit from an energy cost competitive advantage, based on having land available for generating lower cost energy from solar/wind, and wastes for generating biogas? Potentially, this emerging competitive energy cost advantage could support new opportunities for the agriculture sector to add more value at farm/in the local region, through on-site, highly automated (and artificial intelligence optimised) modular manufacturing, and other energy using value adding activities.

Pilot project concepts

There is a wonderful opportunity to accelerate energy productivity improvement in agriculture due to the rapid global technological advancement in IoT and digitalisation, electrification, biogas production, solar and storage, as well as increasingly flexible financing and 'green' investment funds e.g. from Clean Energy Finance Corporation (CEFC) and international banks like HSBC and green bonds. DPI can assist in transformation in many ways. In particular it can reduce risks between project concepts and widespread adoption by supporting initial technology implementations in NSW.

A key element of this project was thus to identify some initial concepts for pilot projects, which could be facilitated, potentially through part-funding, by DPI. These pilots would be innovative for the industry, offer a substantial improvement in energy productivity, and have extensive replication potential.

Such pilots could have a significant impact on the applicable sectors, accelerating rates of technology transfer in Australia from international and local best practices presently constrained by business conservatism in investment, risk aversion and broader economic factors.

The following factors were considered when identifying examples of potential pilot concepts for energy productivity investment:

1. Large energy productivity improvement and carbon savings potential, including potential revenue from creation of carbon offsets.
2. High replication potential of the projects, particularly in these applications within the sector, and potentially in similar applications in other sectors.
3. Support from the industry, and suitable industry, association, government technology and research partner organisations with enthusiasm for participation and energy benefits. In doing this work, the project team sought advice from the sectoral associations on what projects might be well received by the farmers in the sector, and were believed to have the greatest potential impact on their overall productivity and energy costs.
4. Potential for co-funding from other organisations e.g. grant funding from Rural Research and Development Corporations (RRDC) and Australian Renewable Energy Agency (ARENA), supplemented by CEFC or other sources of finance including from third party BOO (Build Own Operate) businesses.

When developing example pilot project concepts, the following matters were also taken into account:

- Social licence to operate - this is becoming an increasingly important issue for farmers, particularly in relation to animal welfare and environmental responsibility e.g. emissions, water use. This is an emerging major potential driver for change in, for example, animal waste handling. Note that social licence to operate considerations can be a driver to increase energy use unless well managed.
- The potential to reduce farmers' vulnerability to the challenges of climate change and enhance their capacity to adapt. Pressure on farmers to minimise emissions is also connected to maintaining their license to operate and contribute to achievement of national emission reduction targets. Emissions reductions also provide an opportunity to create revenue from creation and sale of ACCUs, LGCs and EE certificates - combined with cost saving and value enhancement from energy productivity improvements, farmers benefit from improved financial resilience and competitiveness.

Note that there are many potential projects identified in each sector, and we have tried to provide examples of those with the greatest potential benefit. We have not focused on incremental energy efficiency improvements which have been, and continue to be, addressed by many hundreds of energy audits and improvement programs from the industry.

The example pilot project concepts discussed in this paper are listed in the table below:

Ref	Sector	Pilot project name
F1	Cattle feedlots	Feedlot manure to biogas
F2	Cattle feedlots	Optimising cattle feed preparation to reduce steam use in steam flaking
F3	Cattle feedlots	Solar PV plus storage with electrification of heating and optimal integration with networks

E1	Eggs	Solar PV plus batteries integrated with the grid
C1	Chickens	Chicken farm biogas generation from chicken litter and disposal of dead birds
C2	Chickens	Free range energy efficient tunnel sheds
D1	Dairy	Biogas production (and potential link with robotization)
D2	Dairy	High energy productivity heating and cooling
D3	Dairy	Milking equipment improvement
P1	Piggeries	Manure to biogas at small scale and for multiple biogas applications
P2	Piggeries	Interaction of piggeries with electricity grids, peer-to-peer trading and wheeling of power between sites
P3	Piggeries	Improve comfort, health and productivity through improvement in heating, cooling and ventilation
P4	Piggeries	Use of biogas to replace liquid fuels on-site and locally
H1	Horticulture	Postharvest temperature optimisation – Cold store
H2	Horticulture	Cold chain optimisation – Temperature monitoring
H3	Horticulture	Postharvest processing – On-farm energy and processes
O1	All	On-farm value adding
Supplementary pilot project concepts		
D4	Dairy	Improvement in energy assessment of dairies
D5	Dairy	On-site vehicle energy use
P4	Piggeries	Alternative sourcing and processing of feed

These projects have been analysed at concept stage. While we expect them to be feasible based on the information we have been able to access in the relatively short amount of time available, many are unproven locally. There is more work required on each of these before they should be finally selected for funding.

As we are aware that DPI would like to have some projects underway by the end of June 2019, we have highlighted in green those projects in the table which we believe could potentially be contracted within this time period.

Recommendations and forward plan

A2EP makes the following recommendations regarding next steps:

1. Pilot Projects

- Review the pilot concepts, based on appropriate additional analysis and documentation, with stakeholders, and confirm interest to pursue them as priorities. It should be noted that some pilot concepts may challenge widely-held views or require reconsideration of existing

practices or technologies, so quality information and appropriate dialogue will be needed as part of this process.

- Identify potentially suitable sites for application and options for supply chain and project participants.
 - Conduct additional analysis and prepare full feasibility studies at sites selected by DPI to confirm project feasibility, capital cost and other key project parameters.
 - Select priority pilots and seek co-funders as required.
 - Set up mechanisms to implement and manage the selected pilots with appropriate oversight.
2. Conduct an energy productivity opportunities study on irrigation. This topic is sufficiently large, complex and specialised to warrant separate study. It would be important for the project to engage with researchers, technology providers and operators to document and build upon the large amount of existing work, then identify gaps, enhancements and opportunities.
 3. Improve industry energy productivity information: define the scope of work to improve energy productivity information in several areas where we have found data deficiencies, working with each subsector's stakeholders and providers of relevant data.
 4. We recommend setting up an ongoing applied research program on energy productivity opportunities working with RDCs, and include this in the outreach support DPI is planning deliver to the farmers on best practices.

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1 Analysis of energy productivity performance and potential

Energy is a critical enabler of economic activity. In order to operate competitively, the agricultural sector is dependent on both the reliable and economical supply of energy and the effective use of energy. This report examines energy productivity in agriculture in New South Wales, including key sub-sectors, and suggests some major opportunities for improving energy productivity.

Energy productivity (EP) measures the value created from using a unit of energy. EP improvement – increased economic value added – is achieved by using energy more effectively. This results from using less energy input for the same output and/or increasing the output from the same energy input.

$$EP = \text{Value added (\$)} / \text{Energy (primary, GJ)}.$$

Energy productivity considers all aspects of energy on sites – grid supply, local generation or production, storage, demand management and use-efficiency. Energy productivity also focuses on how energy can be applied more effectively to derive increased value – through increased throughput, reduced waste, improved quality, or reduced maintenance and increased plant reliability. Energy efficiency is an important consideration, but is only one element of the available opportunities.

Given prevailing margins in Australian agriculture, energy cost is equal to about a third of pre-tax profit in the sector. Energy cost is growing, due to the steep escalation of energy prices over the last decade and the historic under-investment in farm energy demand management, use efficiency and self-sufficiency. Energy cost is now regarded by farmers as a priority issue and bodies such as NSW Farmers, Dairy Australia, Australian Pork Limited and Apple & Pear Australia have moved to implement farm energy efficiency programs.

At the same time, technology and business model development now offers farmers increasing potential to take control of energy costs, reducing cost volatility and increases. And investment in energy productivity improvement through technologies, practices and smarts can be integrated with other investments needed to maintain competitiveness, license to operate and capture of ‘points of difference’ for marketing.

For most dairy and broadacre sub-sectors tracked through the ABARES Farm Survey (which includes less controllable costs such as seed) aggregate energy cost ranges between 7% and 10% of total cash cost¹. This is in line with more detailed studies of grain producers, which estimate that energy cost

¹ Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES). (2014). Surveys: Summary of AAGIS and DDIS data tables (broadacre and dairy). Canberra: Author. Retrieved from <http://www.agriculture.gov.au/abares/surveys>; Valle, H. (2014). Australian vegetable growing farms: An economic survey 2012–13 and 2013–14. Canberra: ABARES. Retrieved from <http://data.daff.gov.au/data/warehouse/9aab/9aabf/2014/avfesd9absf20141114/>

constitutes between 8% and 10% of total cash cost². Energy cost for vegetable growers is also estimated at 10% of total cash cost³.

The cost for individual farms and farmers can be higher, however, with variation resulting from factors including farm location and farming practice, the age and efficiency of equipment. Relatively higher energy spend may be warranted to exploit favourable climatic, locational and pricing conditions. Farmers across all sectors surveyed by NSW Farmers reported that energy cost can account for 6–30%⁴ of the cost of production, with heavy vehicles and irrigation pumping generally being the main energy sinks for extensive farmers and heating, ventilation and air-conditioning (HVAC) being the main energy sink for intensive producers⁵.

Unlike many production inputs, energy costs are controllable to an extent and the lower the operating margin of a farm business, the more significant the contribution to profitability from increased energy productivity. Many farmers, however, treat energy as a fixed, rather than variable, cost and are often unaware of their ability to negotiate more favourable energy supply contracts, better manage demand, implement energy efficient practices and improve the relative energy efficiency of their equipment⁶. Energy efficiency is rarely considered when vendors are marketing heavy farm machinery such as tractors and harvesters⁷.

Energy savings of 20% or more are achievable in many instances, including farm vehicle fuel efficiency, electricity use in intensive farm operations such as dairy, as well as irrigation systems. There are also significant opportunities for the strategic deployment of renewable energy technologies. Equally important, farm energy efficiency goes hand in hand with the deployment of broader efficiency technologies that enable gains in water, soil, fertiliser and agrichemical productivity. For example, automated sensor-driven irrigation control systems enable optimisation of water application while minimising energy used for pumping.

In addition, the impact of energy applications on yield and quality is understood well in some areas of farm operations e.g. ventilation and temperature control of animal sheds, but this is not universal across farm operations. There is still a very large untapped opportunity for increased use of waste and other renewable energy in the farm sector that could dramatically boost energy productivity as well as minimise carbon emissions.

Agriculture stands to gain significantly from an energy productivity agenda. This is further evident when considering the food and fibre value chain. While many farm enterprises already include

² Australian Farm Institute. (2011). The impact of a carbon price on Australian farm businesses: Grain production. Surry Hills, NSW: Author; Australian Farm Institute. (2011). The impact of a carbon price on Australian farm businesses: Rice farming. Surry Hills, NSW: Author.

³ Valle, H. (2014). Australian vegetable growing farms: An economic survey 2012–13 and 2013–14. Canberra: ABARES. Retrieved from <http://data.daff.gov.au/data/warehouse/9aab/9aabf/2014/avfesa9absf20141114/>

⁴ NSW Farmers notes that caution is needed when interpreting the upper range since some farmers undervalue or exclude the value of their own labour when reporting input costs.

⁵ NSW Farmers Association. (2014). Research and development initiatives. St Leonards, NSW: Author. Retrieved from <http://www.nswfarmers.org.au/r-and-d>

⁶ NSW Farmers Association. (2014). Research and development initiatives. St Leonards, NSW: Author. Retrieved from <http://www.nswfarmers.org.au/r-and-d>

⁷ NSW Farmers Association. (2013c). Purchasing a fuel-efficient tractor. St Leonards, NSW: Author. Retrieved from <http://aginnovators.org.au/sites/default/files/Efficient%20Farm%20Vehicles%20-%20Purchasing%20a%20fuel%20efficient%20tractor.pdf>

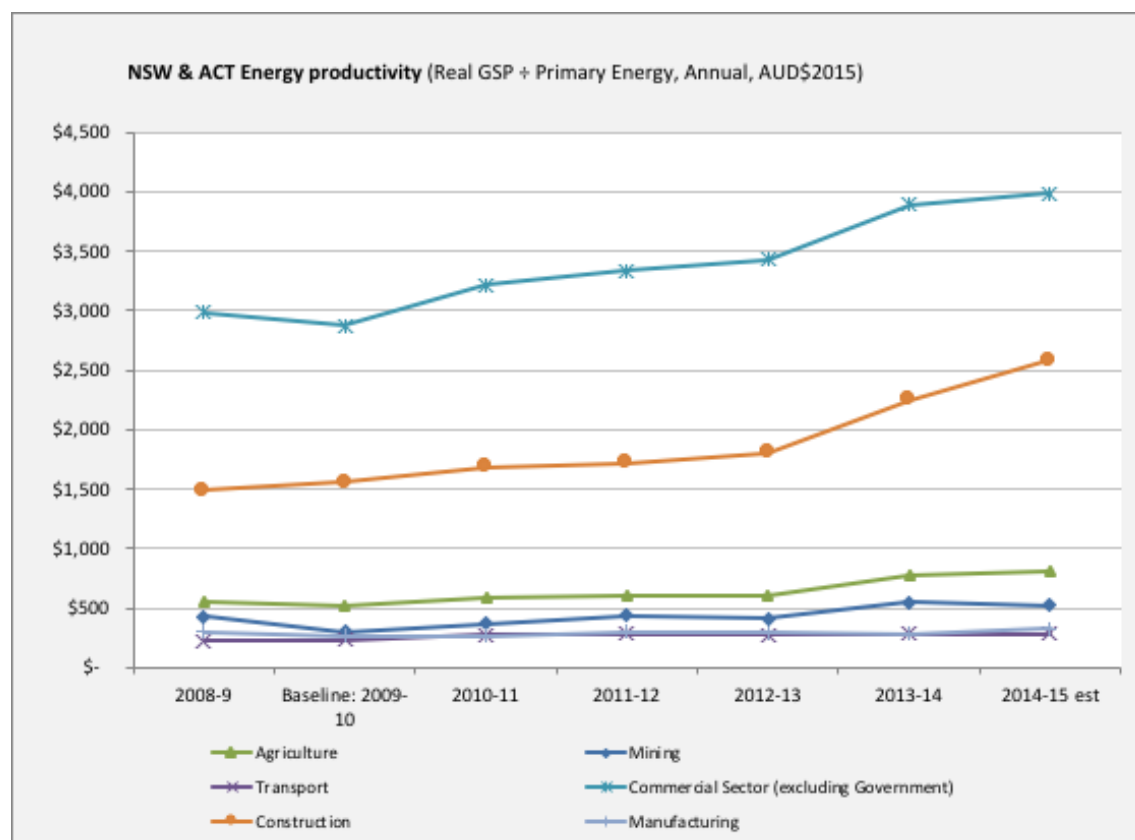
processing, packing, distribution and marketing functions, a more pro-active approach by the agriculture sector can unlock further business opportunities along the value chain, up- and downstream in areas such as waste management, transport logistics and demand side response.

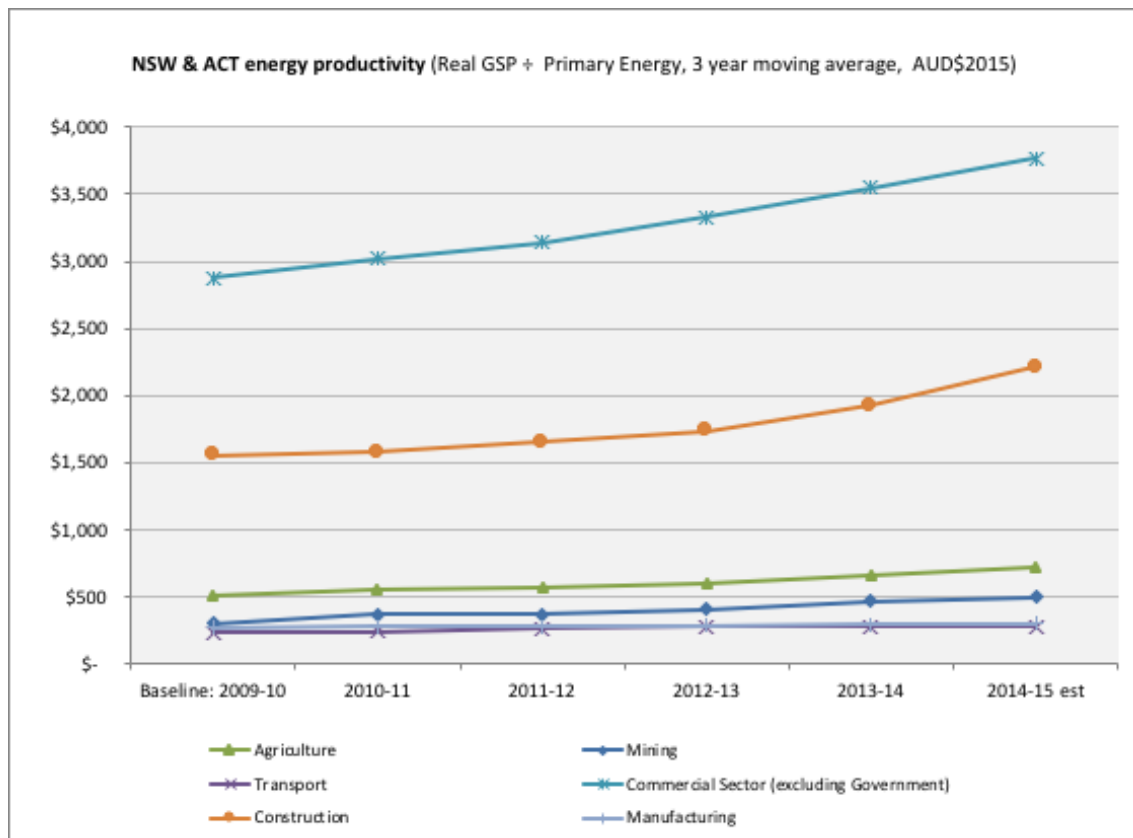
Consequently, the extent to which the agriculture sector embraces productivity improvement, including energy productivity, will shape both its future international competitiveness and the extent to which it remains the anchor of Australia’s rural economy.

1.1 Energy productivity in agriculture in New South Wales

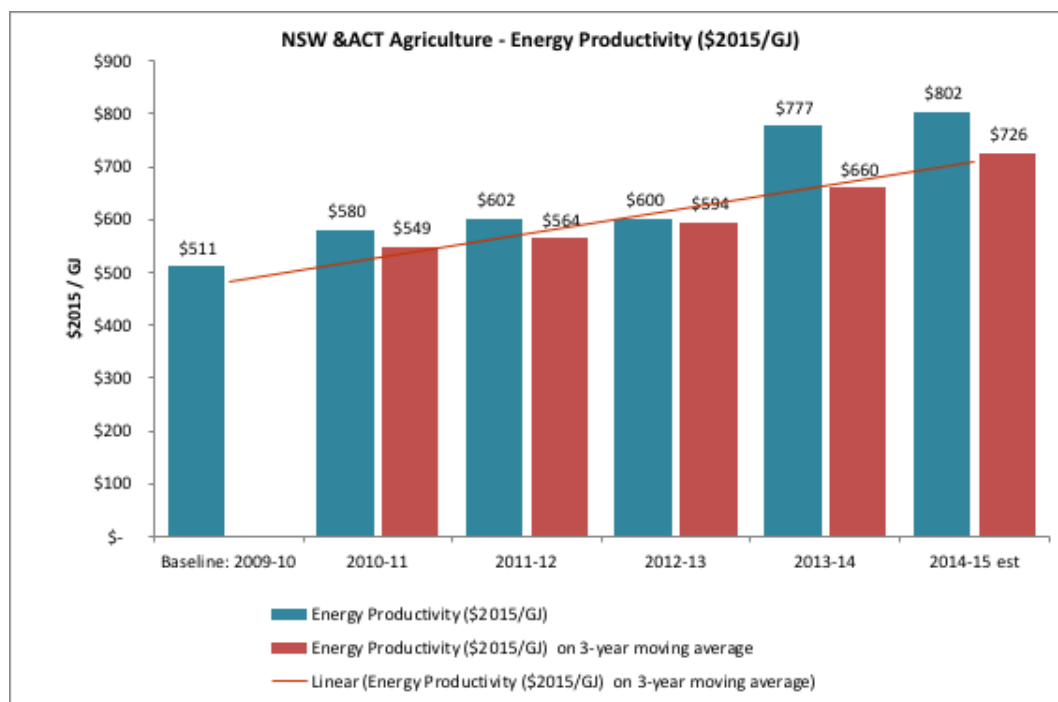
The EP approach aims to improve energy productivity by more than it would have improved without intervention. The metric, of itself, reflects the impacts of many forces. Our focus is on the identification and implementation of energy-related measures that deliver business benefit as reflected in the GVP (or basically net profit) of individual facilities, which accumulate to improve overall sector GVP relative to what it would have been. To make a significant improvement in EP, the sector must both utilise energy more effectively, and add more value by moving away from a commodity model to a quality and service focus. A2EP’s approach helps by identifying actions that deliver both these outcomes.

The two graphs below show energy productivity by sector in NSW and ACT for the period 2009-10 to 2014-15. The top graph shows annual energy productivity and the bottom graph shows the three-year moving average. As can be seen from the graphs, energy productivity in the agricultural sector is slowly improving, but it is much lower than the commercial and construction sectors and similar to manufacturing and mining.





The graph below depicts energy productivity for the agricultural sector only for the same period. The agricultural sector experienced small improvements in energy productivity during the period 2009-10 to 2012-13, with larger improvements in the more recent years. Many factors feed into agriculture’s energy productivity, but as data are generally poor data, and there is a lack of detailed metering, it is difficult to identify energy use by activity and the drivers of changes in energy productivity. Further, a lack of understanding of actual relative efficiencies of various processes and systems means we have very little idea of how much energy is actually needed to deliver the fundamental services required for agriculture.



The energy productivity metric as applied to agriculture is affected by both energy (input) and commodity (output) prices which are sensitive to factors beyond the control of agricultural enterprises such as exchange rates and seasonal conditions. The nature of the EP metric also means that, used by itself, it can be quite misleading in understanding underlying trends in energy performance. Therefore, it is important to isolate or average the impact of commodity price fluctuations to see the true, underlying change in EP performance over time by also measuring units of energy used per unit of throughput.

Unlike most other sectors, the gross national output value at current prices for this sector is available from the Australian Bureau of Statistics (Catalogue No. 5204, Table 50)⁸. However, a number of key challenges remain at a macro level:

- **Weather variation/climate variability:** Due to variations in the weather, the relationship between agricultural outputs and inputs can be erratic from year to year. They can also result in the 'nature of the task' required to deliver the same output changing over time (i.e. irrigation may be required in some years, but not others).
- **Commodity price volatility:** The value of outputs (i.e. numerator) can change significantly due to changes in the price of commodities, which could, in the case of exports, also be influenced by the Australian dollar exchange rate.
- **Primary energy use and final energy cost:** Data is only available at ANZSIC Division A level for 'agriculture' as a whole, bundled with fisheries and forestry. Additional analysis is required to estimate the share to be allocated to agriculture.

⁸ Australian Bureau of Statistics, 2018, <http://www.abs.gov.au/ausstats/abs@.nsf/mf/5204.0>

1.2 Improving energy efficiency in on-farm diesel applications

This report is primarily concerned with identifying transformative opportunities for improving energy productivity in agriculture beyond conventional energy efficiency opportunities. However, it is important to note that conventional energy efficiency measures, which are not covered in detail in this report as they are already the subject of many other reports, are well suited to the extensive sub-sectors with high levels of diesel use.

The graph below, reproduced from the Australian Farm Institute 2018 research report *The impacts of energy costs on the Australian agriculture sector*⁹ shows the breakdown of energy costs in the Australian agricultural sector. It can be seen that diesel use is responsible for a significant proportion of energy costs in the agricultural supply chain, accounting for about half of agricultural production energy costs, and all of transport energy costs in the agriculture supply chain.

Total estimated cost of energy (by energy source) used by the Australian agricultural sector (by supply chain)

Total estimated cost of energy for each supply chain segment (all sectors) (\$millions)				
Supply chain segment	Electricity	Gas*	Diesel**	Total
Input	155	680	-	835
Production	1,218	185	1,382	2,785
Transport	-	-	1,112	1,112
Processing	980	124	9	1,113
Total	2,353	990	2,503	5,845

* Includes all gas types

** Includes diesel, petrol and oil

Source: Australian Farm Institute, 2018, *The impacts of energy costs on the Australian agricultural sector*

Extensive sub-sectors, such as broadacre farming, generally use a higher proportion of diesel, compared to electricity and gas, than intensive sub-sectors. These extensive sectors with high levels of diesel consumption have significant potential to benefit from a conventional energy efficiency approach by improving the use-efficiency of existing equipment or by updating equipment. An example of updating equipment would be the selection of more fuel-efficient tractor.

Reduction in diesel use for stationary farm equipment such as pumps can be achieved by benchmarking equipment performance and implementing energy efficiency measures such as regular maintenance and use of variable speed drives on pumps, correctly sized pumps and pipes, sensor networks e.g. for soil moisture, smart metering and automation¹⁰. In addition, use of on-site energy generation such as solar PV (in combination with batteries if economical) may provide an opportunity to reduce on farm diesel use for stationary equipment such as irrigation pumps. There are many resources available which provide further information on this option.¹¹¹²

⁹ www.farminstitute.org.au/publications/research_report/energy

¹⁰ <http://www.aginnovators.org.au/initiatives/energy/themes/water-and-energy>

¹¹ <http://www.aginnovators.org.au/initiatives/energy/information-papers/solar-powered-pumping-agriculture-guide-low-bandwidth-version>

¹² http://www.aginnovators.org.au/search/site/?f%5B0%5D=im_field_theme%3A1816

Improving the energy efficiency of diesel fuelled farm equipment is best addressed by product standards and labelling programs supported through the provision of information and education i.e. providing farmers with energy performance information to help them make better decisions, or perhaps in some instances having minimum efficiency performance standards. Careful benchmarking of performance relative to service delivered is important as a basis for building a business case for action that may involve changes in practices, equipment selection, IoT-based optimisation systems, etc. While valuable, such measures are outside the scope of this report.

This project is focussed on transformative change, and transformative change in relation to diesel powered mobile equipment used in extensive agriculture, such as the electrification of tractors, may not currently be feasible. This is because the batteries required would not be practical or economic at this time. It is noted that electric farm vehicles viable in the future or for light duties, noting they offer a convenient portable source of electricity to run machinery and equipment in paddocks away from power lines and as an alternative to inefficient use of diesel power via a Power Take-Off shaft e.g. John Deere has developed an electric tractor¹³.

Energy productivity improvements related to irrigation requires specific attention which was not possible in this initial investigation. Further work into irrigation in a future project is suggested, with the following recommendations for improving the energy performance of irrigation systems as a starting point:

- Replace old, inefficient pumps.
- Improve the performance of existing large electrical pumps by installing variable speed drives (VSDs). Lowering the speed of a motor by just 20% can produce an energy saving of up to 50%¹⁴. Note this may require storage of water or a change in timing of irrigation.
- Maintain pumps; real time tracking and benchmarking of performance. Pump efficiency deteriorates over time, leading to energy wastage. Efficiency losses of 5–15% can occur after 10 years of operation. Motors should be rebound. Blocked air filters (e.g. due to past flooding) could also lead to pumps overheating and running at reduced efficiency¹⁵.
- Optimise new irrigation systems by recalibrating pumps and installing the appropriately sized pump outlet pipes.
- Remove throttling of 'gate valves' to control the downstream flow rate.
- Deploy warning systems to inform farmers of system shut-down, e.g. during night irrigation.

¹³ <https://www.agriland.ie/farming-news/electric-john-deere-tractor-runs-for-4-hours-on-a-charge>

¹⁴ NSW Farmers Association. (2013f). Variable speed drives on pumps. St Leonards, NSW: Author. Retrieved from http://www.nswfarmers.org.au/__data/assets/pdf_file/0003/35859/Energy-Irrigation-Variable-speed-drives-on-pumps.pdf

¹⁵ NSW Farmers Association. (2013d). Saving energy in irrigation. St Leonards, NSW: Author. Retrieved from http://www.nswfarmers.org.au/__data/assets/pdf_file/0010/35857/Energy-Irrigation-Saving-energy-in-irrigation.pdf

- Adjust pressure and flow rates of pumps on pivot irrigation systems to cover the extreme boundary of an elevated field and scaling back pumping parameters when the same equipment is moved to lower elevations¹⁶.

Significant energy savings can, therefore, be achieved on many irrigated farms, ranging from 'quick wins' to modification of practices and adoption of new energy efficient technologies. New technologies include use of the Internet of Things (IoT) to monitor moisture content at multiple points across a property to control water application such that it is used only where and when it is needed.

Where feasible, farmers should also consider switching from diesel to electric pumps. Electric pumping is cheaper and much more efficient (70–80% efficiency) than diesel-driven pumps (30–40% efficiency), and can deliver financial savings of \$250 per MWh¹⁷. However, some farmers cannot connect to the grid – in these cases wind and solar PV pumping systems can complement diesel powered pumps. Diesel pumps can deliver large amounts of water but its fundamentals (assuming diesel at over \$1/litre is equivalent to electricity at around 30c/kWh – PV (including some storage) is now cheaper than this, and means operator takes control of costs, while diesel fuel prices are volatile.

Future work into energy productivity in irrigation should take a systems and services approach: start by looking at what services are provided - water as input to crop growth. Identify causes of loads on pumps – volume of water (losses from evaporation and seepage, targeting of water to plants), flow resistance of pipes, valves, real world pump efficiency, electricity pricing structures, timing of pumping and management of flow rates, noting losses are very non-linear. Education and training programs will be an important aspect of improving energy productivity in irrigation.

¹⁶ Queensland Cane Growers Organisation Ltd. (n.d.). Energy efficiency in irrigation systems (Fact Sheet). Brisbane: Author. Retrieved from http://www.canegrowers.com.au/icms_docs/196337_Energy_efficiency_

¹⁷ NSW Farmers Association. (2013b). Diesel versus electric pumps. St Leonards, NSW: Author. Retrieved from http://www.nswfarmers.org.au/__data/assets/pdf_file/0007/35854/Energy-Irrigation-Diesel-versus-electric-pumps.pdf

2 Priority sectors for investment

2.1 Priority sector assessment

Six assessment criteria have been used to identify the agricultural sub-sectors in NSW that have the greatest potential to benefit from investment through an energy productivity improvement program:

1. Contribution of sector to NSW Gross Value of Production (GVP)
2. Sector growth
3. Value chain benefits
4. Reliance on energy
5. Energy intensity trends
6. Potential for opportunities

These six criteria are grouped into two categories:

- Sector economic materiality assessment
- Sector energy assessment

The assessment criteria are outlined below. The project team analysed a range of agricultural sectors to understand which sectors would most benefit from energy productivity investment. Each sector was scored as low (L), medium (M) or high (H) against each of the criteria. See the tables in sections 2.1.2 and 2.1.4 below for scoring of each of the sectors.

2.1.1 Sector economic materiality assessment criteria

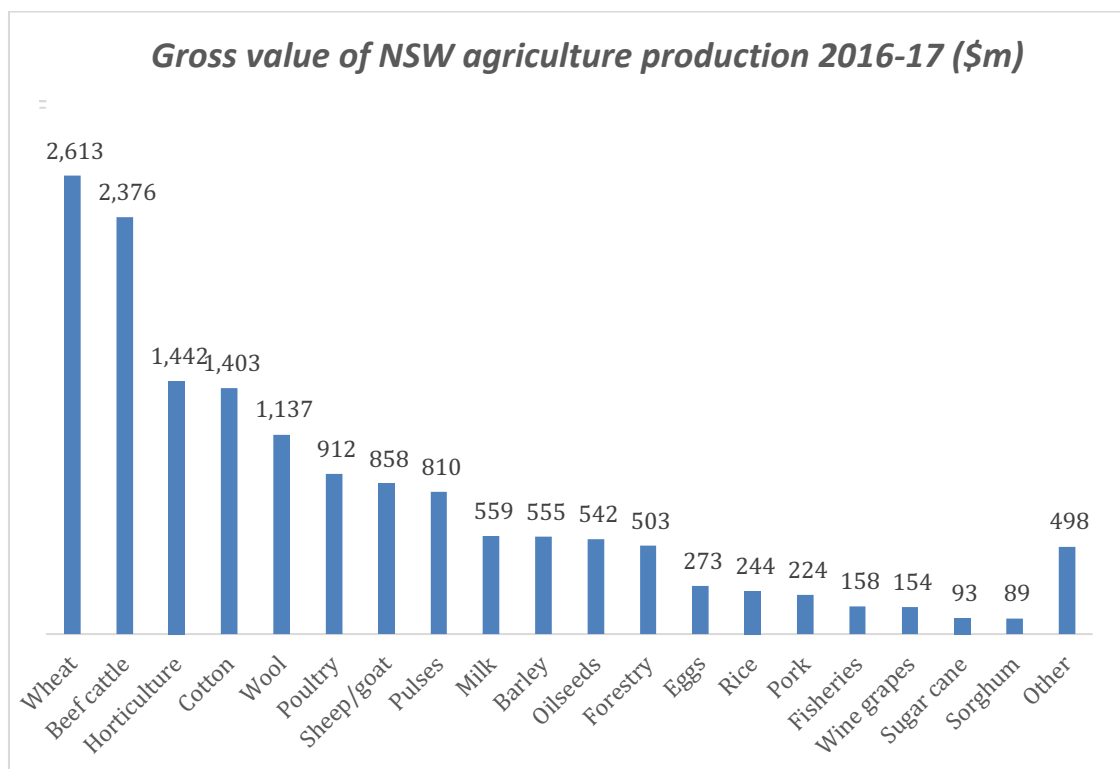
The first three criteria were used to give the project team a sense of the scale of the economic contribution and potential upside of the sectors assessed in the context of NSW agriculture.

Assessment criterion 1: Contribution of sector to NSW GVP

The contribution of the sector to total NSW agriculture gross value of production (GVP) was considered in selecting priority sectors. GVP is measured as a unit volume of each commodity produced by the respective commodity unit price achieved at the “farmgate” or in the wholesale market.

The total gross value of production of NSW agriculture was estimated to be \$15,442 million in 2016-17, with the breakdown by commodity shown in the graph below.¹⁸

¹⁸ www.dpi.nsw.gov.au/data/assets/pdf_file/0009/814788/PDI2017_web.pdf



Source of data: NSW Department of Primary Industry

Scoring

High: Sector GVP greater than \$1 billion

Medium: Sector GVP less than \$1 billion and greater than \$500 million

Low: Sector GVP less than \$500 million

Assessment criterion 2: Sector growth

The potential for both domestic and export growth, and shifting to higher value production were considered, although export markets provide much of the potential for sector growth, with Australia currently exporting approximately 65% of total agricultural production¹⁹. The National Farmers Federation²⁰ has announced a vision to increase the farmgate value of Australia's agricultural production to \$100 billion in 2030 from its current level of around \$60 billion per annum. This ramp up in the value of production will in part require investment in improved data monitoring and analysis, systems connectivity and new technologies, and a significant expansion in exports while further exploiting and building upon Australia's existing reputation for high quality, safe food using production methods that meet high environmental and animal welfare standards. Improving energy productivity of energy intense, export focussed industries may be a significant factor in improving the competitiveness and performance standards of these industries.

The recently settled North Asian Free Trade Agreements (FTAs) with Japan, China and Korea provide additional opportunities for Australian agricultural producers to export. Numerous other FTAs are under negotiation, with further potential to expand export markets²¹. This raises the question of

¹⁹ <https://dfat.gov.au/trade/organisations/wto/Pages/agricultural-trade.aspx>

²⁰ www.nff.org.au/read/5873/budget-roadmap-charts-course-for-100.html

²¹ www.horticulture.com.au/wp-content/uploads/2016/06/Hort-Innovation-Strategic-Plan-Web.pdf

what products (and product attributes) overseas buyers will want, and what implications that may have for farmers in terms of changes to crops and stock, product selection, marketing strategies and documentation to support environmental or other claims (e.g. ‘organic’).

Scoring

A judgement regarding the potential for sector growth as high, medium or low was made for each of the sectors assessed based on review of different sources of information including NSW DPI, industry associations and the National Farmers Federation.

Assessment criterion 3: Value chain benefits

The potential to improve outcomes across the value chain was considered when establishing priority sectors. An example would be increasing the proportion of value adding activity in the agricultural (i.e. pre-farmgate) part of the supply chain, such as drying plums on-farm to produce prunes, thereby minimising the time between harvest and processing to maximise quality, reducing the volume of product that has to be transported and linking primary producers more closely to end consumers. Another example is the Food Trust blockchain technology used by Walmart to track the treatment and provenance of products as they move through the supply chain to the store, resulting in improved food quality and safety, and reduced food losses and food fraud.

Scoring

A judgement regarding the potential to realise value chain benefits was made for each of the sectors assessed as high, medium or low, based on review of different sources of information including previous A2EP research, NSW DPI, industry associations and the National Farmers Federation.

2.1.2 Sector economic materiality assessment

The table below sets out the scoring of a range of sectors against the three economic materiality assessment criteria described above.

	Sector economic materiality assessment		
	1. Sector GVP	2. Sector growth	3. Value chain benefits
Horticulture	H	H	H
Chicken meat & egg	H	M-H	H
Piggeries	L	M-H	H
Cattle - feedlots	M	H	H
Dairy	M	M-H	H
Extensive cropping	H	H	L
Cattle - pasture	H	M	H
Sheep – meat & wool	H	M	H
Cotton	H	M	M
Wine grapes	L	L-M	H
Sugar cane	L	L	L

2.1.3 Sector energy assessment criteria

The three sector energy assessment criteria were used establish which of the NSW agricultural sectors assessed had the greatest potential to benefit from energy productivity investment.

Assessment criterion 4: Reliance on energy

Total energy cost and the cost of energy as a proportion of GVP are considered. The primary reference for assessing each sector's reliance on energy was the Australian Farm Institute 2018 research report *The impacts of energy costs on the Australian agriculture sector*²². The table below, reproduced from the report, summarises the total estimated cost of energy used by the Australian agricultural sector (excluding processing), sector value in terms of GVP and the cost of energy as a proportion of GVP.

Total estimated cost of energy used by the Australian agricultural sector (excluding processing) as a proportion of GVP

Sector	Energy costs (\$ million)*	Sector value (GVP) (\$million)**	Energy costs as a proportion of GVP
Chicken meat	435	2,729	16%
Sugar	252	1,622	16%
Dairy	464	3,687	13%
Wine grapes	135	1,040	13%
Cotton	195	1,934	10%
Pork	129	1,342	10%
Grains	1,496	16,972	9%
Eggs	71	808	9%
Horticulture (vegetables)	319	3,904	8%
Beef	804	12,139	7%
Sheep	431	7,367	6%
Total	4,732	53,544	9%

* Excludes post-farm/processing

** Data for post-farm/processing sectors is included only for the red meat (beef and sheep), dairy, chicken meat, cotton, wine grapes and pork sectors; Grains industry processing costs includes grains used for milling feed only.

Source: Australian Farm Institute, 2018²³.

Scoring – total energy costs

High: sector total energy costs greater than \$1 billion p.a.

Medium: sector total energy costs less than \$1 billion and greater than \$500 million p.a.

Low: sector total energy costs less than \$500 million p.a.

Scoring – energy costs as a proportion of GVP

High: sector energy costs as a proportion of GVP are greater than 10%

Medium: sector energy costs as a proportion of GVP are between 8% and 10%

Low: sector energy costs as a proportion of GVP are less than 8%

Assessment criterion 5: Energy intensity trends

A trending increase in energy intensity is a major driver for sector response to energy demand. Generally, there is a trend towards more intensive agriculture e.g. protected cropping and finishing livestock in feedlots²⁴. The drivers of intensification include: pursuit of increased productivity/economies of scale; increased vertical integration of supply chains and regional co-location; consumer expectations of more consistent and/or higher quality product; availability of technology improvements and automation; and more recently to meet social licence to operate e.g. environmental and animal welfare expectations in intensive livestock industries. For sectors

²² www.farminstitute.org.au/publications/research_report/energy

²³ www.farminstitute.org.au/publications/research_report/energy

²⁴ www.farminstitute.org.au/publications/research_report/energy

experiencing increasing energy intensity, the benefits of deploying innovative solutions to improve energy productivity can be significant.

Scoring

A judgement regarding energy intensity trends was made for each of the sectors assessed as high, medium or low based on review of different sources of information including previous A2EP research, NSW DPI, industry associations and the National Farmers Federation.

Assessment criterion 6: Potential for EP opportunities

Improvements in energy productivity arise when there is an increase in the value of output per unit of energy input used. The potential for transformative change through enhanced business benefit, total potential energy reduction and carbon emission reduction was a fundamental consideration when selecting priority sectors. Energy productivity improvements can reduce farmers' vulnerability to the challenges of climate change and enhance of their capacity to adapt e.g. on site generation reduces vulnerability to blackouts due to extreme weather events. In addition, the potential for replication within the sector, and possibly other sectors was also considered.

Examples of measures or tools that can deliver outcomes of value, as well as energy savings and risk reduction, that is, improve energy productivity, that are specific to the agricultural sector include:

- On -farm renewable energy supply can hand more control to operators and allow them to take advantage of (or reduce impacts of) external changes such as energy tariffs and prices. On-site generation may also be able to help stabilise fragile grids.
- Increased animal welfare and improved management of manure and other wastes linked to maintaining 'license to operate'. Pressure on farmers to minimise emissions is also connected to maintaining their license to operate and contribute to achievement of national emission reduction targets. Emissions reductions also provide an opportunity to create revenue from creation and sale of ACCUs, LGCs and EE certificates - combined with cost saving and value enhancement from energy productivity improvements, farmers benefit from improved financial resilience and competitiveness.
- Measures that save labour/time so fewer people are needed or the timing can be shifted to a more civilised time. E.g. robotic milking in pastures can reduce labour requirements.
- More time and information (in useful forms) to spend on optimising business outcomes and processes on farm. Some farms already use a lot of sensors (e.g. heat stress, animal identity, ovulation etc) but there is currently limited utilisation of multiple data streams or application of data to energy management.
- Increased reliability/resilience of equipment, including ensuring access to maintenance. This might be via local contractors or, increasingly, through remote monitoring/management to support preventive maintenance or limit the number of maintenance calls, inclusion of redundancies into equipment so it can 'work around' failures, etc.

Scoring

A judgement regarding the potential for energy productivity improvements through transformative change was made for each of the sectors assessed as high, medium or low based on information including previous A2EP research, review of international case studies and other sources of information including NSW DPI and industry associations.

2.1.4 Sector energy assessment

The table below sets out the scoring of a range of sectors against the three energy assessment criteria described in section 2.1.3 above.

	Sector energy assessment			
	4a. Reliance on energy: total energy cost	4b. Reliance on energy: energy costs as proportion of GVP	5. Energy intensity trends	6. EP opportunity potential
Horticulture	L	M-H	H	H
Chicken meat & egg	M	M-H	H	H
Piggeries	L	M	H	H
Cattle - feedlots	L	H	H	H
Dairy	L-M	H	H	H
Extensive cropping	H	M	L-M	L
Cattle - pasture	M	L	L	L
Sheep – meat & wool	L-M	L	L	L
Cotton	L	M	L-M	L
Wine grapes	L	H	L-M	L
Sugar cane	L	H	L-M	L

2.2 Priority sectors for energy productivity investment

It was ascertained through the assessment process using the criteria described in section 2.1 that the sectors listed below should be prioritised for investment in this initial DPI energy productivity improvement project:

- horticulture
- chicken meat and egg production
- piggeries
- cattle feedlots
- dairy.

The following pages in this section describe these sectors, providing an overview of the sector, its economic contribution, energy use and activities that offer an opportunity to improve energy productivity.

It is noted that while some extensive sectors, such as extensive cropping and cattle (on pasture), have high economic impact, they are not included in the list above of priority sectors for energy productivity investment. As discussed in section 1.2, these sectors are more suited to conventional energy efficiency initiatives delivered through training and education programs.

2.2.1 Horticulture

Sector overview²⁵²⁶²⁷

Horticulture includes the fruit, vegetable, nursery, cut flower and turf industries. Major horticulture growing areas in NSW include the Murrumbidgee Irrigation Area/Riverina, the Sunraysia district and the Northern Rivers.

Horticulture is the most labour-intensive agricultural industry due to requirements for hand picking, with the majority of production occurring on small-scale family owned farms. However, there is a trend towards larger scale operations to gain economies of scale and streamline supply chains.

Of particular interest to this research report are protected cropping operations (mainly glasshouses with heating and cooling requirements), which utilise greenhouses and hydroponics, and tend to be more energy intensive than conventional growing methods. The protected cropping industry, also known as controlled environment horticulture, is the fastest growing food production sector in Australia, expanding at 4-6% per annum. Around 30% of all Australian vegetable growers farm using protected cropping. The trend towards protected cropping has been driven by its advantages over traditional production methods including: faster growth; higher yields; better quality output; ability to grow out of season; and reduced use of water, pesticides and fertiliser.

Economic value²⁸

Horticulture's gross value of production (GVP) in NSW was \$1,442m in 2016-17. At 9% of

total NSW agriculture GVP, horticulture was the third highest value primary industry in NSW, after wheat and beef.

Fruit and nuts account for approximately half of NSW's horticulture GVP, with citrus, predominantly oranges, being the largest single industry. Vegetables account for 30% of NSW horticulture GVP, with nurseries, cut flowers and turf contributing the remainder. Nuts and blueberries are key growth industries in NSW.

Exports of NSW horticultural products were valued at \$325m in 2016-17 and are expanding rapidly, benefiting from Australia's reputation as a producer of high quality, safe food. Three quarters (by value) of NSW horticultural exports are bound for Asian markets. Nuts dominate, accounting for approximately half of all NSW horticulture exports.

Energy use²⁹³⁰

- It has been estimated that the total cost of energy used in Australian horticulture as a proportion of gross value of production is 8%, noting, however that the horticulture sector is made up of diverse industries with varying levels of energy intensity.
- Protected cropping is the most energy intensive form of horticulture with greater energy requirements for heating, cooling and climate control than other horticulture farming methods. For example, an Agrifutures report found on-

²⁵ <http://www.agriculture.gov.au>

²⁶ www.horticulture.com.au/wp-content/uploads/2016/06/Hort-Innovation-Strategic-Plan-Web.pdf

²⁷ <http://www.protectedcroppingaustralia.com/wp-content/uploads/2016/06/National-Training-Centre-for-Controlled-Environment-Horticulture-PART-1.pdf>

²⁸ www.dpi.nsw.gov.au/_data/assets/pdf_file/0009/814788/PDI2017_web.pdf

²⁹ www.farminstitute.org.au/publications/research_report/energy

³⁰ <https://www.agrifutures.com.au/product/benchmarking-energy-use-on-farm/>

farm energy use ranged from 89 GJ/ha (1.49 MJ/kg) for tomatoes grown in a Queensland field to 5,955 GJ/ha (17.51 MJ/kg) for tomatoes grown in a medium tech Sydney greenhouse with an artificial heating system.

- Electricity is typically the dominant form of energy used in horticulture. However, the split between electricity and diesel use is significantly influenced by whether pumps for irrigation are electricity or diesel driven.
- The most energy-intensive activities in the horticultural supply chain are cold chain operations and irrigation, with approximately 90% of Australian horticulture under irrigation. Crops harvested in summer tend to be more energy-intensive due to higher cooling requirements, particularly for more temperature sensitive horticultural products that require cooling immediately after harvest.

Activities to improve energy productivity

- Improve quality, extend shelf life and reduce waste of horticultural products on-farm and in supply chain by e.g. monitoring product core temperature and providing consistent optimal temperature control for product³¹; improving stock control such that first to ripen is first to market; using packaging with thermal control, ethylene management or pathogen inhibiting properties; developing varieties of horticultural products less susceptible to spoilage.
- Invest in on-site waste to energy plant. Case study: When Van Wyk Flowers were

faced with a massive hike in gas prices, with gas used to heat a high tech indoor growing environment, their solution was to install a new waste to energy biomass plant, with a 2 million litre heat storage facility and underground transport main to deliver energy to existing distribution centres around the property³².

- Use waste such as husks and hulls as a fuel source for biomass plants (noting this will need to be more economical than current use, e.g. stock feed, to be viable).
- Opportunities may also exist to contribute waste to regional shared biomass/biogas to power plants.
- Electrify operations and use on-site renewables such as solar PV, energy storage (e.g. thermal storage or batteries) and dynamic load management. Install demand control software to optimise energy use and reduce energy costs. May also provide opportunities to earn revenue from participating in electricity network demand response programs.³³
- Generate excess power for value adding activities such as on farm hospitality and production and sales of specialty foods.
- Improve the thermal performance of structures such as greenhouses and cool rooms e.g. install insulation and shading; paint heat reflective coatings on roofs; spectrally selective glazing and plastic coatings.
- Invest in high tech glasshouses with aim to maximise harvest windows and yields, while minimising energy, labour, nutrient and water inputs³⁴. Digitalise operations e.g. use sensor technology, ideally automated, to optimise inputs. Note

³¹www.a2ep.org.au/files/Reports/A2EP_Cold_Chain_Report_OEH_v2.pdf

³² <http://enriva.com.au/projects/lyndhurst-vic/>

³³arena.gov.au/assets/2018/10/REALM_FactSheet_agribusiness.pdf

³⁴ www.horticulture.com.au/new-high-tech-facility-to-help-meet-food-demand

these high-tech structures require a reliable source of energy for the functioning of automated controls and features.

- Install solar PV and heat pumps for warming greenhouses and drying (and maybe roasting) nuts.
- Microwave and solar thermal technologies may be an option for nuts and other food drying e.g. prunes. Microwaves can be particularly useful where a husk or shell mitigates conducted heat transfer, as it delivers heat directly inside items.
- Explore alternative business models e.g. develop modular, transportable equipment, e.g. drying equipment, that can be better utilised, i.e. shared between growers or/and between products, and offers reliability and flexibility through having multiple units/uses. As intensity of activities increases, the scope for diversification that reduces variability of revenues also increases.
- Improve the energy efficiency of equipment e.g. variable speed drives on pumping equipment, reducing pipe and valve losses, high efficiency refrigeration plant and wavelength optimised LED lighting.
- Optimise water pumping and irrigation (e.g. drip vs spray).
- Recover water vapour and heat from exhaust air.
- Optimise CO₂ levels.

- Invest in innovative technologies including mechanisation, automation, genomics and protected cropping.³⁵
- Value chain integration e.g. on-site processing or regional processing centre to add value, reduce dependence on commodity-focused supply chains and reduce transport volumes, cost and time.
- Improve the energy efficiency of diesel-fuelled farm vehicles, e.g. implementing a regular maintenance program and driver training, or replace vehicles with more efficient or hybrid/electric models.
- Deploy advanced energy assessment approaches and diagnostic techniques to better understand energy flows and potential for energy productivity improvements.

Case study: Toshiba vertical lettuce factory, Japan³⁶³⁷

Japanese electronics firm Toshiba has converted one of its old warehouses into a high-tech lettuce factory, growing three million bags of greens a year by recreating sunlight conditions using fluorescent lights with an output wavelength optimised for vegetables growth; air-conditioning systems to maintain optimal temperature and moisture levels; remote monitoring systems to track growth; sterilisation systems for packing materials and soil-less growing methods. Production commenced in 2014 and the production management system is based on semiconductor device production. The system enables vegetables to grow in near-sterile conditions, considerably extending freshness and shelf-life. Indoor farms focus on

³⁵ www.horticulture.com.au/wp-content/uploads/2016/06/Hort-Innovation-Strategic-Plan-Web.pdf

³⁶ https://www.toshiba.co.jp/about/press/2014_09/pr3001.htm

³⁷ <https://www.afr.com/news/special-reports/industry-trends/agriculture-goes-vertical-as-buildings-become-the-new-farms-20160216-gmv7z8>

fast-growing, high value crops that can be stacked easily. They have the advantage of producing higher yields than traditional agriculture and can be located closer to markets. Panasonic is also moving into vertical farming of leafy greens in warehouses in Singapore.



Case study: National Vegetable Protected Cropping Centre, Australia³⁸³⁹

Western Sydney University and Hort Innovation opened a \$7 million high tech glasshouse in 2017 for protected cropping industry research. The glasshouse has eight temperature-controlled chambers and transitional glass that adjusts in colour with exterior light levels to optimise heat levels for plant growth and yield. Use of solar glass to contribute to energy production will also be assessed. Researchers aim to produce the highest possible commercial-yields with minimal energy, labour, nutrients and water outputs.

³⁸<https://www.westernsydney.edu.au/nvpcc/research>

³⁹ <https://horticulture.com.au/new-high-tech-facility-to-help-meet-food-demand/>

⁴⁰ <http://www.aginnovators.org.au/news/wa's-world-first-solar-glass-set-power-self-sustaining-agri-oases>

Case study: Energy producing glass for greenhouses, Australia⁴⁰

An Australian innovation developed at Edith Cowan University in Perth is 'solar glass' which has a film embedded with micro and nanoparticles that extract 90% of the UV and infrared rays from solar energy and transfer them to compact photovoltaic cells embedded on the edges of the panels where they are converted to electrical energy. The panels allow 70% of visible light to pass into the greenhouse. The solar glass also has insulative properties superior to traditional glass used in greenhouses, reducing heating and cooling loads.

Case study: Solar thermal drying of pomace, United States⁴¹

Pomace is the heavy puree left over after fruits and vegetables are juiced and processed and contains a lot of nutrients. However, wet pomace is only available during the harvest season and moulds if stored more than a few days. Dehydration of pomace is traditionally achieved using heat from natural gas. The United States Department of Agriculture and the University of California have demonstrated that a solar thermal-powered drum dryer can process prune and tomato pomace into useful dehydrated products. The technology works efficiently, even on cloudy days.

Case study: Infrared drying of walnuts, United States⁴²

Walnuts must be harvested, washed, dehulled (hulls removed from shells), and dried. These processes use a lot of energy. Drying walnuts

⁴¹<https://www.usda.gov/media/blog/2018/09/11/using-energy-sun-dry-pomace>

⁴²<https://agresearchmag.ars.usda.gov/2017/aug/infrared/>

with hot air takes more than 24 hours and uses a significant amount of natural gas and/or electricity. Infrared is a type of electromagnetic radiation, as are radio waves, ultraviolet radiation, x rays, and microwaves. Infrared is a form of light that we cannot see—but we can feel its heat on our skin. It was discovered that up to 25 percent of the energy used to dry walnuts could be saved by pre-drying them with infrared heat, followed by standard hot-air drying. The new infrared-drying process quickly removes moisture from the surface of walnuts, which shortens total drying time by 35 percent. It reduces over-drying and under-drying and allows the walnuts inside the shells to maintain their colour and exceptional polyunsaturated fat content.

Links

NSW Department of Primary Industries:
www.dpi.nsw.gov.au

Australian Government Department of
Agriculture and Water Resources:
www.agriculture.gov.au

Horticulture industry associations: find links
listed at <http://www.agriculture.gov.au/ag-farm-food/hort-policy/links#australian-government-agencies>

Hort Innovation, a Rural Research and
Development Corporation (RDC), is funded by
grower levies and Australian Government
contributions and seeks to improve the
productivity, farm gate productivity and
global competitiveness of Australian
horticultural industries:
www.horticulture.com.au

2.2.2 Chicken meat and egg production

Sector overview

*Chicken meat*⁴³⁴⁴⁴⁵

Australians are among the largest per capita consumers of chicken meat in the world, with demand driven in part by the relatively low cost of chicken meat compared to other meats. Of the 530 farms producing broilers in Australia, 183, or 35%, are located in NSW. Of the national flock of over 90 million head, approximately 30 million are farmed in NSW.

Regions involved in the growing of broilers in NSW include the outskirts of the Sydney metropolitan area, Mangrove Mountain/Central Coast, Newcastle, the Tamworth and Griffith areas and Byron Bay. Broiler farms are generally located within 200km of a processing plant. Processing plants have historically often been located with 100km of a capital city, although there has been a trend in the last decade for growth in processing in regional areas such as Griffith and Tamworth.

Commercial broiler production usually occurs under a contractual arrangement where the processor provides the birds, feed and veterinary care and the contract farmer provides the housing, day-to-day management of the farm, bedding, water, gas and electricity for which the farmer is paid an agreed fee per bird or on the basis of space/area. Processing companies generally own, control and invest across the supply chain. The supply chain includes breeding farms that produce fertile eggs, hatcheries where fertilised eggs are incubated, broiler farms for growing chickens from one day old to around 5 to 7 weeks of age, feed mills and processing plants.

⁴³ www.nff.org.au/farm-facts.html

⁴⁴ www.farminstitute.org.au/publications/research_report/energy

⁴⁵ www.chicken.org.au/structure-of-the-industry/

Eggs⁴⁶

Egg production requires the same husbandry skills and animal care as chicken meat production, but also entails processing and quality control of eggs. The egg industry in Australia is dominated by large scale producers who sell direct to large retailers and are generally located near the market they sell to. The highest concentration of commercial egg production is in the Greater Sydney and Hunter regions.

Adult laying hens are most productive when kept at a temperature range of 21-28°C with a relative humidity of 60-80% and adequate ventilation. Hen housing systems are designed to maintain these conditions. All sheds require cooling to prevent birds overheating, especially at night.

There are three main types of housing systems used in Australia for commercial egg production: cage, barn and free-range. Cage systems use rows of steel cages in hen houses with advantages including higher production levels, better bird health and more protection from predators. In barn and free-range systems, the floor of the housing is spread with litter, with advantages including the ability of birds to move around freely, socialise and display natural behaviours. In free range systems the layers have access to an outdoor area for at least eight hours per day. Biosecurity issues are most prevalent in free range systems due to them being in a less controlled environment.

Eggs are collected as soon as possible after laying, generally in the morning, and placed in refrigerated storage at 13°C. The eggs are then graded and packed, usually on-farm.

⁴⁶ www.agrifutures.com.au/farm-diversity/eggs-chicken/

Eggs are graded by weight using an automatic egg grader. Eggs are transported in refrigerated or insulated trucks to market.

Economic value⁴⁷

The gross value of production (GVP) of poultry in NSW was \$912m in 2016-17. At 6% of total NSW agriculture GVP, poultry was the sixth highest value primary industry in NSW.

Eggs contributed \$273m, or 2%, to total NSW agriculture GVP in 2016-17. Eggs were ranked the 13th highest contributor to NSW agriculture GVP.

In recent years demand has increased in all egg categories, with demand for free-range eggs experiencing the greatest growth. The increasing proportion of free-range eggs sold (currently approximately 40% of all NSW egg sales) has impacted productivity during winter as fewer eggs are laid by free range hens when days are shorter and colder.

Export of poultry meat accounts for a relatively small share of NSW poultry meat production and tends to be volatile from year to year, reflecting price sensitivity in export markets and trade restrictions. Likewise, exports of eggs are a small proportion of total NSW egg production, although exports of eggs more than doubled in 2016-17 compared to the previous year, the increase largely due to outbreaks of Avian Influenza in destination countries.

⁴⁷www.dpi.nsw.gov.au/data/assets/pdf_file/0009/814788/PDI2017_web.pdf

⁴⁸www.farminstitute.org.au/publications/research_report/energy

Energy use^{48,49}

Chicken meat

- It has been estimated that the total cost of energy used in Australian chicken meat production as a proportion of gross value of production is 16%, which is the highest percentage of energy costs as a proportion of GVP estimated for the Australian agricultural sector, and on par with the sugar industry.
- The benchmark for on farm energy use in poultry production in Australia is 0.51 – 0.88 MJ/kg live weight (excludes feed production).
- Electricity is the main form of energy used in the chicken meat industry, with diesel, LPG, natural gas and petrol also used.
- The most energy-intensive activities in grow out farms are associated with heating and cooling requirements for sheds on-farm, with seasonal and locality variations. Lighting and feeding systems are other energy consuming activities on farms.
- Broilers at slaughter weight are transported to large, highly mechanised chicken meat processing plants. Here chickens are unloaded, slaughtered, plucked, cleaned, cooled, graded and packed or processed into other products. Processing plant energy requirements for activities such as refrigeration, packing and sanitisation are predominantly electricity, followed by natural gas, LPG, diesel and petrol.
- There is a lack of data available regarding the breakdown of energy consumption

⁴⁹<https://www.agrifutures.com.au/product/benchmarking-energy-use-on-farm/>

between the different points in the chicken meat production process.

Eggs

- It has been estimated that the total estimated cost of energy used in Australian egg production as a proportion of gross value of production is 9%, which is also the average for the Australian agricultural sector.
- Most energy used in egg production is in the form of electricity. Ventilation, lighting and the motors that supply feed are the primary consumers of energy on egg farms, with ventilation fans estimated to be responsible for 60-70% of shed energy use. Once eggs are collected they must be cooled and stored in a refrigerated environment, which also contributes to the energy load of egg farms.
- Energy consumption in egg farms varies according to the way the layer hens are kept. Energy use will also vary with season and location.
- To comply with animal welfare requirements egg producers keep their layer hens in environmentally controlled sheds. Tunnel ventilated sheds are fitted with ventilation fans at one end, with air inlets along the length of the shed and cooling pads at the opposite end of the shed. These sheds are more energy intensive than naturally ventilated sheds. Some sheds are insulated.
- In order to ensure animal welfare is continuously maintained egg farms require a backup energy supply in case of blackout.

⁵⁰ http://biomassproducer.com.au/producing-biomass/biomass-types/animal-waste/poultry-litter/#.W8_P_y17EQ8

Activities to improve energy productivity

- Biogas can be generated from chicken litter, composed of cellulosic bedding materials such as wood shavings, chicken manure and feed⁵⁰.
- Biogas can also be generated by capping wastewater ponds, as Baiada Poultry Pty Limited have done at their Beresfield processing facility⁵¹. Turbines use the trapped methane blended with pipeline natural gas to provide electricity and heat to Baiada's plant.
- Opportunities may also exist to contribute waste to regional shared biomass/biogas to power plants. Excess biogas may be cleaned and compressed for tractors etc.
- Optimise for energy efficiency large scale tunnel shed design with free range access.
- Optimise shed operations using the Internet of Things for real time data and automated control systems.
- Improve the thermal performance of shed structures e.g. insulation and shading; paint heat reflective coatings on roofs. Situate new build hen houses on sites with good airflow.
- Utilise heat pumps linked to refrigeration waste heat.
- Improve the energy efficiency of equipment e.g. efficient ventilation fans and ducting with variable speed drives based on accurate monitoring of conditions, variable speed drives on pumping equipment, avoid valves, optimise pipes, high efficiency refrigeration plant and LED lighting. LED lamps with optimised wavelengths are very efficient.

⁵¹ http://biomassproducer.com.au/project/baiada-poultry-eases-costs-with-onsite-biogas-production/#.W8_OzC17EQ8

- Improve the energy efficiency of diesel-fuelled farm vehicles, e.g. implementing a regular maintenance program and driver training, or replace vehicles with more efficient or hybrid/electric models.
- Electrify operations and use on-site renewables such as solar PV, energy storage (e.g. thermal storage or batteries) and peak load management. Install demand control software to optimise energy use and reduce energy costs. May also provide opportunities to earn revenue from participating in electricity network demand response programs.⁵² Solar PV is well suited to matching the daily peak in energy demand in the middle of the day related to chicken shed cooling requirements. Installation of energy storage also ensures continuous energy supply and adherence to animal welfare requirements in event of blackout.
- Further value chain integration e.g. on-site processing to add value and reduce transport volumes and cost.
- Develop export markets. While costs of production are relatively high in Australia compared to many other countries, producers may be able to exploit Australia's high health and biosecurity standards to access premium markets for chicken and eggs products.
- Deploy advanced energy assessment approaches and diagnostic techniques to better understand energy flows and potential for energy productivity improvements.

⁵²arena.gov.au/assets/2018/10/REALM_FactSheet_agribusiness.pdf

⁵³ <http://www.energyfarmers.com.au/get-involved/bioenergy/chandala-poultr/>

Case study: Chandala Poultry, Western Australia⁵³

Pyrolysis will be used to process the chicken litter at the farm, which produces 1.7 million birds for the poultry meat industry each year. Pyrolysis will heat the organic material at around 400-500°C releasing gases locked up in the litter. The gas will be burnt to produce heat and Organic Rankine Cycle turbines will then recover the heat to produce electricity. Low grade heat from the process can be used for heating and cooling the chicken sheds. A by-product of the process is biochar. Biochar is a stable form of carbon and depending on the conversion temperature can retain nutrients and be used as a soil conditioner/fertiliser. There is also work being done in Australia under the Carbon Farming Initiative (CFI) and internationally on using biochar to sequester carbon as well as using biochar to reduce methane and nitrous oxide emissions.

Case study: SunBro poultry unit, Netherlands⁵⁴

Dutch poultry farmer Paul Grefte designed his own energy neutral poultry shed when deciding to expand his operation. He now sells the shed he designed. The resulting design is an A frame barn with a 90,000 bird capacity, split down the middle with a vent capable of scrubbing bad smells from the air it expels. Heating and cooling are provided by a ground source heat pump. The bulk of the pipe system that carries the water is located in an adjacent arable field. The ground water is typically 10°C. The water does not flow away and so acts like a big swimming pool (two hectares in area) that stores the warmth generated by the poultry shed as heat energy.

⁵⁴ <https://www.nfuonline.com/sectors/poultry/poultry-news/dutch-broiler-farm-is-energy-neutral/>

The temperature of the water increases to 13-14°C as heat is transferred from the shed to the water and falls to 6°C as heat is transferred from the water to heat the shed i.e. an eight degree temperature range. The main heat for the birds is in the form of underfloor heating. The aim is to keep the floor temperature at 30°C – the floor can get up to 40°C so 10°C is exported to the arable field. When the warmth from the water is transferred into the shed to heat the birds the cooler water is then stored in the arable field to use in the summer months to cool the incoming warm ambient air. The ventilation is so precise there is little need to adjust the air inlets. The air inlets are capable of pre-heating incoming air for a uniform temperature in the birds' environment. Windows are triple glazed and roller shutter blinds are automatically linked to a photocell in the shed to control light intensity and save energy on artificial light. Also, solar tubes are installed in the roof to increase natural light entering the shed. Artificial lighting is LEDs. The shed has 100mm of roof insulation and 80mm of wall insulation.

Case study: Valdimah Park chicken meat farm, Tamworth NSW⁵⁵

Valdimah Park is a chicken meat farm outside Tamworth that has sophisticated sheds that automatically regulate temperature, air quality and light conditions. Gas is used for heating to keep newly hatched chickens in temperatures of at least 30°C. For older chickens, ventilation systems are used, with evaporative cooling pads on the walls of the buildings, to pull heat out of the sheds, provide fresh air for the birds and keep them from overheating. Fan motors for ventilation account for the greatest proportion of

electricity used. In addition to cooling, electricity is also used to run pumps for water, augers and conveyers for food, and shed lighting. Despite being one of the more efficient chicken growing businesses in NSW, the equipment used results in high energy use, especially during hot weather.

Opportunities to reduce energy use and costs include: installation of a 7kW solar PV system per shed, with generation well matched to fan and light load; improved shed design for new sheds including VSD controllers with control systems; improved insulation and roof line designed to optimise ventilation and reduce heating and cooling loads; upgrade T8 lighting with T5s or LEDs; potentially replace LPG for heating with biogas generated from chicken litter.

See also Ag Innovators (NSW Farmers) information sheet on energy-efficient poultry sheds:

<http://www.aginnovators.org.au/initiatives/energy/farm-types/poultry>

<http://www.aginnovators.org.au/initiatives/energy/information-papers/energy-efficient-heating-poultry-sheds>

<http://www.aginnovators.org.au/initiatives/energy/information-papers/energy-efficient-poultry-shed-ventilation>

⁵⁵<http://www.aginnovators.org.au/initiatives/energy/case-studies/solar-proves-winner-delivering-real-savings-chicken-growers>

Links

NSW Department of Primary Industries:
www.dpi.nsw.gov.au

Australian Government Department of
Agriculture and Water Resources:
www.agriculture.gov.au

The Australian Chicken Meat Federation is the
peak coordinating body for participants in the
chicken meat industry including chicken
growers and processors: www.chicken.org.au.

The Australian Chicken Meat Growers Council
represents the interests of contract meat
chicken growers and turkey producers:
www.acgc.org.au.

Egg Farmers Australia is the national industry
body for Australian egg farmers:
www.eggfarmersaustralia.org

Poultry Hub is an ideas exchange for
commercial poultry production developed by
the Poultry CRC: www.poultryhub.org

Rural Research and Development
Corporations (RDCs): Australian Eggs Limited
www.australianeggs.org.au and AgriFutures
Australia www.agrifutures.com.au.

For discussion re waste to bioenergy see:
Cantrell et al 2008 Livestock waste to
bioenergy generation opportunities, available
online at:
<https://www.sciencedirect.com/science/article/pii/S0960852408002769>

2.2.3 Piggeries

Sector overview⁵⁶⁵⁷⁵⁸

The pork industry is one of Australia's smallest livestock industries. Approximately 60% of national production is consumed fresh, 30% processed into products such as ham and bacon and the remaining 10% exported.

Of the 2,800 piggeries in Australia, about 700, or a quarter, are located in NSW. There are over 58,000 breeding sows, or just over 20% of the national herd, located in NSW.

There are three main categories of pork production systems: indoor housing, outdoor bred and free range. Around 90% of Australian pigs are housed indoors for each stage of the production cycle. Indoor production allows producers to better monitor and manage their pigs. Outdoor bred systems entail sows and boars living outside and their progeny, when weaned, being brought inside into shelters and raised on straw. In a free-range system all sows, boars and their piglets live outside.

All Australian piggeries, regardless of production system, are classed as intensive, as all piggeries acquire more than 50% of the pig feed from off farm sources.

Greenhouse gas emissions produced by the pork industry are significantly lower than other agricultural sectors. The industry has a target to reduce emissions to an even lower level of 1kg CO₂-e per kilogram of pork produced from piggeries.

The Australian pig herd is free from many of viral and bacterial diseases that occur in other pork producing countries. Therefore on-farm

biosecurity is an important aspect of Australian pork production.

Economic value⁵⁹

The gross value of NSW production (GVP) of pig meat was \$224m in 2016-17. Contributing 1.5% of total NSW agriculture GVP, pig meat production was the 15th highest value agriculture industry in NSW.

Despite its relatively low ranking in terms of contribution to total NSW agriculture GVP, pig meat production is of interest to this project due to its energy intensive nature and its potential for market growth. Domestic demand for pig meat has grown such that it is now the second most consumed meat after chicken in Australia. However Australian pig meat producers face increasing competition in the domestic market from cheap, pre-cooked imports of pork products, with imports of pig meat products to Australia valued at \$163m in 2016-17.

The quantity and value of pig meat exported from Australia has been increasing rapidly, albeit from a small base, with pig meat exports valued at \$27m in 2016-17. The Singapore market, characterised by strong demand for high value products, dominates Australian pig meat exports, accounting for 45% of total exports in 2016-17. Other destination countries for Australian pork products include the Philippines, New Zealand and Papua New Guinea.

⁵⁶<https://aussiepigfarmers.com.au/pigs/our-farming-systems/>

⁵⁷www.farminstitute.org.au/publications/research_report/energy

⁵⁸www.nff.org.au/farm-facts.html

⁵⁹www.dpi.nsw.gov.au/data/assets/pdf_file/0009/814788/PDI2017_web.pdf

Energy use⁶⁰⁶¹⁶²

- It has been estimated that the cost of energy used in Australian pork production as a proportion of gross value of production is 10%, compared to an average of 9% for the Australian agricultural sector as a whole.
- One of the main costs of production for the pork industry is energy. Energy costs are estimated to have increased between 25-40% in recent years across the majority of pig producing areas.
- The benchmark for on farm energy use in pig production in Australia is 0.61 – 3.78 MJ/kg live weight (excluding feed production).
- There is a large variation in energy use per kilogram live weight in pork production due to difference in factors such as: farm size, type of housing system and number of sows, with seasons and geographic locations also driving heating and cooling requirements. Generally, energy demand will peak over summer due to increased fan activity to control temperature.
- Key energy use activities in all piggery housing systems include heating and ventilation. Feed management can also be a large energy consumer for piggeries if a feed mill is located on-site.
- Piggeries with tunnel or mechanical ventilation use more energy than those that are naturally ventilated. Mechanical ventilation systems may contribute up to

60-80% of the total power requirements of a piggery.

- Feed mills may contribute up to 20-30% of total direct energy consumption on piggeries that have feed mills located on site.
- The use of heat lamps and electric heat pads to warm young piglets are a major driver of energy costs for farrowing sheds.
- Electricity is the dominant form of energy used in piggeries, estimated to account for around three quarters of total energy use. This is followed by diesel, accounting for around 15% of total on-farm energy use for operation of motors and pumps.

Activities to improve energy productivity

- Biogas generation: the majority of greenhouse gas emissions from conventional piggeries originate from effluent treatment systems, providing an opportunity to reduce emissions and produce biogas⁶³.

Note the Pork CRC has a Bioenergy support program⁶⁴, which is being replaced by APRIL (Australian Pork Research Institute Ltd).

- Maximise the benefits of bio-gas systems by:
 1. Co-digesting piggery effluent with various off-farm waste or by-products supplied by nearby industries^{65 66}
 2. Upgrading excess biogas to bio-methane, especially in compressed (CNG)

⁶⁰www.farminstitute.org.au/publications/research_report/energy

⁶¹ http://australianpork.com.au/wp-content/uploads/2013/10/BMP04_RECIP_03_Ir.pdf

⁶²<https://www.agrifutures.com.au/product/benchmarking-energy-use-on-farm/>

⁶³ <http://australianpork.com.au/industry-focus/environment/renewable-energy-biogas/>

⁶⁴ <http://porkcrc.com.au/research/program-4/bio-energy-support-program/>

⁶⁵ <http://porkcrc.com.au/wp-content/uploads/2017/07/4C-109-Final-Report.pdf>

⁶⁶ <http://porkcrc.com.au/wp-content/uploads/2018/02/4C-113-Project-Final-Research-Report.pdf>

form, to mobilise the biogas energy for higher value applications such as fuel for vehicles or for sale as a portable fuel source. The viability of biogas upgrading will be investigated by a proposed Australian Pork Limited research project.⁶⁷

3. Employing sophisticated electricity spot price monitoring technology to control on-farm generator operation and the sale of biogas-derived electricity during higher demand/spot price periods.⁶⁸

- Optimise shed design to improve thermal performance, resulting in greater comfort, health and productivity e.g. Internet of Things control of VSD fans and heat pump heating, insulated huts or lids on crates in farrowing pens to retain heat for piglets, use of curtains to section off areas within sheds that need heating from those that don't.
- Improve the energy efficiency of equipment e.g. ventilation fans with variable speed drives based on accurate monitoring of conditions, automated thermostat control of heat lamps in farrowing sheds or replace heat lamps with electrically or warm water heated floor pads, variable speed drives on pumping equipment, and LED lighting.
- Improve the energy efficiency of diesel-fuelled farm vehicles, e.g. implementing a regular maintenance program and driver training, or replace vehicles with more efficient or hybrid/electric models.
- For sites with feed mills, use them at off peak times or when excess solar power is available to avoid contributing to peak

load as their use results in a spike in energy consumption.

- Electrify operations and use on-site renewables such as solar PV, energy storage (e.g. thermal storage or batteries) and peak load management. Install demand control software to optimise energy use and reduce energy costs. These strategies may also provide opportunities to earn revenue from participating in electricity network demand response programs.⁶⁹
- Engage in peer-to-peer energy trading and wheeling of power between sites.
- Value chain integration e.g. on-site processing or regional processing centre to add value and reduce transport volumes and cost.
- Further develop export markets for high value products.
- Deploy advanced energy assessment approaches and diagnostic techniques to better understand energy flows and potential for energy productivity improvements.

Case study: Bio-Up system to upgrade biogas to biomethane, Netherlands^{70,71}

The Bio-Up system is designed to upgrade biogas to biomethane using amine scrubbing technology at atmospheric pressure and is connected to an ordinary manure digestion installation on farm. The resulting biomethane is natural gas grid quality and can be used in vehicles when compressed. The Bio-Up system is fully automated and remote

⁶⁷ <http://porkcrc.com.au/wp-content/uploads/2018/08/4C-116-Final-Report-web-version-Part-1.pdf>

⁶⁸ <http://porkcrc.com.au/wp-content/uploads/2018/08/4C-116-Final-Report-web-version-Part-1.pdf>

⁶⁹ arena.gov.au/assets/2018/10/REALM_FactSheet_agribusiness.pdf

⁷⁰ <http://www.bioenergyfarm.eu/wp-content/uploads/2015/05/Bio-Up-English.pdf>

⁷¹ <http://bioup.nl/en/about-bio-up/>

controlled. It allows heat recovery and integration of the recovered heat in the digester. The first Bio-UP was built on the research farm of Wageningen University in the Netherlands.

Case study: Thorso centralised co-digestion biogas plant, Denmark⁷²

The Thorso centralised co-digestion biogas plant has been operating since 1994, is owned by a 43 member farmer co-operative and digests mainly animal slurry from local piggeries and dairies. The plant sells CO₂ neutral biogas in the form of electricity and heat. The heat is delivered into the local district heating system.

See also IEA Bioenergy case studies⁷³ for examples of centralised plants producing biomethane for vehicle fuel.

Case study: Systemic Project, Europe⁷⁴

Demonstration projects being carried out in 11 locations across Europe to produce biogas and other products such as fertiliser from animal manure. As well as generating power

from the biogas, uses for heat produced from the biogas are being investigated including food and digestate drying (for fertilisers) and heating digesters and greenhouses located on site and nearby.

Case study: Pig City, Denmark⁷⁵

Combination of pork production with a tomato greenhouse to maximise utilisation of manure and heat from the pigs. The complex includes a bio digester unit and a composting unit produce heat, electricity and fertiliser.

Links

NSW Department of Primary Industries:
www.dpi.nsw.gov.au

Australian Government Department of Agriculture and Water Resources:
www.agriculture.gov.au

Industry association and Rural Research and Development Corporation (RDC): Australian Pork Limited www.australianpork.com.au

Cooperative research centre: Pork CRC
www.porkcrc.com.au

⁷² <http://www.thorsobiogas.dk/about-thorsoe-biogas.htm>

⁷³ <http://task37.ieabioenergy.com/case-stories.html>

⁷⁴ [https://systemicproject.eu/wp-content/uploads/2018/07/D3.3 Factsheets Outreach.pdf](https://systemicproject.eu/wp-content/uploads/2018/07/D3.3_Factsheets_Outreach.pdf)

⁷⁵ http://www.gottliebpaludan.com/sites/default/files/project/1/attachment/pig_city_flyer_a3_english_nyny_0.pdf

2.2.4 Cattle feedlots

Sector overview⁷⁶⁷⁷⁷⁸⁷⁹

Feedlotting involves intensive grain-based ration feeding of cattle in a managed facility to control nutrition and maintain consistent quality levels before cattle are processed into meat for consumption at abattoirs.

In 2017 2.9 million cattle were turned off on Australian feedlots. Approximately 40% of Australia's total beef supply and 80% of beef sold in major domestic supermarkets is sourced from the Australian feedlot sector. Feedlot share of total cattle slaughtered has been steadily rising in recent years, in part due to drought and reduced availability of pasture feed and also an improved operating environment related to increased global beef prices. The increasing use of feedlots to finish cattle has increased the energy intensity of the Australian beef production industry.

At any one time around 2% of Australia's cattle population are located in feedlots. The average period cattle spend in a feedlot is 50-120 days, equivalent to about 10-15% of their total lifespan. Australia has a 1.3 million head feedlot capacity and utilisation of national feedlot capacity is about 80%. NSW feedlot utilisation is slightly lower at about 75%.

There are around 450 feedlots throughout Australia. Queensland is the predominant feedlot state, with approximately 60% of the national total of cattle on feed, followed by NSW, with about 30% of the national total of cattle on feed. NSW and Queensland are both large producers of grain and cattle, the two primary inputs of the feedlot industry. The

NSW feedlotting industry is mainly located in the Northern Tablelands and Riverina areas.

The feedlot industry is experiencing intensification as expansion over the last decade has occurred in medium sized feedlots (capacity of 1,000 to 10,000 head) and even more so in larger feedlots (capacity of more than 10,000 head).

The Australian stock feed market is the largest domestic user of Australian grain, accounting for around of a quarter of total national grain purchases. Almost 4 million tonnes of feed is manufactured for the beef industry each year, with a large proportion consumed by the beef feedlot sector (although there is supplementary feeding of grain to animals on farms, particularly during periods of low pasture availability).

Economic value⁸⁰⁸¹

The gross value of production (GVP) of beef cattle in NSW was \$2,376m in 2016-17. Beef cattle contributed 15% of total NSW agriculture GVP and was the 2nd highest value primary industry in NSW after wheat.

Of interest to this project are beef cattle finished on feedlots, as this is more energy intensive than pasture fed beef, and many cattle spend part of their lives in feedlots. Deloitte Access Economics analysis found the direct economic contribution of the NSW feedlot industry in 2017 was \$140m. This analysis found the total direct and indirect

⁷⁶www.feedlots.com.au

⁷⁷www.farminstitute.org.au/publications/research_report/energy

⁷⁸<https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Regional-feedlot-investment-study/3834>

⁷⁹<https://www.agrifutures.com.au/product/benchmarking-energy-use-on-farm/>

⁸⁰www.dpi.nsw.gov.au/_data/assets/pdf_file/0009/814788/PDI2017_web.pdf

⁸¹<https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Regional-feedlot-investment-study/3834>

economic contribution of the NSW feedlot industry to be \$1,225m in 2017.

NSW has very well-developed export markets for beef. Exports of NSW beef (both grain and pasture finished) were valued at \$1,303m in 2016-17, with the primary export destinations being Japan, the United States and South Korea. Approximately 40% of Australian grain fed beef is exported, with Japan being the primary international market, reflecting Japanese consumer preferences for high levels of marbling achieved by grain feeding.

Energy use⁸²⁸³⁸⁴⁸⁵

- It has been estimated that the total cost of energy used in Australian beef production as a proportion of gross value of production is 7%. However, for beef finished in a feedlot, which increases the energy intensity of beef the production, the figure may be higher, depending on potentially higher value of product, especially for export.
- An MLA study found total direct energy use on feedlots ranged from 444MJ/head to 1,483MJ/head.
- The primary driver of direct energy consumption in a feedlot is feed management, including feed processing (milling/steam flaking) and feed delivery. Water supply, administration activities and waste management also contribute to energy loads. The majority of water used on feedlots is for animal drinking water. Water is also used in the feed milling

process, to suppress dust and to wash cattle.

- The type of feed processing system used and depth of groundwater and distance to supply are factors that influence total energy consumption on individual feedlots. For feedlots with steam flaking systems, feed processing and distribution accounts for approximately 80% of total direct energy usage, compared to 45% for feedlots that process grain by other means.
- Transporting cattle and feed are the main indirect energy uses.
- The energy mix is different at each individual feedlot and may include a combination of gas (including LPG and butane), diesel and electricity. The dominant energy sources are 3-phase electric power and diesel, with gas used mostly at facilities with steam flaking feed processing as a fuel source for boilers.

Activities to improve energy productivity

- Invest in waste to energy plant: manure to biogas. Gas or heat produced may be used to pre-heat water and/or replace or fuel boilers in steam-flaking feed processing operations.

See Meat & Livestock Australia 2015 report "Feasibility of using feedlot manure for biogas production"⁸⁶, in particular findings relating to the economic viability of using feedlot

⁸²www.farminstitute.org.au/publications/research_report/energy

⁸³ <https://www.mla.com.au/research-and-development/feeding-finish-nutrition/Lotfeeding-intensive-finish/energy-and-water-use/>

⁸⁴ <https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Environment-On-Farm/Quantifying-the-Water-and-Energy-Usage-of-Individual-Activities-within-Australian-Feedlots/264>

⁸⁵<https://www.agrifutures.com.au/product/benchmarking-energy-use-on-farm/>

⁸⁶ <https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Environment-On-Farm/Feasibility-of-using-feedlot-manure-for-biogas-production/3461>

manure for anaerobic digestion. Economic viability is largely determined by the composition (quality) of the manure e.g. stockpiled manure biogas generation is 7.5% of the amount generated by clean pen manure because valuable energy sources are lost during drying. Note that more frequent manure removal may impact the health, welfare and weight gain of cattle⁸⁷.

- Opportunities may also exist to contribute waste to regional shared biomass/biogas to power plants.
- Optimise on-lot feed processing and delivery.
- Optimise on-site vehicle movement e.g. for feeding.
- Improve the energy efficiency of diesel-fuelled farm vehicles, e.g. implementing a regular maintenance program and driver training, or replace vehicles with more efficient or hybrid/electric models.
- Improve the energy efficiency of equipment e.g. variable speed drives and direct drives on pumping equipment and LED lighting.
- Electrify operations and use on-site renewables such as solar PV, energy storage (e.g. thermal storage or batteries) and peak load management. Install demand control software to optimise energy use and reduce energy costs. May also provide opportunities to earn revenue from participating in electricity network demand response programs.⁸⁸
- Improve the thermal performance of buildings.

- Further develop export markets for high value products.
- Deploy advanced energy assessment approaches and diagnostic techniques to better understand energy flows and potential for energy productivity improvements.

Case study: Bioelectric micro biogas plant, Belgium⁸⁹

A fully automated mono-digester micro biogas plant takes 2900m³ of liquid cattle manure to produce 155.2kWh of electric energy and 335MWh of thermal energy. Each day the biogas plant pumps a predetermined amount of slurry from the reactor to the digestate stock and supplies the transported volume with fresh slurry from the basement. The slurry in the reactor is heated to 38°C using warm water circulating in tubes along the side of the reactor. The formed biogas is fed through filter to the engine. Electricity and heat are produced, with heat recovered to heat up the reactor or transported for use on farm.

See also

<https://www.wur.nl/en/article/fuelledbycow-manure.htm>

<http://www.acres.nl/en/green-gas-supply-chain/>

<http://www.issinstitute.org.au/wp-content/media/2013/06/WILSON-Report-LowRes.pdf>

⁸⁷ <https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Environment-On-Farm/Quantifying-the-Water-and-Energy-Usage-of-Individual-Activities-within-Australian-Feedlots/264>

⁸⁸ www.arena.gov.au/assets/2018/10/REALM_FactSheet_agribusiness.pdf

⁸⁹ http://www.bioenergyfarm.eu/wp-content/uploads/2015/05/Case-belgium-English-version_template.pdf

Links

NSW Department of Primary Industries:
www.dpi.nsw.gov.au

Australian Government Department of
Agriculture and Water Resources:
www.agriculture.gov.au

Industry association: Australian Lot Feeders'
Association www.feedlots.com.au

Rural Research and Development
Corporations (RDCs): Australian Meat
Processor Corporation www.ampc.com.au &
Meat & Livestock Australia www.mla.com.au

2.2.5 Dairy

Sector overview⁹⁰⁹¹

NSW has 685 dairy farms, or about 11% of all farms nationally (almost 70% of Australian dairy farms are located in Victoria). Of the national herd of 1.663 million dairy cows, 177,000 or 11% are located in NSW.

NSW produces over a billion litres of milk per year. Approximately 60% of milk produced in NSW is used for drinking milk, with the remainder processed to produce dairy products such as cheese and milk powder. About half of these processed dairy products are consumed domestically and the balance exported.

Around half of the milk produced in NSW comes from the southern region, about 30% is produced on the North Coast and the remainder in the inland/central region.

In Australia the average herd size has increased from 93 cows in 1985 to the current estimate of 284 cows. There is also an emerging trend for very large dairy farms with 1,000 plus head of dairy cattle.

Dairy farms are largely pasture based, with around three quarters of feed requirements coming from grazing in a normal season. The Australian dairy industry accounts for around a quarter of all fertiliser used in Australia as dairy producers aim for strong pasture growth. The manufacture of fertilisers is energy and carbon intensive and prices are increasingly linked to prices in the natural gas market. Fertiliser use is also associated with high climate impact N₂O emissions. During drier seasons and periods of low pasture

growth there may be reliance upon manufactured feed brought on farm.

The dairy industry is heavily reliant upon water availability. It is the second largest user of irrigation water in Australia. Water is used on farm primarily for growing pasture. Water is also used for dairy shed operations and cattle drinking water.

Economic value⁹²⁹³

The gross value of production (GVP) of milk and milk products in NSW was \$559m in 2016-17. Milk and milk products contributed 3.6% of total NSW agriculture GVP, the 9th highest value primary industry in NSW in that year.

The NSW dairy industry was affected by lower milk prices and difficult seasonal conditions in 2016-17. With costs generally remaining fairly constant, farm profitability declined. State milk production declined 5% on the previous year to 1.13 billion litres.

The majority of drinking milk is produced in the central and northern NSW regions and sold into the domestic market. In contrast the southern region is more export focussed, with much of the milk produced processed into milk powders and other milk products. Producers in the southern regions have been significantly more exposed to volatile global dairy prices, which have been lower than prices received by farmers for domestic drinking milk in recent times. The main export markets are Singapore, China and Taiwan.

⁹⁰ www.nff.org.au/farm-facts.html

⁹¹ www.dpi.nsw.gov.au/data/assets/pdf_file/0009/814788/PDI2017_web.pdf

⁹² www.dpi.nsw.gov.au/data/assets/pdf_file/0009/814788/PDI2017_web.pdf

⁹³ www.dairyaustralia.com.au/dairyfarmmonitor

Energy use^{94,95,96}

- It has been estimated that the total cost of energy used in the Australian dairy industry as a proportion of gross value of production is 13%. This is relatively high, as compared to the 9% average for the Australian agricultural sector as a whole, reflecting the energy intensive nature of the dairy industry.
- There is a trend of increasing energy intensification in Australian dairy farming reflecting an increased use of supplementary feeding, although the majority, approximately 75%, of feed requirements currently come from grazed pastures.
- The most energy-intensive activities in dairy sheds are milk cooling (average of 38% of total NSW dairy shed energy costs), water heating (average of 22% of NSW dairy shed energy costs) and milk harvesting (average of 17% of NSW dairy shed energy costs).
- For dairy farms with irrigated pasture, irrigation can be a significant consumer of energy, and depending on the season, irrigation can be the biggest consumer of energy on irrigated farms. It is estimated 57% of Australian dairy farms irrigate their pastures, with around 90% of irrigation pumping powered by electricity.
- Electricity is the dominant form of energy used on dairy farms, accounting for about two thirds of total energy use. Energy use on a typical dairy farm would be split between electricity for shed operations (20%) and water irrigation pumping (47%) and diesel for tractor field operations (30%) and truck transportation (3%). Since

many dairy farms are mixed activity, it may be that energy data for irrigation and on-site vehicle use blur energy use for cropping with dairying energy.

- Farm scale impacts energy use with energy use per kilolitre of milk produced falling with larger herd sizes. The type of milking system used also impacts energy use, with automatic/robotic milking systems using a greater amount of energy for milk harvesting.

Activities to improve energy productivity

- Produce biogas from manure.
- Co-produce fertiliser and phosphorus from biogas production.
- Electrify operations and use on-site renewables such as solar PV, energy storage (e.g. thermal storage or batteries) and peak load management. Install demand control software to optimise energy use and reduce energy costs. May also provide opportunities to earn revenue from participating in electricity network demand response programs.⁹⁷ Also power line losses to rural properties can be very high (up to 50%) so 1 kWh saved on farm is equivalent to up to 2 kWh generated.
- Optimise pasture irrigation using low/renewable energy solutions.
- Utilise heat pumps for simultaneous heating and cooling (may also be useful to include thermal storage). Also consider use of evaporative cooling of stored water to near wet bulb temperature.

⁹⁴www.farminstitute.org.au/publications/research_report/energy

⁹⁵ RMCG, 2015, Data analysis for 'Smarter Energy Use' project

⁹⁶<https://www.agrifutures.com.au/product/benchmarking-energy-use-on-farm/>

⁹⁷arena.gov.au/assets/2018/10/REALM_FactSheet_agribusiness.pdf

- Use water chilled by solar powered chillers and stored as a source of cooling for milk.
- Deploy more efficient milking equipment e.g. robotised milking systems. While these use more energy per litre, they can improve labour and overall business productivity and hence energy productivity. And since at least some of the extra energy use is due to longer periods of operation of vacuum pumps and compressors, and herd management fuel use may be reduced, there is potential for smart, high efficiency systems to close the energy gap with conventional milking
- Utilise 'virtual' paddock technologies, i.e. stock and pasture management using sensors transmitting data in real time, to reduce vehicle use, save time and optimise resource inputs such as water for irrigation.
- Reduce hot water use for sanitisation by optimising cleaning practices e.g. spray nozzles or using chemical sanitisers.
- Improve the thermal performance of buildings. e.g. install insulation and shading; paint heat reflective coatings on roofs.
- Improve the energy efficiency of diesel-fuelled farm vehicles, e.g. implementing a regular maintenance program and driver training, or replace vehicles with more efficient or hybrid/electric models.
- Use thermal imaging, ultrasonic sensors (to pick up air leaks).
- Improve the energy efficiency of equipment e.g. variable speed drives on

pumping equipment, improved vacuum pump design and LED lighting.

- Double milk concentration using reverse osmosis to value add on farm and reduce transport costs.
- Further develop export markets for high value products.
- Deploy advanced energy assessment approaches and diagnostic techniques to better understand energy flows and potential for energy productivity improvements.

Case study: Dairy Cooperative Tine, Norway⁹⁸

The heat recovery system utilises waste heat from the dairy's refrigeration system to fulfil the dairy's demand for CIP water at 73°C (Coefficient of performance (COP) of 5.8 i.e. 5.8 units of cooling/heating per unit of electricity input). The system is also connected to a local heating network which supplies heat to nearby greenhouses at 58°C (COP of 9.0). The cooling installation provides the cooling duty for the butter and cheese manufacturing process. The system uses ammonia refrigerant.

Case study: Moxey Farms, Gooloogong, NSW

Moxey Farms has 6,000 head of dairy cattle producing around 30 kilograms of waste per head a day. This equates to about 5,700 tonnes of dung a year. In 2018 Moxey Farms constructed bio-digester pits for anaerobic fermentation of the manure to produce biogas. The biogas will be used to generate 3 MW of power, providing 100% of the farm's power requirements, with excess power sold

⁹⁸ Case study 7.5:

<http://heatpumpingtechnologies.org/publications/application-of-industrial-heat-pumps-part-2/>

back into the grid. Moxey Farms is also carrying out a nutrient recovery process of leftover material, recovering phosphorous and nitrogen which can be sold as a natural fertiliser. Another benefit is odour reduction, with odour being a concern of neighbours. The cost of the bio-digester is \$1 million and is part of a larger expansion of the dairy, including a robotic milking facility.^{99,100} Design and construction of the bio-digester is being undertaken by Bathurst-based firm Akura¹⁰¹.

Also, Ballarat-based Gaia EnviroTech has recently developed a modular bio-digester to generate gas, electricity and heat which is being trialled at A.J. Trig Farm, Bundaree.¹⁰² The design includes six modules able to treat up to 20 cubic metres of cow manure a day. The farm is a robotic dairy with automated effluent collection 24 hours a day.

Case study: Shanghai Dairy Company, China¹⁰³

All animal waste is used as feedstock in two 1,000 cubic metre digesters to produce biogas. A very efficient CHP plant produces sufficient power for the heating and cooling needs of the farm and the digestate is spread back on cropping fields as fertiliser. There is a large degree of automation in the system.

Links

NSW Department of Primary Industries:
www.dpi.nsw.gov.au

Australian Government Department of Agriculture and Water Resources:
www.agriculture.gov.au

Industry associations: Australian Dairy Farmers www.australiandairyfarmers.com.au & NSW Farmers Association www.nswfarmers.org.au

Rural Research and Development Corporation (RDC): Dairy Australia
www.dairyaustralia.com.au

⁹⁹ <https://amp.smh.com.au/business/the-economy/poo-power-farm-to-run-100-per-cent-on-green-electricity-20180828-p50064.html>

¹⁰⁰ <https://www.canowindranews.com.au/story/567956/2/22-million-dairy-plan-for-moxey-at-goologong/>

¹⁰¹ https://akura.com.au/project/dairy-buildings/attachment/img_2762-medium/

¹⁰² <http://www.gaia-enviro.com/gaia-envirotech-trials-new-biodigester-technology>

¹⁰³ <http://www.issinstitute.org.au/wp-content/media/2013/06/WILSON-Report-LowRes.pdf> - see p20

3 Pilot projects

3.1 Pilot concept identification

The following factors should be considered when identifying potential pilot concepts for energy productivity investment:

1. **Energy intensity/highest EP improvement potential**

A material enhancement in the value of output is likely to be created by using energy more effectively. This criterion focuses on the potential to enhance the value of output of a process by using energy more effectively (while energy consumption will either increase more slowly, stay the same, or even decrease in absolute terms). This is often the key to major EP improvements as the total value from EP projects is often a large multiple of the value of energy savings. The International Energy Agency¹⁰⁴ and others have increasingly recognised that apart from energy savings there were other 'multiple benefits' of energy efficiency improvement projects, and found these additional benefits could be worth as much as 2.5 times the value of the energy saved.

Energy productivity includes all potential value added, including improved labour and other factor productivity; enhanced social licence to operate as a result of, for example, improved animal welfare or environmental performance; reduction in farmers' vulnerability to the challenges of climate change and enhancement of their capacity to adapt; improved safety; reduced health costs; better product quality and value; improved reliability/resilience; reduced resources/water use; reduced cost of effluent disposal; improved access to export markets; and, indirect benefits such as reduced energy supply infrastructure costs - for example, deployment of on-site solar PV and storage can reduce energy demand from the electricity grid at peak times, reducing the need for investment in electricity grid infrastructure.

2. **Suitable regions for locating pilots with potential for local replication (clusters)**

Knowledge transfer is a critical element to maximize the benefit of DPI's investment in energy productivity projects. Locating pilots in regions with good potential for local knowledge transfer and replication is an effective way to leverage DPI's investment. Local replicability also allows the building of local maintenance capability and supply chains for mainstreaming of adoption and to reduce perceived and actual risk for adopters.

3. **Suitable industry, association, technology and research partner organisations with enthusiasm for participation and energy benefits**

These organisations must be engaged to ensure available knowledge is utilised in setting up the project and the results of project are widely disseminated. For example, the pork industry seems to be a sophisticated leader in biogas production from animal wastes and co-digestion of multiple organic inputs that could benefit other sectors. Example organisations include industry associations and rural research and development

¹⁰⁴ International Energy Agency, 2014. *Capturing the Multiple Benefits of Energy Efficiency* Paris

corporations. Industry partner organisations are critical to the outcome of the project and must be adequately engaged for the project to be a success.

4. **Potential for co-funding pilots with other organisations (e.g. RDC, ARENA, CEFC) that may also have their own resources**

Leveraging co-funding will allow more ambitious projects to be completed.

3.2 Considerations for DPI funded pilot projects

The DPI project is the beginning of a longer-term strategy. It will operate within a rapidly changing context, the nature of which should be considered in selection of demonstration projects and stakeholder engagement.

Some considerations to keep in mind include:

- **Climate:** There is substantial climate variation between regions, so solutions developed for any sub-sector within agriculture need to be adaptable to a variety of climates. Further, some sub-sectors are shifting towards inland locations where weather is more extreme and drier. Climate change is driving more extremes and greater variability. Tools that help farmers to adapt technologies or systems to different climates will be important if significant replication and associated economies of scale are to be captured
- Trends in consumer preferences may affect selection of crops and animals, as well as operational practices and the need for documentation and quality assurance, for example, consumer interest in free range meat and eggs or low use of antibiotics. Innovations need to take such possibilities into account. Other factors, such as access to transport, reduced problems with neighbours, access to suitable workforces, etc, can drive relocation of activities. This can be a response, or can be influenced by government action.
- There are trends towards higher intensity of operations to control more factors (e.g. feedlots, intensive piggeries and chicken sheds). The potential to capture and utilise 'wastes' such as manure and crop wastes is increasing: these can produce useful energy, be recycled into fertilisers, etc, while waste management issues may become more challenging, adding to incentives for change. Another outcome of this is that production of food for animals is becoming more separated from animal husbandry as operations become more intensive, while the structure of supply chains may change. So new business relationships are emerging that may impact on ability of individual operators to take actions or control key factors. Irrigation and glasshouses (heating and cooling) are increasing issues as plant production becomes more intense. These drive more focus on water efficiency and quality, energy use to transport water, etc.
- For many operators, reliability and cost of energy supply for all activities including mobile equipment and transport of food and product is becoming a bigger issue. Access to low cost thermal energy (from gas) is an emerging problem as gas prices increase, but agriculture has access to enormous renewable energy resources, including solar, wind, manure, crop wastes, energy crops (e.g. bushes and trees that provide wind breaks and biomass, and can be grown quickly and coppiced (cut back while leaving roots in ground so regrowth is rapid)).

- New revenue streams are emerging, including export of renewable energy (which is less variable than most agricultural activities, so can provide base income). On-site, local or regional product processing can capture a larger proportion of the overall value, reduce dependence on powerful downstream processors and retailers and provide better quality control.
- There are emerging potential synergies between farming, food processing and local communities regarding energy systems e.g. shared energy storage and local energy production can help homes, local businesses and agricultural enterprises to capture economies of scale, and reduce dependence on fragile power lines. Another driver of change in energy is that cost-based network pricing is beginning to drive up rural and regional energy costs compared with urban networks. And exposure to bushfire and grass fire risk means conventional rural power supply networks can be shut down or damaged, with major impacts for community and business.
- A lot of harvesting involves capital investment in equipment that is only used for a short period each year, and adds to peak energy demands. There is scope to develop modular, transportable equipment that can be better utilised and offers reliability and flexibility through having multiple units. As intensity of activities increases, the scope for diversification that reduces variability of revenue also increases.
- There is increasing focus on selection of higher value crops, and the market value of quality assurance, certification, branding and reputation are changing priorities.

3.3 Examples of pilot projects

In considering options for pilot or demonstration projects, it is worth keeping in mind that some projects may have application across agricultural sub-sectors. Key cross-sectoral activities relevant to multiple sectors include:

- space heating and cooling e.g. to maintain animal health and welfare
- cooling of product – both lowering temperature and maintaining required conditions
- movement using motorised equipment, on-site and between sites
- irrigation (not considered in detail in this report, but a separate investigation into energy productivity opportunities is recommended).

For example, the chicken, egg, pork and beef industries are all focused on providing comfortable, healthy environmental conditions and nutrition for animals to optimise growth/production while limiting energy costs and maintaining license to operate. They have similar requirements for shelter and comfortable conditions for their animals. So, for example, aspects of a project focusing on improving performance and energy efficiency of a tunnel shed for chickens could be applied to piggeries, while the expertise of the pork industry in biogas production could be utilised by other sectors

There is also potential to identify technologies and practices used in other industries for application within agriculture. For example, AirChange, a NSW firm, specialises in equipment for recovery of thermal energy from sensible and latent heat in exhaust air from aquatic

centres and commercial buildings. Another NSW firm, Pooled Energy, has developed sophisticated smart controls, monitoring and benchmarking systems for swimming pool filter pumps, including demand response and pump and filter selection. This could be applied to irrigation, and potentially optimisation of fan use.

Note that all the following are concepts and need to be tested firstly with RDCs, technology providers and other stakeholders, and several may need engineering assessments or further research and development to be undertaken. In some cases there are multiple and potentially integrated projects for each sector.

The table below summarises examples of possible pilot concepts, with each of pilot concepts described in the following pages.

Ref	Sector	Pilot project name
F1	Cattle feedlots	Feedlot manure to biogas
F2	Cattle feedlots	Optimising cattle feed preparation to reduce steam use in steam flaking
F3	Cattle feedlots	Solar PV plus storage with electrification of heating and optimal integration with networks
E1	Eggs	Solar PV plus batteries integrated with the grid
C1	Chickens	Chicken farm biogas generation from chicken litter and disposal of dead birds
C2	Chickens	Free range energy efficient tunnel sheds
D1	Dairy	Biogas production (and potential link with robotization)
D2	Dairy	High energy productivity heating and cooling
D3	Dairy	Milking equipment improvement
P1	Piggeries	Manure to biogas at small scale and for multiple biogas applications
P2	Piggeries	Interaction of piggeries with electricity grids, peer-to-peer trading and wheeling of power between sites
P3	Piggeries	Improve comfort, health and productivity through improvement in heating, cooling and ventilation
P4	Piggeries	Use of biogas to replace liquid fuels on-site and locally
H1	Horticulture	Postharvest temperature optimisation – Cold store
H3	Horticulture	Cold chain optimisation – Temperature monitoring
H3	Horticulture	Postharvest processing – On-farm energy and processes
O1	All	On farm value adding
<i>Supplementary pilot project concepts</i>		
D4	Dairy	Improvement in energy assessment of dairies
D5	Dairy	On-site vehicle energy use
P4	Piggeries	Alternative sourcing and processing of feed

3.3.1 Sector: Cattle Feedlots

Background data: See section 2.2.4 Cattle feedlots

Industry engagement:

Meetings held with:

Jim Cudmore – Ex-President Feedlot Association

Verity Price – Feedlot Association

Doug McNicoll – Innovation Management - MLA

Gareth Forde – All Energy (consultant to MLA)

Warren Leitao – CEO - Renu Energy – BOO of biogas/power plants

Fiona Waterhouse – CEO - Utilitas group - BOO of biogas/power plants

Jemena – Mike Davis – Interest in biogas from all agricultural applications

Key industry issues identified that may be addressed through energy productivity measures addressed in proposed pilots:

- Cost of gas and electricity and price escalation. Red meat industry uses \$1.7B/year of purchased energy and growing.
- Energy supply reliability.
- Odour and health regulation issues with spreading manure on farmland - licence to operate. Not critical yet in most areas but can see emerging as the industry grows and regulations tighten.
- Greenhouse emissions from beef farming - MLA target to be carbon neutral by 2030. This is a reputational issue for the industry.
- Interest in biogas and solar, but the red meat businesses want a relatively fast payback for their investments and are reluctant to commit to long term supply contracts.
- Poor energy efficiency of grain flaking (both electricity and heat) and high cost of energy for that task

Pilot F1: Feedlot manure to biogas

- generate biogas for steam flaking, power generation, and perhaps supplement diesel in farm equipment

Project situation (the problem/opportunity/rationale/potential):

- Feedlots have to dispose of a large amount of manure: 1.5-2.75kg dry mass/cow/day or 0.5-1 t dry mass/year so for a 25,000 head (large) feedlot this is 40,000-70,000 t dry mass/year, and the energy content of this is substantial (200-300 litres of raw biogas/kg manure organics) though it degrades with age so it must be harvested frequently and loaded into the digester. The collection, cleaning and utilisation of biogas could provide a useful income stream from the gas/power, and revenue from renewable energy certificates. Avoiding methane emissions can create Australian Carbon Credit Units (ACCUs) which can be sold internationally. A large 25,000 cow feedlot could generate enough biogas to make >4,000 MWh/year of power, worth >\$0.8M/year at \$200/MWh power cost.
- Manure is currently spread on farm land. In doing so it has little value, and there are likely to be emerging health and regulatory constraints to this form of disposal, impacting on long term license to operate.
- Manure also releases substantial greenhouse emissions. Decomposing manure emits considerable methane: But the more it is spread, the lower the methane emissions. As a result, the CO₂ equivalent emissions can vary greatly between 100 and 500kT/year as the emission coefficient of methane is 25 times that of CO₂. Manure washed by rain into collection dams will have very significant methane generation.
- Manure can be converted by anaerobic digestion to usable energy with significant value, as well as a more valuable fertiliser from the digestate. However, the process is capital intensive (typically \$3-\$8+ million), and likely to deliver an ROI below the requirements of most feedlot owners, even though it delivers a net financial return and other benefits. In Australia, there no feedlots which currently process their manure.
- The combination of much higher grid gas prices and improvements in bio digestion technologies and financing mean biogas is now much more attractive and equipment is more easily controlled than in the past. In addition, there are 3rd party businesses operating in Australia with capital to invest in these projects that are interested to invest at the ROI available from these projects.
- Biogas can be used for boiler fuel for flakers and/or for power generation. It can also potentially be used as a fuel for farm vehicles (on site or for sale to other nearby fuel users, directly as Compressed Natural Gas (CNG) in a blend with diesel, or possibly through conversion to other fuels).
- This represents a very large energy resource for the industry. It has the key elements for a valuable pilot as it can be transformative in its impact on the energy balance for feedlots, appears to be technically and commercially viable, can be facilitated by an injection of government support, and has potential replication to the approx. 150 beef feedlots in NSW.

- MLA contracted (see link <https://www.mla.com.au/research-and-development/search-rd-reports/final-report-details/Environment-On-Farm/Feasibility-of-using-feedlot-manure-for-biogas-production/3461>) research indicates that this is a feasible approach for the industry.

Pilot proposed:

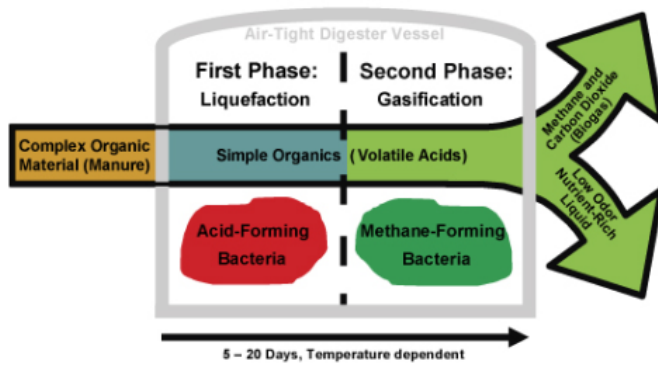
Implement a biogas and power generation plant. Propose 3rd party financing and operation as a build/own/operate and arrangement with power off-take agreement for minimum 7-10 years with the feedlot/local power network. 3rd party would lease land from a feedlot and be off balance sheet for the feedlots. Part-funding from DPI, ARENA, and MLA to de-risk the initial project and reduce the length of the offtake agreement. Location at a large feedlot or where multiple large feedlots are adjacent. Tamworth seems like an ideal location with potentially 2 * 20k+ feedlots alongside and potential for accessing supplementary feedstock and also potential to support a local electricity supply constraint. The facility could potentially support a future project focused on replacing vehicle fuel.

It is noted that more frequent scraping of manure may result in negative impacts that would require assessment as part of a feasibility study. These impacts may include increased labour and machinery costs and reduced animal welfare due to increased animal stress and reduced comfort as less manure is available for bedding.

Brief description:

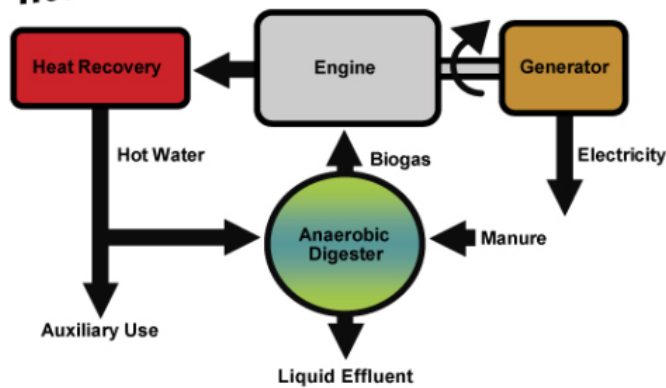
Collection, processing, and either cleaning/use of the gas directly for steam generation or power generation. Use of front-end loaders to collect the manure as fresh as possible – separation tank to remove gravel, and then biogas tanks, gas cleaning and gas storage balloon. Where waste treatment lagoons are in place, using covers to collect methane can offer a lower cost first step towards methane recovery and utilisation. Rivalea has taken such an approach.

How it works...



Methane goes to gas cleaning if required, and then boiler for steam flaking and engine for power generation

How it's used...



Project outcome:

Industry advice would indicate an order of magnitude 4-7 year payback project with a capital cost of \$3-\$8+M. This could be owned by the feedlot, or a third-party build, own, operate model (BOO) with a 10 year gas and power offtake agreement. This would generate cashflows from gas produced, and/or from power if the biogas is used to generate power in a diesel genset, and from renewable energy certificates (LGCs), (and potentially carbon mitigation incentives by creating ACCUs through ERF if an appropriate methodology can be developed). Given that, beyond 2021, LGCs may have little value if the current government was returned, a focus on developing ways of creating ACCUs may be desirable.

The involvement of DPI could be to provide incentive funding, along with potentially MLA/ARENA etc to make a third party financed project more acceptable to the feedlot owner by reducing the period of off-take agreement required. DPI could also play a key role in working with other government agencies to develop methodologies for creation of ACCUs from farm-sourced biogas.

The pork industry has significant relevant experience, and has also been able to improve the economics of smaller scale biogas plants.

Benefits (energy savings, productivity, carbon, adoption):

- Directly replace fuel used in the boilers for flaking feed – this is often expensive LPG, LNG or high cost natural gas from a spur line.
- Could also potentially use Compressed Natural/Bio Gas (CNG) or derived liquid fuels to displace diesel.
- Potential to replace all the electricity imported from the grid with lower cost power from the plant. Sell surplus power to the grid – the plant economics will be impacted by the price received for electricity sales.
- Enhanced reliability of electricity supply, local grid support depending on the specific needs of the local power network, and potential demand response revenue.
- Health and safety/disposal/odour benefits due to the processing of manure, which addresses license to operate and regulatory risk.
- Substantially reduce greenhouse emissions and allow creation of tradable carbon permits, addressing cattle industry target of zero net carbon emissions by 2030.
- Heat may also be recovered from the generator to pre-heat boiler feedwater.
- Potential to extract nutrients/enhance fertiliser value of the manure.
- On-site availability of (lower cost) power may enable expanded irrigation of farmland in some cases.
- increase/accelerate renewables uptake, displace fossil fuels

Project outcomes:

Potentially replicable to as many as 150 feedlots in NSW, though depending on locational factors and scale, some will be more attractive than others. Locational factors include scale, operational ability to collect (without much gravel) and process manure promptly, cost of fuel (higher the better), cost of electricity (higher the better), local need for electrical network augmentation, business culture, willingness of business to accept 7-10 year offtake agreement. Note that there are 4 large feedlots in the Tamworth area, two 20,000 cattle feedlots are apparently very close to each other. And Tamworth electricity supply may be in need of augmentation, though this would have to be confirmed.

Potential stakeholders/associations: MLA, Australian Feedlot Association, technology providers including AGO, Australian biogas development companies, gas network companies like Jemena, research organisations specialising in biogas generation.

Pilot F2: Optimising cattle feed preparation to reduce the steam use in steam flaking

Project situation (the problem/rationale/potential):

Large feedlots use steam to process feed in steam flakers, as well as substantial amounts of electricity in grain mills. These make the feed more digestible for cattle, and aid weight gain. A large feedlot with 25,000 cattle, typically will need 1.5-2MW of steam in traditional steamers. This can be expensive to deliver e.g. if using expensive fuel like LPG or LNG where the site is not on a gas pipe-line, the feedlot could be using \$30-50k/month of fuel.

Steam flaking requires moisture, retention time and temperature. The temperature (100°C) and moisture (typically 10%) are provided by the steam, and the retention time by the size/design of the steamer/steam chest. Retention times can be decreased (i.e. steamer size reduced) by pre-soaking the grain, but this increases moisture content and may then require more steam to drive it off.

The problem addressed here is large energy costs, due to the substantial use of fossil fuels associated with steam flaking. If the process could be made more effective so it requires less steam residence time and wastes less heat by improving insulation, it may improve animal nutrition, and/or reduce the capital cost of steamers. If expensive fossil fuel used could be replaced with renewable energy sources (like solar thermal), or displaced by using heat pumps supplied with solar PV electricity, it would provide both economic and carbon mitigation benefits.

Pilot proposed:

Study and pilot a range of possible alternative solutions:

1. Feasibility/piloting pre-heating boiler feedwater using a heat pump powered by solar PV electricity supply. NOTE: heat pumps that can produce steam at 120-165°C exist, but are not available in Australia. 120°C steam and pre-heated grain in well-insulated systems with heat recovery (as a heat source for the heat pump) could potentially transform this process.

This project could include testing the effect of pre-soaking grain in hot water from heat recovery, heat pump or other source, which preheats as well as softens the grain.

2. Reduce steam use in flakers using improved steamer design, including optimising thermal insulation of all components of system, and recover waste heat. Also examine improving electricity efficiency of steamers using better motor selection, and use of variable speed drives.
3. One final possible option would be application of solar thermal supply of low-pressure steam for flaking. Note however that this option is potentially competing with steam generated from biogas in existing boilers (see F1). which is likely to provide a better overall energy productivity solution.

Brief description:

- Conduct an international best practices review. Note also local design review work by MLA and their consultants like All Energy.
- Do a desk top technical and economic review of the above options.
- Find pilot site(s) which is to planning invest in a new/supplementary flaker to trial these options.

Project outcome:

Developed and trialled options to typical steam flaking from dry feed using cold boiler feedwater and using fossil fuels for the source of steam. This should have good replication potential to all other larger feedlots that steam flake their feed.

Benefits (energy savings, productivity, carbon, adoption)

Key benefits are likely to include:

- Reduced fossil fuel consumption.
- Potentially improved feed quality and/or reduced capital cost of steamers.
- Reduced carbon emissions.
- Increase/accelerate renewables uptake, displace fossil fuels.
- On-farm energy security/reliability, independence.

Pilot F3: Solar PV plus storage, with electrification of heating and optimal integration with networks

Project situation (problem/rationale/opportunity/potential):

Large feedlots typically have at least 250kW of on-site load for feed treatment and other applications, and electricity is a major and escalating operating cost. Feedlots with plenty of available land are ideal locations for solar PV applications. Tracking solar has the ideal load output pattern to match the demand profile of daily feedlot power usage, and has not been used in the industry yet.

Direct drive high efficiency motors with variable speed drives could vary electricity loads of feed mills, pumps, fans and materials management systems to match varying PV output, increasing utilisation of PV and reducing peak demand charges. Low cost solar could be used to reduce fossil fuel use for flakers by using electric heat pump pre-heating (See F2).

Feedlots are also typically in edge of power grid situations, and local generation at feedlots could potentially be valuable to energy distributors to support their network, particularly if accompanied by battery storage and/or standby generators. Present energy market arrangements do not encourage such cooperation, but rule changes are in train, and some innovative retailers and network operators are rewarding such actions in advance.

Pilot proposed:

Demonstration of tracking on-ground solar (and/or perhaps solar awnings to provide shading for cattle), use of battery/other storage in a rural setting, and optimal integration of these elements and site electricity demand, together with integration with the local supply network.

Brief description:

Pilot with the following elements:

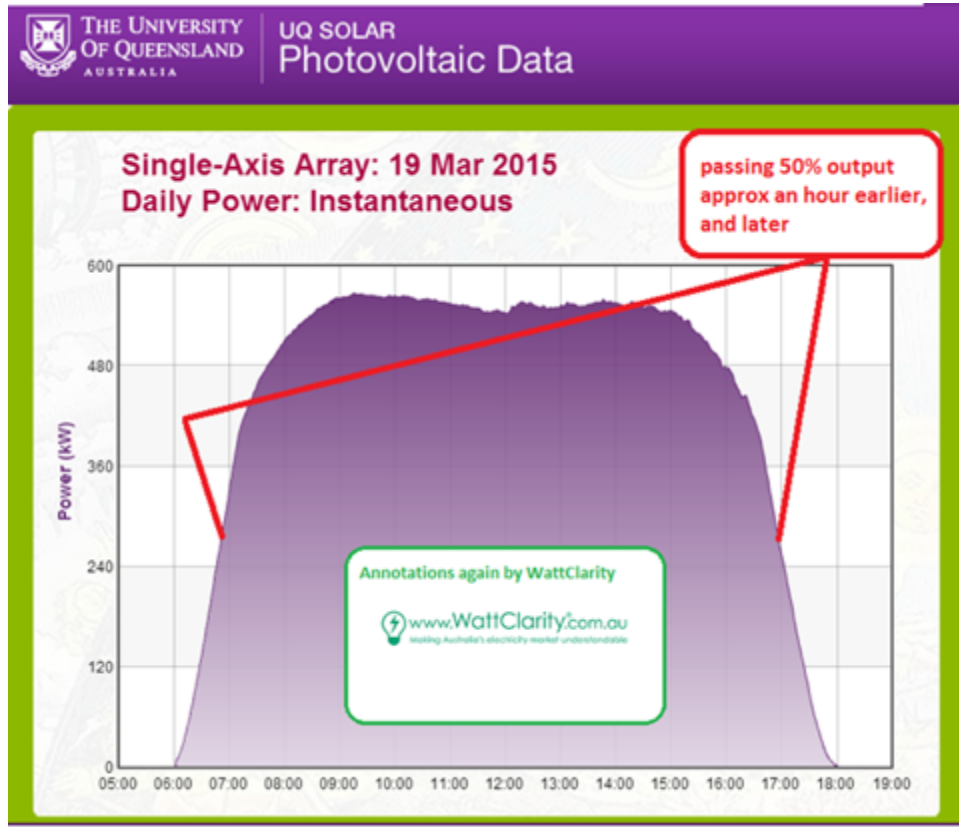
- Design and implement energy efficiency upgrades to reduce electricity demand (feed preparation, lighting, and other loads including irrigation if done on site).
- Install tracking PV with enough capacity to cover peak demand in mid-season, and design optimal level of energy storage – thermal and/or a small battery and/or backup diesel genset, and smart load management software, and trial optimisation of supply to minimise total electricity costs. This would ideally include testing a cost reflective network pricing agreement with a cooperative network operator.
- This would be ideally implemented at a site where the local energy distribution network has a need for local system augmentation, and is willing to reflect this in supply agreements and/or potential to sell into grid or wheel locally.

(Note that this type of project, potentially including a local micro-grid, could be implemented in any agricultural setting – It does not need to be a feedlot, as long as it has significant on-site electricity demand).

Project outcomes:

This project is about demonstrating tracking solar PV in a rural setting, and electricity optimisation and integration with networks in a 'fringe of grid' situation, which is common for the agricultural industries so it has potential replication right across the sector. It also will include demonstrating optimal integration with the operation of the plant.

Project key outcome will be reduced energy costs for the plant, and improved reliability, as well as benefits for the network/local community. Another option that could be demonstrated, though is likely to be less economical and replicable, is to use local generation and solar to go off grid and eliminate network charges.



Benefits (energy savings, productivity, carbon, adoption):

Key benefits are:

- Greatly reduced electricity energy purchase cost.
- Reduced carbon emissions from renewable energy.
- Additional plant energy security.
- Potential to reduce network charges by demonstrating a local area network supported by generation at the site and receive revenue from feed-in to grid. Alternatively demonstrate the opportunity to go off grid and eliminate network charges.
- Potential for using excess solar at any time to pre-heat boiler feedwater with either resistive heating or a heat pump (which is 3-4 times more efficient) if economical.
- Increase/accelerate renewables uptake, displace fossil fuels.

3.3.2 Sector: Eggs

Background data: See section 2.2.2 Chicken meat and egg production

Industry engagement:

Meetings held with:

Rowan McMonnies: Managing Director, Australian Eggs

Key energy issues Identified:

- Egg industry is effectively bifurcated into two sub-sectors:
 - The major producers are very proficient in managing energy use in sheds, use best international technology and practices and do not seek further input. Major energy productivity related concerns and opportunities are:
 - Biohazard reduction, odour, licence to operate
 - Animal welfare as increasing license to operate, cost and marketing issue
 - Cost of gas and electricity and price escalation is a concern to the big end of town who operate with smaller margins.
 - Smaller boutique producers are not interested generally in improving technology as they are gaining a large premium price from selling a non-technological free-range farming approach.
- Because of the bifurcation, it may be difficult get the industry interested in pilots due to existing sophistication and continued technology investment from the big end of town and lack of interest from small end of town. McMonnies suggested though that due to the interest of the industry in solar at present, a project on the optimal application of solar could be of interest.
- There would also be some interest in biogas generation from chicken manure. There is also potential for biogas generation in the egg industry and there is already one recent installation in Queensland. See Chickens 1, though the application is somewhat different as it would only be for manure rather than chicken litter, so easier to treat but lower volume of material to digest. There may be a case to investigate a local bio-digester that services multiple sites, so economies of scale can be captured. The challenge with this may be biosecurity concerns.
- Where electricity is generated from bioenergy, there is increasing interest in reasonably priced 'wheeling' of electricity between nearby sites rather than having to sell surplus power back to the grid.

Pilot E1: Roof top (and/or perhaps tracking) Solar plus batteries integrated with the grid

Project situation (problem/rationale/opportunity/potential):

The egg industry is increasingly implementing solar (on shed and on ground in some cases as well). But there is concern that it may not be optimally implemented to gain best benefits for the farmer or the network.

Brief description:

Solar is often poorly implemented due to shortage of knowledge about optimal application. The industry may be interested (needs to be tested at company level) in the optimal selection and application of solar PV, including use of storage (thermal, material, pumped as well as battery), demand management and control, and optimisation of on-site electricity generation to integrate with local networks. (See ARENA 'REALM' (renewable energy and load management for business) project report: <https://arena.gov.au/projects/realm-renewable-energy-load-management-businesses/>).

On the latter point, where the local network owner has augmentation needs, there may be an opportunity to provide some of this through on-site generation and demand management. This project could explore such opportunities. It could also look at co-operating with the local distribution network owned to test alternative network tariffs which better reflect local network costs and may provide additional potential for growers to reduce their average energy prices and reduce costs.

It is proposed that a desk top study be conducted for 2-3 ideal sites – perhaps one which has recently installed solar and one where it is planning in the near future, to identify load management opportunities and to design optimal REALM solutions, and then to provide part-funding to assist with the implementation of storage/control systems to deliver the solutions in cooperation with the local network.

Project outcome:

The pilot would demonstrate how to implement optimal solar solutions to deliver the best benefits for farmers as well as networks. This could be replicated across the egg farms in NSW.

Benefits (energy savings, productivity, carbon, adoption)

Potential for substantial energy cost savings and to facilitate increased use and size of solar PV installations across the industry, which would also deliver carbon mitigation benefits.

- Increase/accelerate renewables uptake, displace fossil fuels.

3.3.3 Sector: Chickens

Background data: See section 2.2.2 Chicken meat and egg production

Industry engagement:

Meetings held with:

Vivienne Kite: Executive Director, Australian Chicken Meat Federation

We have not yet spoken to the poultry CRC or the research organisations below.

Note, the chicken meat industry is vertically integrated. Two large companies supply more than 70% of Australia's chicken meat. Some producers and sites are highly sophisticated, others less so.

Key energy issues identified:

- Biohazard reduction, odour, chicken litter disposal, licence to operate
- Animal welfare as increasing license to operate and marketing issue, and adverse energy impact of making openings in the sides of tunnel sheds to meet 'free range' criteria relating to marketing and profit.
- Cost of gas and electricity and price escalation
- Potential application of on-site renewables (especially solar PV) and storage
- Relationship between application/optimisation of energy and animal welfare and production outcomes i.e. health/mortality, conversion of feed to meat, weight at turn-off.

References provided:

Waste to Energy reports:

<https://www.agrifutures.com.au/wp-content/uploads/publications/14-096.pdf>

<https://www.agrifutures.com.au/product/conversion-of-waste-to-energy-in-the-chicken-meat-industry/>

<https://www.agrifutures.com.au/wp-content/uploads/publications/16-028.pdf>

Solar Energy options:

<https://www.agrifutures.com.au/wp-content/uploads/publications/14-105.pdf>

<https://www.agrifutures.com.au/product/two-case-studies-of-commercial-viability-for-solar-photovoltaic-systems-on-meat-chicken-farms/>

Fan energy efficiency:

<https://www.agrifutures.com.au/wp-content/uploads/publications/14-062.pdf>

<https://www.agrifutures.com.au/wp-content/uploads/publications/15-018.pdf>

<https://www.agrifutures.com.au/wp-content/uploads/publications/15-035.pdf>

<https://www.agrifutures.com.au/product/guide-how-to-reduce-costs-and-energy-by-replacing-inefficient-ventilation-fans-on-meat-chicken-sheds/>

Contacts

Corporate grower, Proten: Daniel@proten.com.au. Proten has a number of big farms in NSW and may have looked at energy alternatives.

Company that presented in SA about solar on chicken farms is <https://smartconsult.com.au/>

Researchers:

Dr Mark Dunlop Mark.Dunlop@daf.qld.gov.au

Dr Stephan Tait Stephan.tait@usq.edu.au

Pilot C1: Chicken farm biogas generation from chicken litter and disposal of dead birds

Project situation (problem/rationale/opportunity/potential):

The chicken industry has a chicken litter disposal issue, and a dead bird disposal issue - both challenges relate to biohazards and increasing regulatory controls. The chicken litter disposal problem could be turned into an opportunity as it could be a feed for biogas generation in anaerobic digestors, and power generation to reduce energy costs and carbon emissions.

Pilot proposed:

Biogas generation from chicken litter.

Brief description:

Chicken litter is to be converted to biogas using anaerobic digestion in this pilot. This feed is quite challenging. It would also be useful if the system could handle waste grain and other organic wastes from the farms.

Ideally, the chicken industry would also like to be able to bio-digest dead birds, as this is a big issue for the industry: 1 shed = 40k birds. 4% mortality – mainly when young. 6-8 sheds average farm, and some up to 20 sheds. (So, a large farm may have to handle 32,000 dead birds/6 week cycle). Note that it is quite likely that a separate pre-processing/digester system will be required for dead birds (which may involve thermophilic digestion at higher temperatures and much shorter residence time).

This is a relatively novel and technically challenging application which will require government funding to support the initial projects. It does not seem to have been implemented in Australia for this specific application and there are few plants internationally – the ones in the literature have all been commissioned in the last few years.

Case examples: There is one Australian egg producer that has biogas generation (from chicken manure, not litter): http://biomassproducer.com.au/case_study/poultry-manure-to-power-in-the-darling-downs/#ad This case example was for 390,000 hens producing 130 tonnes of chicken manure per day and generating 250kW of power, with an overall project payback of 5-7 years, and \$3M capital investment.

The first European plant to process chicken litter is a centralised plant in Northern Ireland which was heavily supported by government funding, and handles 40,000 tonnes of litter/manure annually and generates 3MW of power. The plant cost nearly \$40M and generates income of about \$5M/year from electricity sales. It is normally difficult to convert large amounts of poultry manure in biogas plants because of the high levels of nitrogen inhibiting the bacteria that produce biogas. Danish company Xergi developed 'NiX' technology to reduce the nitrogen content in the biogas process. Poultry manure is fed into hoppers with walking floors that feed it to the next stage where it is mixed with recirculated liquid before being pumped into the digesters. During the mesophilic (30-38°C) digestion process bacteria break down the litter and produce biogas. The total digestion time is approximately 45 days and the biogas produced by the plant is fed into two 1.5MW gas engines that generate electricity on site which is then exported. The digestate is pasteurised before being separated into a fibre and liquid fraction. Most of the liquid fraction passes

through an ammonia removal process before being mixed with the incoming poultry litter. The remaining liquid and the fibre digestate are a safe nutrient-rich fertiliser.



Note energy demand varies greatly in sheds through the 6-8 week cycle and is also highly seasonal, so there will be a need to sell surplus power to the grid at a reasonable export price.

Project outcome:

The operation of such plants would resolve major problems for the industry, and support a more sustainable long term license to operate. In addition, the plant would generate cashflows from gas produced, and from power where biogas is also used to generate power in a diesel genset, and from renewable energy certificates. There would be additional income streams from waste disposal and fertiliser sales. Once this technology is more commonplace, it would be expected such facilities could make an attractive utility ROI.

Benefits (energy savings, productivity, carbon, adoption):

The potential benefits include:

- Biohazard reduction from the litter (and dead birds if these can be also processed), and reduction in waste disposal costs. This is becoming an increasingly important issue for the industry.
- New source of revenue from gas, electricity and renewable energy certificates or ACCUs.
- Potential for recovering waste heat from the engine for shed heating in cooler periods.
- Improved value fertiliser from the digestate – captures nitrogen from the waste.
- Odour reduction.
- Significant reduction in carbon emissions.

This seems like an ideal pilot project as it is innovative, resolves major problems for the industry, and progress requires an injection of government support to overcome the risk of the initial installation. Would be an ideal project for ARENA participation.

The Northern Ireland plant takes feed from multiple farms. It would be important to ensure that this did not increase biohazard risk – though litter is apparently being collected by contractors and taken off-farm now. A group plant could be located in Tamworth or Riverina, and use a BOO model.

Pilot C2: Free Range energy efficient tunnel sheds

Project situation (problem/rationale/opportunity/potential):

Australian free-range meat chicken production has grown to 15% of the market in 2015, from being a 'cottage industry' in 2006. This growth is significant compared to other developed countries. The consumer-driven expansion of free-range production in Australia has led to the conversion of older, conventional farms into free range systems, as well as the development of new free range farms.

The industry has done considerable work to implement world best practice technology for tunnel shed design, which incorporates energy efficiency (including use of sophisticated shed monitoring, modelling of air flows and use of variable speed fans). However, the industry association sees that the trend to free range operations, and modification of sheds to enable this through implementing pop holes to up to 60% of the wall area is potentially undermining the design parameters of the shed, and likely increase energy use/reduce energy efficiency as a result.

Note, this pilot is relevant for both broiler and layer sheds.

Pilot proposed:

Funded pilot to model, design, trial and document energy performance optimisation for large scale sheds with free range access.

Brief description:

This pilot would combine energy and chicken farming experts (and perhaps interaction with pig farmers and others with similar challenges for housing stock) to address energy optimisation in chicken sheds that have free range access – including flow design, fan design and integration, use of smart sensors and variable speed drives for flow optimisation, optimal insulation, optimal heating and cooling options and other issues. The project would include workshops, analysis and piloting of solutions with monitoring and verification of outcomes.

Project outcome:

The key outcome would be knowledge sharing of learnings from the pilot to inform the industry dealing with increased free-range access requirements on optimal energy and bird welfare through temperature and air flow control solutions. This may also have applicability to the egg industry.

Benefits (energy savings, productivity, carbon, adoption)

- Energy savings
- Improved bird welfare in free range conditions.

3.3.4 Sector: Dairy

Background data: See section 2.2.5 Dairy

Based on industry data available, irrigation (90% of which is electric) dominates dairy farming energy use (47%) – which is large, given that only 57% of Australian dairy farms irrigate. So for those who irrigate, it is a major cost and issue. Irrigation is best dealt with as a cross-sectoral issue, as it is widely used in many sectors of agriculture.

There are additional indirect energy costs, not included in the industry statistics, including water supply and embodied energy/emissions in fertiliser. Despite spreading of manure on pastures, dairy is still a large consumer of artificial fertilisers. These are costly, have high embodied climate emissions, and they may increase emissions of the very active greenhouse gas N₂O from soils.

Vehicles, mainly tractor use (30%) and trucks (3% but we suspect under-reported) are next largest, according to industry data. Experts consulted in this project seemed surprised that on-farm vehicle use in dairy was so large, and questioned the accuracy of the data. If the data are correct, it may be that pasture management, animal management, food distribution and other activities require more detailed analysis, so energy and other costs can be reduced. Practices from other areas, such as ‘virtual fences’ and remote management can be applied. Robotic milking may reduce vehicle use. One speculative project related to hybrid tractor development is included in this list of pilot project proposals.

‘Shed’ energy accounts for 20% of on-site energy use.

Indirect energy use beyond sites includes fertiliser, transport, imported feed (about a quarter of all cow feed), but this is outside the scope of this project.

Energy use in sheds is mostly electricity and is dominated by milk cooling (38%), water heating (22%, but perhaps declining as cleaning shifts to chemical sanitisers), and milk harvesting (17%). (Note that NZ data is slightly different, with water heating 32%, milk chilling 21% and milk production 26%. This may reflect variations in climate, scale of operations and/or practices).

The capture of energy from ‘wastes’ and locally available renewable energy also are opportunities for reducing energy costs and potentially generating additional income streams.

Key factors affecting dairy energy use and cost, and potential for application of innovations, are likely to include climate, location and scale of operation. To date, data identified in this project has provided limited insights into the significance of these factors for dairy, and for broader agricultural innovation. It seems that we need to build a more comprehensive data base over time, to optimise policy and program focus.

Industry engagement:

Consultation with Michael Cashen, DPI and:

Nick Bullock, independent energy consultant referred by DPI

Nicolas Lyons, DPI robotic milking expert Ian Olmstead: Dairy Australia

Alan Pears’ involvement in an advisory panel for a Victorian agricultural funding scheme.

Literature review: see notes throughout pilot proposal

Key issues that may be addressed through energy productivity measures Identified:

Factors which offer potential value to dairy farmers that emerged from discussions include:

- Measures that save labour/time so fewer people are needed or the timing can be shifted. E.g. robotic milking on average DPI research found improvement in productivity from 100 units/person to 153. BUT, these measures tend to increase energy consumption due to longer periods of operation of equipment such as vacuum pumps and compressors. This suggests a case for more emphasis on efficiency improvement of this equipment and optimisation of its operation. However, these approaches may also improve energy productivity and overall productivity. For example, initial reports indicate some improvement in animal health, reproductive performance and reduced lameness: work is in progress to document outcomes.
- Reliability/resilience of equipment, including ensuring access to maintenance. This might be via local contractors or, increasingly, through remote monitoring/management to support preventive maintenance or limit the number of maintenance calls, inclusion of redundancies into equipment so it can 'work around' failures, etc.
- A barrier to energy productivity measures is perception of increased risk for limited benefit. Examples include:
 - Reliance on technologies that rely on reliable and stable electricity supply.
 - Heat pumps for hot water have a poor reputation, because cheap, low quality units designed for residential use were installed in the early days of the Small Renewable Energy Target. Given the potentially valuable role of heat pumps in this sector, this barrier must be specifically targeted in project and program design.
 - A Victorian trial of partial dewatering of milk, which reduces transport costs and downstream processing costs seems to have been promising, but has not been adopted more widely, apparently due to logistical and other problems.
- Technologies/offering that hand more control to operators, allow them to take advantage of (or reduce impacts of) external changes such as energy tariffs and prices, cheap energy prices, energy trading, payment for services that stabilise the grid, can be attractions.
 - On-site energy generation can help to overcome energy supply reliability and cost.
 - Changes in energy market rules and energy industry business models (e.g. see recent AGL scheme offering exporters 'tokens' that can be used by friends and family or sold to those who want to support renewable energy; FlowPower flexible tariffs and wheeling arrangements for transfer of electricity between sites, etc).

- Confidence of financial returns. Operators don't want to be exposed to debt related risk unless they are very confident of returns. Responses may include Flexible financing mechanisms, offers to 'buy back' equipment if it does not meet expectations, Build-Own-Operate-Transfer can also reduce risk.
- Increasing focus on animal welfare, linked to maintaining 'license to operate', reputation, marketing advantage and potential introduction of tighter regulations. Reduced noise, odours, improved management of manure and other wastes, etc help.

NOTE: a number of energy productivity measures not specifically included in the following proposals are listed in the overview report. References Provided:

<https://www.daf.qld.gov.au/business-priorities/animal-industries/pigs>

Further Information

- CowTime Energy Monitor: <http://www.cowtime.com.au/EnergyMonitor/index.aspx>
- Genesis Automation (Aust): <http://genesisauto.com.au/html/dairy.htm>
- Dairy Farm Energy Guide (US): <http://www.dairyfarmenergy.com/page1.html>
- Energy efficiency on your farm (NZ): <http://www.mfe.govt.nz/publications/climate/farm-energy-efficiency/farm-energy-efficiency.html>
- Genesis Energy Dairy Savings (NZ): <http://www.dairysavings.co.nz/default.aspx>
- InfoSheets on Efficient Dairy Layout and Design:
 - InfoSheets on Efficient Dairy Operation: http://www.dairyindustrysa.com.au/technical_info_for_farmers/starting_a_dairy

Pilot D1: Biogas production (and potential link with robotization)

Project situation (problem/rationale/opportunity/potential):

- Dairy farms have to dispose of a large amount of manure: (25-30kg/day/cow with 85% water content * say 6,000 cattle). It is generally in the form of a slurry which is pumped onto farmland. Manure is generally now spread on farm land. In doing so it has little value, there is a lot of odour which can be a real issue with neighbours, and increasingly there may be health and regulatory constraints to its disposal like this (impacting license to operate). The untreated manure in anaerobic conditions releases methane which is a powerful greenhouse gas (emission factor of 25). The collection, cleaning and utilisation of biogas could provide a useful income stream from the gas/power – producing enough to run the dairy and excess, and revenue from renewable energy certificates.

Pilot proposed:

- Ideally find a dairy modernising and putting in robotic milking and include in this set-up manure collection. Install an anaerobic digester for producing biogas and gas engine for power generation. This could be owned by the farmer or 3rd party owned and operated.
- Utilise experience of pork industry in optimisation of design and operation, including consideration of co-digestion.

Brief description:

See F1. Similar basic setup, but dairy effluent tends to be wet which means most of the manure is available in a slurry and this changes the front-end processing plant. Dairy farms also tend to have a lower number of cattle.

Case examples:

Link to ABC Landline segment on Victorian robotic dairy with bio-digester:

<https://www.abc.net.au/news/2018-02-18/waste-not-want-not-the-bio-digester-turning-farm/9459758>

Ballarat-based Gaia EnviroTech has recently developed a modular bio-digester to generate gas, electricity and heat which is being trialled at A.J. Trig Farm Bundaree.¹⁰⁵ The design includes six modules able to treat up to 20 cubic metres of cow manure a day. The farm is a robotic dairy with automated effluent collection 24 hours a day.

Moxey Farms, Gooloogong: Moxey Farms has 6,000 head of cattle producing around 20,000 litres of waste a day. This equates to about 5,700 tonnes of dung a year. In 2018 Moxey Farms constructed bio-digester pits for anaerobic fermentation of the manure to produce biogas. The biogas will be used to generate 3 MW of power, providing 100% of the farm's power requirements, with excess power sold back into the grid. This is the first such plant in the NSW diary industry. Moxey Farms is also carrying out a nutrient recovery process of leftover material, recovering phosphorous and nitrogen which can be sold as a natural

¹⁰⁵ <http://www.gaia-enviro.com/gaia-envirotech-trials-new-biodigester-technology>

fertiliser. The cost of the bio-digester was \$1 million and is part of a \$22M expansion of the dairy including a robotic milking facility.¹⁰⁶¹⁰⁷ Design and construction of the bio-digester is being undertaken by Bathurst-based firm Akura¹⁰⁸.



Project outcome:

Industry advice would indicate order of magnitude 4-8 year payback project with a capital cost of \$2-\$3M. This could be owned by the dairy farm, or a third party build, own, operate model (BOO) with a say 10 year gas and power offtake agreement. This would generate cashflows from gas produced, and/or from power if the biogas is used to generate power in a diesel genset, and from renewable energy certificates, (and potentially carbon mitigation incentives through ERF).

Benefits (energy savings, productivity, carbon, adoption)

- Odour/health (no pathogens) or weed seeds/ license to operate
- Improved quality fertiliser
- Energy Cost reduction – gas and electricity if also use generator. Replace all the power imported from the grid with lower cost power from the plant.
- Major reduction of greenhouse gas emissions and potential to create ACCUs (Australian Carbon Credit Units) for sale or internal offsetting through Emission Reduction Fund methodology. Creation of Large Generation Units may also create a revenue stream.
- Heat may also be recovered from the generator for hot water use for cleaning.
- Potentially replace diesel consumption with compressed biogas.
- Enhanced odourless fertiliser value from the digestate

¹⁰⁶ <https://amp.smh.com.au/business/the-economy/poo-power-farm-to-run-100-per-cent-on-green-electricity-20180828-p50064.html>

¹⁰⁷ <https://www.canowindranews.com.au/story/5679562/22-million-dairy-plan-for-moxey-at-gooloogong/>

¹⁰⁸ https://akura.com.au/project/dairy-buildings/attachment/img_2762-medium/

Pilot D2: High energy productivity heating and cooling

Project situation (problem/rationale/opportunity/potential):

Dairy sheds have a significant requirement for both cooling (mainly milk) and heating (for sanitizing, cleaning etc). These comprise around 60% of shed energy, though different reports show varying shares of heating and cooling – and the mix of heating and cooling could vary over time and with operational scale, technical change and climate change. Emerging heat pump technologies can provide both heating and cooling at very high efficiency. The actual efficiencies of existing equipment are not well understood, due to lack of measurement and real time benchmarking.

Many dairies make use of pre-cooling using alternatives to refrigeration e.g. sources of cold water such as streams or bores, or cooling towers (which can be inefficient due to high fan and pumping energy and may require chemicals for legionella management).

Pilot proposed:

A range of options could be used to address these issues in one or more pilot projects, such as:

- Evaluate potential application of heat pumps to provide both heating and cooling via integrated or separate equipment (with hot and cold water storage). This technology offers the potential to substantially reduce heating and cooling costs using much higher energy productivity electricity technology, particularly when linked with on-site production of solar PV electricity. If this proves to be economically attractive, implement a full scale trial project, probably at a DPI facility. This is particularly important due to the poor reputation of heat pumps resulting from sales practices and installation of unsuitable equipment a decade ago in the dairy industry.
- Conduct evaluation and benchmarking of existing equipment performance from a 'systems and services' perspective and the potential for higher efficiency conventional equipment, improved practices (e.g. water-efficient sprays, regular cleaning of heat exchangers, optimising temperatures, adding insulation, replacing heated water with sanitizers (e.g. <https://www.ewater systems.com/> produces low toxicity sanitizers on-site using electrolyzers – working with supermarkets, which replace caustic soda and other sanitizers).
- Evaluate the feasibility of evaporative cooling of stored water to near wet bulb temperature for pre-cooling.

Brief description:

The pilot would have several elements:

- Systems analysis of efficiencies of existing systems for heating and cooling, and potential for improved practices and selection of more efficient conventional equipment to deliver benefits. Evaluation of the sensitivity of demand for heating

and cooling to a variety of factors including changing scale, introduction of alternatives (such as sanitizers, alternative pre-cooling solutions, etc).

- Comparative analysis of use of high efficiency separate coolers and heat pumps or combined systems, and potential with thermal storage to provide demand response and reduce costs through demand management, as well as interaction with onsite renewable energy and energy storage systems.
- Pilot installation of the best options.

Project outcome:

Demonstration of improving heat pump technologies; development of guidelines for improved maintenance and operation of existing cooling and heating equipment; potential benefits of thermal storage and integration with onsite renewable energy systems and batteries; help to overcome high risk perception related to heat pumps and other emerging technologies

Benefits (energy savings, productivity, carbon, adoption)

Heating and cooling comprise around 60% of on-site electricity use on dairy farms (excluding irrigation), so there is potential to use technologies like heat pumps to substantially reduce energy costs, improve reliability, particularly utilising on-site solar electricity.

There is also potential for improvement in quality of service through faster cooling, lower and more stable cold temperatures.

Pilot D3: Milking equipment efficiency improvement and robotisation

Project situation (problem/rationale/opportunity/potential):

Robotised milking is evolving rapidly, and potentially offers multiple benefits for many sites, but is associated with much higher energy use by milking equipment. Milking equipment consumes around 17% of NSW dairy shed energy (26% for NZ). Vacuum pumps comprise around 80% of this (<http://www.dairyingfortomorrow.com.au/wp-content/uploads/RRR-fact-sheet-Dairy-Pumps-and-Motors-low-res.pdf>).

Pilot proposed:

Demonstration of techniques to optimise the energy efficiency of robotised milking equipment, with particular focus on vacuum and compressor systems.

Brief description:

The latest developments in robotised milking would be demonstrated, with emphasis on vacuum and compressor systems. Monitoring would provide evidence to farmers on the benefits including reduced labour and need for operators to be present at times inconvenient to farmers, reduced incidence of health problems such as mastitis, higher milk output and improved energy management.

Vacuum systems used for milking can suffer significant inefficiencies, particularly from air leaks, inefficient vacuum pumps, excessive 'effective reserve' and inefficient, fixed speed motors. The project would demonstrate use of diagnostics including ultrasonic detectors (for air leaks), energy and milk production monitoring to provide real time benchmarking of system efficiency, and demonstrate energy savings and other benefits from high efficiency vacuum pumps and high efficiency variable speed motors.

Project outcome:

Work with operators of existing robotised milking equipment to improve its energy efficiency, with emphasis on vacuum and compressor systems.

Improved data and increased awareness would help to reduce perceived risk of change to robotised systems. Data would underpin financial evaluation by potential funding agencies or investors.

Benefits (energy savings, productivity, carbon, adoption):

Cost-effective reductions in energy costs; accelerate adoption of emerging technologies offering improved productivity.

3.3.5 Sector: Piggeries

Background data: See section 2.2.5 Piggeries

Industry engagement:

Consultation with:

Nick Bullock, independent energy consultant referred by DPI

Jayce Morgan, DPI

Review of literature and websites, particularly porkcrc.com.au and its successor <http://apri.com.au/>.

Key energy productivity issues and opportunities identified:

There is great variety in piggeries, from small to large, in a wide range of climates, and from sophisticated monitoring, metering and technology, to basic metering with manual control relying on operator observation.

Even though energy comprises on average 10% of input costs, the optimisation of feeding and animal health, welfare and growth is central to competitiveness. Therefore, it is important that improvements in energy productivity also contribute to overall business productivity. Recent increases in energy prices have led to a focus on biogas production from manure.

The piggery sector has adopted biogas digestion of manure at a rapid pace, with one estimate that around 30% of pigs are now managed at piggeries with digesters. Extensive R&D has been pursued to optimise blending and co-digestion of inputs, and to improve the economics of smaller capacity digesters.

The potential pilot projects identified address major areas of energy use and opportunities for adding value through measures that capture greater business value from each unit of energy.

Pilot P1: Manure to biogas development at small scale and for multiple biogas applications

Project situation (problem/rationale/opportunity/potential):

The pork industry is rapidly adopting biogas production, and has an extensive R&D program to improve outcomes. However, there seems to be potential for ongoing action, utilisation of overseas developments, and to explore options for the best ways to utilise the biogas. There may well be a variety of 'best' solutions for different circumstances. Tools for comparison of options, and tracking of rapid technology and cost developments will be increasingly important.

Pilot proposed:

Comparison tools should be developed and trialled with a diverse sample of existing biogas plants to validate them. Training and support services for use of those tools should be developed and made available to the industry.

Some options that could be considered within the tools include:

- Direct use of biogas for heat compared with electricity generation (potentially with waste heat utilisation) to drive efficient electric technologies or for export to the electricity grid or via peer-to-peer trading, including evaluation of gas storage so that utilisation can be optimised instead of flaring of excess production at some times and shortages at others
- Analysis of economics of smaller biogas units for smaller piggeries as technologies develop and economics evolve. There has already been progress in improving the economics of biogas for smaller facilities.
- Co-digestion with locally available organic materials, including 'wastes' from other sources such as food waste, organic process wastes, etc to improve process efficiency, capture economies of scale and help other local businesses to manage their organic waste streams.

Brief description:

Development of web-based tools and creation of a regularly updated database of technologies, their applications and costs. Development and delivery of training programs for the industry and service providers.

Project outcome:

Acceleration of investment in biogas production from piggery and other local wastes to reduce energy and waste management costs.

Potential for other industries and smaller piggeries to utilise the tools and experience.

Benefits (energy savings, productivity, carbon, adoption)

Biogas production has the potential to dramatically reduce energy and organic waste-related greenhouse gas emissions from piggeries, create new revenue streams and reduce and stabilise operating costs. This could also enhance the reputation of the industry as an environmentally responsible leader.

Pilot P2: Facilitate interaction of piggeries with electricity grids, peer-to-peer trading and wheeling of power between sites

Project situation (problem/rationale/opportunity/potential):

Energy market rules and business models are evolving rapidly, as are distributed energy technologies. Businesses that can vary demand, generate electricity and help to stabilise local grid voltage and power quality, especially those in fragile parts of the grid, will have increasing opportunities to reduce costs and generate profit from these activities. They may also be able to access new sources of finance, such as the Clean Energy Finance Corporation (CEFC), Australian Renewable Energy Agency (ARENA), investors who previously invested in traditional energy technologies, state and national government agencies, etc.

The piggery industry is also well-positioned to use existing mechanisms to profit from creation of internationally tradable Australian Carbon Credit Units and Renewable Energy Certificates (now called Large Generation Certificates) – although LGC prices beyond 2020 may decline to low levels due to excess supply. Voluntary participation in the National Carbon Offset Standard could enhance reputations and provide certification and rights to use the NCOS logo in marketing.

Most piggeries have back-up generators in case grid supply fails. The capital tied up in this equipment is poorly utilised, so exploration of options to use on-site generation, energy storage and demand management could avoid or reduce investment in back-up generation, or support better utilisation of back-up generation to operate some equipment, freeing up more renewable energy generation capacity to export to the grid at times of high prices: diesel generators produce electricity at \$300-400/MWh but wholesale electricity prices can reach up to \$14,000/MWh for short periods.

Pilot proposed:

Conduct 'virtual' experiments with sites that have detailed metering and monitoring and biogas, Demand Management, utilisation of back-up generation, etc to explore how they could benefit from existing and proposed changes in market rules, and new retailing models, by optimising energy management, storage and generation. Publish them as case studies. Fund participants for support to implement strategies based on outcomes and publish outcomes.

Brief description:

As above. This work would require partnerships with experts in energy markets and energy modelling.

Project outcome:

Help firms that are in a position to benefit from emerging energy market rule changes and retailing business models.

Provide realistic case studies to show other firms how they could benefit – and reduce perception of risk associated with engaging with energy markets.

Benefits (energy savings, productivity, carbon, adoption)

See above.

Pilot P3: Improve comfort, health and productivity through improvement in heating, cooling and ventilation

Project situation (problem/rationale/opportunity/potential):

Heating, cooling and ventilation dominates piggery on-site energy use. It drives peak electricity demand, which is costly. At the same time, close control of environmental conditions is critically important in maximising product output, minimising mortality, and meeting changing animal welfare regulation and consumer attitudes to the industry. These factors can apply pressure towards increasing energy use and cost.

Piggeries operate in a wide range of climatic conditions, due to seasonality and location. Climate change is increasing the frequency and extent of extreme events, particularly high temperatures, humidity and rainfall events.

Existing piggeries can face transition challenges to adapt physical features to new equipment, changing climate and animal welfare trends.

Pilot proposed:

A number of potential issues and opportunities have been identified and listed below. A single pilot project may not be able to address them all, so DPI could select options that are seen by the industry and experts as most significant.

Brief description:

Maintaining animal comfort in cold conditions and soon after birth:

- Shifting from use of radiant heating lamps to heated pads with smart controls in crates and creeper areas typically seems to save 50% or more for this activity. Additional insulation under pads may further increase savings. Some pads have been heated using piped water or heated concrete slab floors: pipes can leak and leaks can be costly to identify and repair. So the direction seems to be favouring electrically heated pads. See below for discussion of potential for pads to heat and cool.
- Lids on crates or enclosed crates or kennels, or carefully designed insulation and radiant heat reflecting coatings can trap useful heat that would otherwise be lost: these approaches are widely used in Europe. However, work is needed to respond to Australian issues that include:
 - A preference for workers to be able to visually inspect animal condition as they walk past. Innovative crate design, low cost cameras, education on how European piggeries operate, or other solutions, may be relevant.
 - Appropriate management of ventilation for fresh air and odour management.
 - Minimising animal discomfort and heat stress in warm to hot weather.
- Excess heat from a bio-digester or from biogas-fuelled electricity generation could be used to pre-heat ventilation air and (within limits) warm air or water flowing

through the underfloor area used for manure management to reduce heating requirements.

- There may be potential to recover useful heat from exhaust air to pre-heat ventilation air. A NSW firm, AirChange, has pioneered such approaches in aquatic centres and NSW clubs.

Maintaining animal comfort in warm to hot conditions

Since pigs can't sweat (they pant), they can become heat stressed at temperatures from 28°C and above. Depending on size, pigs can release 70 watts (9kg) to a kilowatt of heat (90 kg), of which 15 to 30% is latent heat. So large numbers of pigs generate a lot of heat in addition to heat flows through building fabric and ventilation/air leakage. They may require cooling, even in moderate weather, or in poorly insulated sheds with high radiant heat transfer.

A variety of approaches is used for cooling across the industry. This reflects the age and size of sheds, climatic conditions, extent of shed insulation, etc. Approaches used and some potential responses include:

- Large fans with evaporative pads
- Natural ventilation
- Evaporative cooling of animals with misting around faces of pigs, drippers above pigs
- Spraying roofs to cool them – especially in humid climates (where evaporative cooling is less effective) or where they are uninsulated
- Sheds with light coloured surfaces and effective insulation minimise exposure to radiant heat and heat build-up in sheds
- Where excess heat is available, absorption chillers and desiccant cooling can provide cooling
- Experiments with cooling drinking water.

Use of fans (with evaporative pads) is the most energy-intensive approach, and is a major contributor to summer peak electricity demand, as discussed in the main report. But increasing intensity of operations and more extreme heat make fan use more likely.

A number of techniques could be used to reduce fan and cooling energy. Identification of 'best practice' examples and documentation of case studies would support wider adoption and upskilling of consultants and supply chains. Pilots that upgrade existing sites and collect 'before and after' data would provide useful experience.

- Fan energy:
 - Use of high efficiency motors with variable speed drives and smart controls managed by sensors throughout the shed, with high efficiency fan blade design.
 - Incorporation of aero upgrades to existing and new fans: the UK Carbon Trust estimates that addition of a 'nose bulb' to smooth air flow can improve efficiency by 10-15%, while optimally shaped air inlet and outlet design can add 10% efficiency.

- Reduction of flow resistance using larger, smoother, straighter ducts and low flow resistance evaporative pads or misting would reduce motor size and energy use.
- Use of exhaust air with a chiller to cool and dehumidify inlet ventilation air: when exhaust air is cooler than ambient air, refrigerative cooling using renewable electricity could potentially reduce the volume of fan-forced air required: high efficiency refrigerative units can be surprisingly efficient when operating over a small temperature difference. As noted earlier, AirChange have experience in this field.
- 'Mixed mode' shed design, so that natural ventilation can be maximised but efficient fan-forced operation is maintained as conditions become more extreme.

Combined heating and cooling solutions

- As noted above, energy recovery from exhaust air can potentially reduce heating and cooling energy requirements, especially during temperature extremes
- (Speculative) Thermo-electric devices use the Peltier Effect: when subjected to an electric current, one side is heated while the other is cooled. Traditionally, these devices have been relatively inefficient and of relatively small capacity, but they are quite cheap. Their efficiency deteriorates rapidly as the temperature difference across which they operate increases. Ongoing development and 'stacking' of modules in series is improving efficiency. Potentially, pads for animals could use these devices to provide heating or cooling at different times. Efficiency could be improved by varying the temperature of the underfloor area where manure is collected, by varying the temperature and flow of flushing water to minimise the temperature difference across the thermo-electric devices.

Project outcome:

Reduction in heating and cooling energy requirements, potential for optimisation of environmental conditions for animals

Benefits (energy savings, productivity, carbon, adoption)

See above

Pilot P4: Use of biogas to replace liquid fuels on-site and locally

Project situation (problem/rationale/opportunity/potential):

The pork industry is rapidly adopting biogas production, and has an extensive R&D program to improve outcomes. Diesel fuel is expensive (at \$1.20/litre it costs \$31/gigajoule and, if used for power generation, over \$275/MWh for fuel only, assuming 40% generation efficiency). Carbon emissions are high (2.9 kg/litre or 74 kg CO₂e/GJ) relative to renewable biogas. There is potential to replace liquid fuels with processed biogas or fuels derived from biogas.

Pilot proposed:

- Conduct a global review of progress in development and application of biogas and derived fuels for use in existing, modified or new engines used by vehicles and equipment to identify approaches suitable for pilots. Negotiate with relevant bodies to access equipment for this pilot
- Work with a piggery that has excess biogas (or could increase output) to trial use of their biogas in suitable vehicles.
- Assess potential for wider application

Brief description:

See above.

3.3.6 Sector: Horticulture

Background data: See section 2.2.1 Horticulture

Industry engagement:

Nicky Mann: Chair, Protected Cropping Australia

Alex Smith: Executive Director, Australian Blueberry Growers Australia

John Golding, Senior Research Scientist, NSW DPI

Meetings with producers of sugar plums and prunes, hazelnuts, almonds, walnuts.

Key energy Issues Identified:

- The cold chain is the biggest consumer of energy in the horticulture supply chain. Refrigeration is critical to productivity and profitability. However, poor temperature control results in reduced food quality and increased spoilage. In some cases inadequate temperature control results in food having to be sold at discounted prices or disposed of. Poor temperature control can be the result of and/or contribute to poor energy management.
- Other postharvest equipment such including on-farm transportation (trucks, forklifts), washers and sorters are also energy consumers.
- Solar PV and battery storage have good potential to reduce energy costs and create a reliable supply of energy generated on site, with a reliable supply of electricity being critical for cold storage.
- A reliable supply of heat is essential for greenhouses. There are examples in the Netherlands of pig farms with bio-digesters selling heat to greenhouses located close by.
- Differentiation between premium and regular markets. If consumers (both domestic and potentially export customers) can recognise the difference between standard and premium produce and are willing to pay a premium for a higher quality product, then higher capital investment, such as in high tech protected cropping, may be viable.
- Shifting to intensive, protected cropping in high tech greenhouses has the potential to result in higher yields, greater land, water, labour and nutrient efficiency, extended production season and lower risks (e.g. animals, disease) compared to outdoor production. However, the benefits of protected cropping have to be balanced against the higher capital investment required and higher energy intensity.
- Self-sufficient on-site generation and storage is of interest for new sites with high grid connection costs.
- Alternatives to artificial refrigeration are in prospect and offer potential to reduce costs and environmental impacts. These alternatives include “ventilation with ambient air, application of an ethylene blocking compound, modified atmosphere [pressure and/or composition]”.

- An A2EP report on cold chain optimisation¹⁰⁹ found the following indicative cost savings related to improving food condition monitoring in the Australian food cold chain:
 - A 5% reduction in food waste would result in a \$1 billion annual saving.
 - A 5% reduction in energy use of stationary elements of the cold chain would result in energy cost savings of approximately \$120 million per year.
 - A 10% reduction in energy use of trucking refrigeration would result in energy cost savings of approximately \$15 million per year.

¹⁰⁹ https://www.a2ep.org.au/files/Reports/A2EP_Cold_Chain_Report_OEH_v2.pdf

Pilot H1: Postharvest temperature optimisation – Cold store

Project situation (problem/rationale/opportunity/potential):

In 2016-17 the gross value (GVP) of horticulture production in NSW was \$1442m, about a tenth of the total value of agriculture and the third highest value primary industry in the State. The sector grew by 16% in the three years from 2013-14. Nearly a quarter of 2016-17 horticulture output was exported to international markets. The share and value of exports is increasing. It has been estimated that the average total cost of energy used in horticulture in Australia is 8% of GVP although there are significant variations depending on crop, season, location, agronomy. Research commissioned by AusVeg reports that “cold chain operations represent approximately 70% of the total energy used across the supply chain”. Recent research by a range of government and industry bodies suggests that there is considerable scope for energy productivity improvement, postharvest but on-farm. The implementation of timely, cost-effective measures offers opportunities to reduce operating costs, improve quality, longevity, and profitability and contribute to the greenhouse emissions reduction task. Given the paucity of data available it is difficult to estimate the potential benefits of action. But if the 8% is reasonable the cost of energy is in the order of \$115 million per annum. A cost saving of 5% equals about \$5 million and likewise a profitability improvement of 5% equals about \$5 million for a total benefit of \$10 million per annum.

The most significant type of energy consumption in the stationary components of the value chain is electricity for refrigeration, mostly grid-supplied. This project has a focus on electricity through measures ranging across equipment and building efficiency, metering and data for management, load/tariff/demand management, onsite generation and storage, handling and process improvement.

Pilot proposed:

A demonstration super-high productivity cold store with:

- product-specific temperature specification and in-store monitoring
- handling and process optimisation including output to transport
- leading edge design, materials and equipment
- on-site solar generation and battery storage
- metering, sub-metering, data collection for real time automated control
- tariff review and load/demand management, export to grid opportunities

Brief description:

Much of the real-world approach to investment in this area is ad hoc and incremental, the result of need from equipment failure or opportunity through a funding program. At its worst this approach can be deleterious to overall energy productivity. This pilot proposes a comprehensive demonstration of integrated measures.

It may also be worthwhile to examine the benefits, costs and the best way to incentivise optimal replacement of HFC refrigeration plant in horticultural operations with highest efficiency CO2 or other natural refrigerant plant.

Project outcome:

- Identification and rectification of temperature control issues in postharvest storage resulting in improved food quality, value and safety, longer shelf life, and less waste.
- Lower operating costs, improved profitability and potential to earn through sale to grid or from wheeling to neighbours
- Improved efficiency and reduced greenhouse gas emissions from refrigeration equipment used in the horticulture cold chain.
- This project could be replicated in other industries/sectors. There is good potential for example for testing it in the dairy industry for cheese and other products.

Benefits (energy savings, productivity, carbon, adoption)

Value gains associated with:

- **Increased value of product**, increased shelf life, reduced product loss/reduced discounting due to improved quality.
- **Indirect cost and logistics benefits** from avoiding transporting, processing and handling product that cannot be sold, and improved scheduling of maintenance.
- **Local area network benefits** including the potential to postpone or avoid the need for augmentation
- **Reputational benefits** from more consistent, good quality food with longer shelf life at home and improved environmental outcomes.
- **Reduced carbon emissions** from reduced energy use, reduced refrigerant leakage and also reduced emissions relating to food waste.

Energy savings associated with:

- **Reduced food waste:** There is a significant opportunity to reduce food waste through optimising conditions in the cold chain, and there are substantial energy losses and greenhouse gas emissions associated with food waste. Energy saving benefits of reducing food waste include avoiding cooling food which is ultimately wasted, and the energy involved in manufacturing the fertiliser and direct energy consumed in growing the food, transporting, processing, storage, and disposal.
- **Reduced operational energy costs and waste:** This includes cooling energy wasted from store doors left open, excessive transfer times, and delays in unloading.
- **Justify investments to control temperatures more precisely** using inverter-driven, high efficiency refrigeration equipment, variable speed fans and controls.
- **Justify improvements in energy performance of cold stores.** Examples of cold store energy performance improvements include: more effective thermal insulation on walls, ceilings and floors; better airflow; providing airlocks to personal and forklift access doors; loading docks with tight seals around truck doors; installing refrigerated loading docks as a break between ambient and chamber temperatures; high speed chamber doors; and, pallet conveyors to reduce use of forklift access doors.

Pilot H2: Cold chain optimisation – Temperature monitoring

Project situation (problem/rationale/opportunity/potential):

As for the proposed cold store pilot above. There are significant additional opportunities and potential from temperature monitoring down chain from the farmgate in transport and logistics operations including trucking and warehousing, as well as for wholesalers, retailers and export.

Pilot proposed:

1. Real time temperature and location tracking of produce from farm to market. This is an expertise area of A2EP. The proposed approach is of likely benefit to a diverse range of temperature sensitive perishable horticultural produce as well as to other agricultural sectors.
2. It would also be worthwhile to examine the benefits, costs and the best way to incentivise optimal replacement of HFC refrigeration plant in horticultural operations with highest efficiency CO2 or other natural refrigerant plant.

Note there is the potential to apply for supplementary funding from Food Innovation Australia Limited (FIAL).

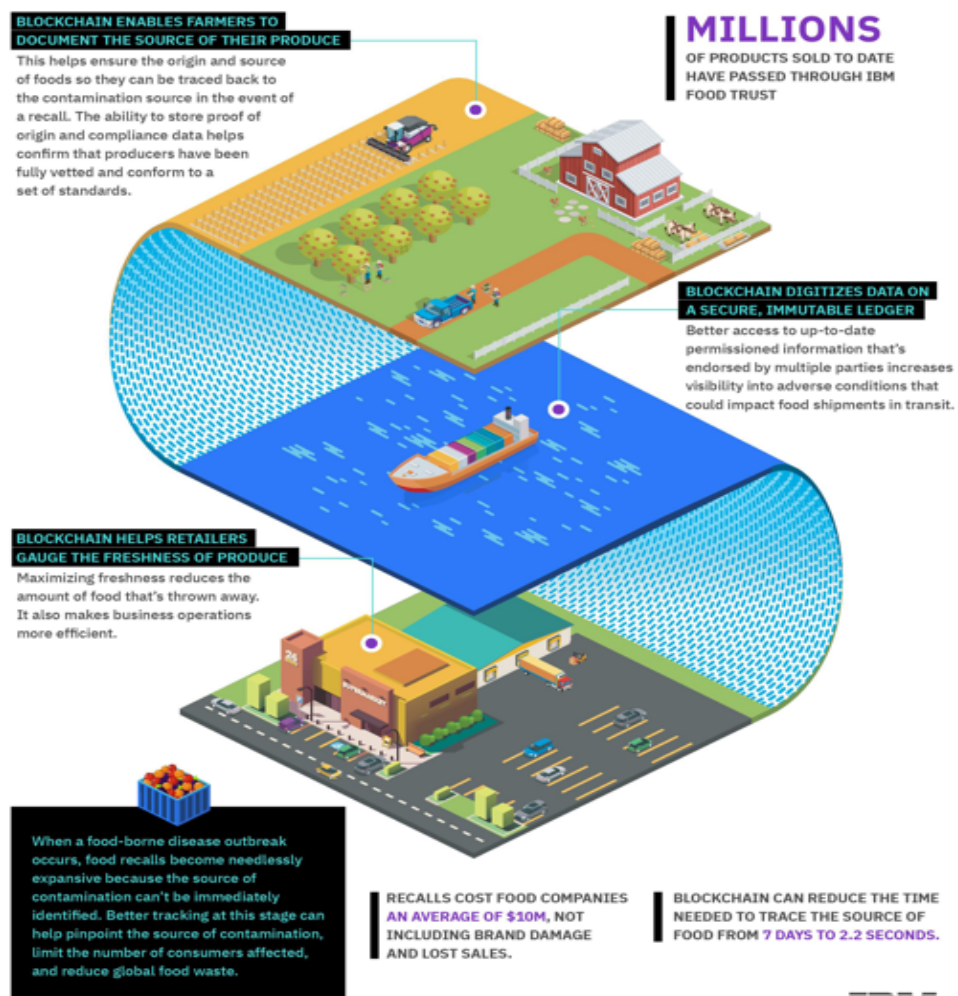
Brief description:

1. Cold chain real time temperature and location tracking
 - Temperature is the most significant factor affecting the shelf life of perishable foods. Storing produce consistently within the recommended temperature range, is critical for maintaining food quality and safety.
 - There is poor visibility of temperatures as produce move through the cold chain, which presents difficulties in ensuring food safety compliance and assigning responsibility between the large number of players along the chain for loss/degradation of product quality. This lack of transparency also inhibits effective targeting of improvements to equipment and practices.
 - The large number of participants involved in the cold chain creates split incentives, where the party that is best able to act may not capture the financial benefits, or face the cost impact of their actions. Improved tracking and a better understanding of the downstream implications of actions will provide greater opportunity to address cold chain problems.
 - Deployment of real time temperature monitoring would provide visibility of the temperature of produce as it moves through the cold chain. Real time tracking systems present a significant opportunity to improve food shelf life, quality and revenue, and reduce food waste, waste disposal costs and associated emissions. Even monitoring of limited samples of product over the cold chain can be very useful for identifying poor practices and equipment issues.
 - By way of example, the Australian Blueberry Growers Association is currently investigating technologies to track the location and temperature of blueberries as they move through the cold chain. Technologies include one developed by the CSIRO's Data 61 group and the Food Trust blockchain technology developed by IBM.

Walmart and Carrefour, amongst other global retailers, are in the process of rolling out the Food Trust system. The Food Trust platform system can be used to trace a broad range of food safety and provenance information, including temperature and location, as depicted in the Food Trust infographic below.

HOW BLOCKCHAIN COULD MEND OUR FRACTURED GLOBAL FOOD SUPPLY

Ever open up a pack of blueberries only to discover that mold has already set in? Better food safety and freshness is just one benefit that can come from applying blockchain technology to the global food industry. By creating a decentralized ledger that records transactions in a global network, IBM Food Trust can be used to help participants find new ways to reduce food fraud, costly batch recalls and provide greater governance over the food ecosystem that suffers from a lack of transparency.



For more information, please visit ibm.com/food.



Source: IBM¹¹⁰

2. Replacement of HFC refrigeration plant with highest efficiency CO2 or other natural refrigerant plant

¹¹⁰ https://newsroom.ibm.com/2018-10-08-IBM-Food-Trust-Expands-Blockchain-Network-to-Foster-a-Safer-More-Transparent-and-Efficient-Global-Food-System-1#assets_all

Refrigeration systems at farms tend to be small, less efficient packaged systems, using high global warming potential (sales now banned) refrigerants. Upgrading refrigeration equipment to more energy efficient models provides an opportunity to convert to low global warming impact refrigerants. There is a good opportunity to ensure the most efficient equipment is installed as HFCs are phased out, but government intervention through incentives will probably be required to ensure that businesses do not just change out the refrigerant (which generally reduces plant efficiency and/or performance). Evaporative pre-cooling of refrigeration equipment is emerging, including mist spraying and evaporative pads (e.g. Munter).

Project outcome:

- Identification and rectification of temperature control issues in the horticulture cold chain using tracking technologies, resulting in improved food quality, value and safety, longer shelf life, and less food waste.
- Improved efficiency and reduced global warming impact of refrigeration equipment used in the cold chain.
- This project could be replicated in other industries/sectors. There is good potential for example for testing it in the dairy industry for cheese and other products.

Benefits (energy savings, productivity, carbon, adoption)

Value gains associated with:

- **Increased value of product**, increased shelf life, reduced product loss/reduced discounting due to improved quality.
- **Indirect cost and logistics benefits** from avoiding transporting, processing and handling product that cannot be sold, and improved scheduling of maintenance activity.
- **Reputational benefits** from more consistent, good quality food with longer shelf life at home and improved environmental outcomes.
- **Reduced carbon emissions** from reduced energy use, reduced refrigerant leakage and also reduced emissions relating to food waste.

Energy savings associated with:

- **Reduced food waste:** There is a significant opportunity to reduce food waste through optimising conditions in the cold chain, and there are substantial energy losses and greenhouse gas emissions associated with food waste. Energy saving benefits of reducing food waste include avoiding cooling food which is ultimately wasted, and the energy involved in manufacturing the fertiliser and direct energy consumed in growing the food, transporting, processing, storage, and disposal.
- **Reduced operational energy costs and waste:** This includes cooling energy wasted from truck doors left open, excessive transfer times, and delays in unloading.

- **Justify action to rectify poorly operating equipment:** Identifying (and then correcting/replacing) poorly designed equipment and poor maintenance and work practices causing high temperature variability within spaces/trucks and heat gain due to poor insulation and seals, particularly in trucks.
- **Justify investments to control temperatures more precisely** using inverter-driven, high efficiency refrigeration equipment, variable speed fans and controls.
- **Justify improvements in energy performance of cold stores.** Examples of cold store energy performance improvements include: more effective thermal insulation on walls, ceilings and floors; better airflow; providing airlocks to personal and forklift access doors; loading docks with tight seals around truck doors; installing refrigerated loading docks as a break between ambient and chamber temperatures; high speed chamber doors; and, pallet conveyors to reduce use of forklift access doors.

Pilot H3: Postharvest processing – On-farm energy and processes

Project situation (problem/rationale/opportunity/potential):

Background regarding sector scope, economic impact and energy use as for the proposed cold store and cold chain pilots above. There are significant opportunities and potential for the application of highly energy productive technologies in a diverse range of on-farm applications, some generic such as overall improvements to the ways in which energy is consumed and produced, and others specific to processes such as drying. The horticulture sector is, potentially, well-placed to exploit and support energy networks, particularly at edge-of-grid. There are emerging but well-tested technologies available for a range of processes that can reduce energy consumption (particularly grid-supplied energy and related emissions), improve product quality and optimise operations.

Pilot proposed:

1. Application of high productivity integrated approaches to consumption and production of energy.
2. Application of alternative technologies for particular processes such as the substitution of heat pumps for boilers or microwave ovens for dryers. These systems could complement eg pre-heating or replace existing systems.

Note there is the potential to apply for supplementary funding from Food Innovation Australia Limited (FIAL).

Brief description:

1. Integrated energy systems for on-farm energy productivity including: highly efficient equipment for lighting, heating, water heating, refrigeration, pumping, on-site transport; electrification of equipment and processes as appropriate; on-site electricity generation, gas production and storage; load/ time-of-use/tariff management; application of metering and other real time data for analysis, control and automation.¹¹¹
2. Application of high-performance technologies for process heat such as cracking and drying. The replacement of low efficiency, fossil-fuelled process heating with high efficiency, temperature-optimised equipment that is renewable energy driven or powered externally through renewable energy offers a very substantial opportunity for direct improvement in energy productivity and reduction of carbon emissions.¹¹²¹¹³

Project outcome:

- Improved efficiency, lower costs, higher profits, reduced emissions
- Information, analysis, control of energy and processes

¹¹¹ Renewable Energy & Load Management – for Agribusiness, Institute for Sustainable Futures
https://arena.gov.au/assets/2018/10/REALM_FactSheet_agribusiness.pdf

¹¹² Innovation to Improve Energy Productivity in the Food Value Chain, Australian Alliance for Energy productivity
<https://www.a2ep.org.au/files/Reports/Innovation-to-Improve-Energy-Productivity-Food-Value-Chain-1.pdf>

¹¹³ High Temperature Heat Pumps for the Australian Food Industry: Opportunities Assessment
https://www.a2ep.org.au/files/Reports/FINAL_A2EP_HT_Heat_pump_report_v2_1_170911.pdf

- Identification and rectification of temperature control issues in process heating resulting in improved food quality, value and safety, less food waste.
- Control over and independence from grid supply
- Potential for income from sale of surplus energy
- This project could be replicated in other industries/sectors.

Benefits (energy savings, productivity, carbon, adoption)

Value gains associated with:

- **Increased value of product**, more consistent, reduced input loss, potential to extend range of products.
- **Indirect cost and logistics benefits** from avoiding transporting, processing and handling product and improved scheduling of maintenance activity.
- **Reputational benefits** from more consistent, high quality product and improved environmental outcomes.
- **Reduced carbon emissions** from reduced fossil fuel energy use, and also reduced emissions relating to food waste.
- **Improved working conditions** as a result of cooler processes and products

Energy savings associated with:

- **Reduced food waste:** There is a significant opportunity to reduce food waste through improving consistency of heat, and there are substantial energy losses and greenhouse gas emissions associated with food waste. Energy saving benefits of reducing food waste include avoiding spoilage of raw product which is ultimately wasted, and the energy involved in manufacturing the fertiliser and direct energy consumed in growing the food, transporting, processing, storage, and disposal.
- **Reduced operational energy costs and waste:** This includes energy wasted from heating and cooling (for product and personnel)
- **Justify action to rectify poorly operating equipment:** Identifying (and then correcting/replacing) poorly designed equipment and poor maintenance and work practices causing high temperature variability within ovens and heat loss due to poor insulation and seals.
- **Justify investments to control temperatures more precisely** using heat pumps, microwave ovens, variable speed fans and controls.
- **Justify improvements in energy performance of equipment.** Examples of energy performance improvements include: more effective thermal insulation on walls, ceilings and floors; better airflow; providing airlocks to personal and forklift access doors; high speed chamber doors; and, pallet conveyors to reduce use of forklift access doors.

Cross Sectoral Pilot Project Proposal

Pilot O1: On Farm Value Adding

Project situation (problem/rationale/opportunity/potential):

With the advent of low cost solar power and highly automated (and energy productive) modularised manufacturing plant, there is an increasing opportunity to increase value adding at farms and smaller rural communities. And maybe it is an opportunity to utilise the other competitive advantage of food freshness and ability to process same day – maybe even same hour of picking, and prove freshness through real time tracking of food temperature and location, right to the customer.

For the first time, farmers now can have a competitive advantage in energy costs, and the fundamental question for the sector is whether/where it makes sense to convert this advantage into an opportunity to farm/local community-based processing.

Pilot proposed:

- Find manufacturers which are already interested to trial on-farm processing. Of particular interest are highly digitalised technologies like high pressure processing.
- Match these with progressive farmers with access to on-site power generation (from solar, biogas, and potentially on-site energy storage).
- Demonstrate the economic benefits of on-site processing with local energy generation.

Brief description:

See above.

Project outcome:

A series of well selected pilots could be the basis for the development of opportunities for farmers to gain a much greater degree of resilience, through the opportunity to supply much higher priced process products direct to market and to by-pass complex supply chains and middle men, as well as avoiding having to sell through the supermarkets.

Benefits (energy savings, productivity, carbon, adoption)

- Take full advantage of land and free waste fuel access on farms to provide an energy cost competitive advantage benefit for the first time for rural properties.
- Increased value adding on farm.
- Ability to pick and process at a level of freshness not otherwise possible.
- Ability to shorten supply chain to the customer.
- Risks are potentially lower level of control of cleanliness and product quality, and reduced labour productivity. It will be important to select applications with high

levels of automation and self-correcting and self-cleaning using AI to ensure these experiments result in replicable value adding opportunities.

3.3.7 Supplementary pilot project concepts

Pilot D4: Improvement in energy assessment of dairies

Project situation (problem/rationale/opportunity/potential):

Identify and demonstrate improved energy assessment approaches and diagnostic techniques. Review of energy audits and fact sheets suggests that many potential energy productivity improvement opportunities have not been identified or sufficiently quantified to support widespread adoption. This pilot attempts to 'fill the gap' and encourage more comprehensive energy assessment across the sector.

Pilot proposed:

Work with leading energy assessors and diagnostics technology providers (including advanced smart data analytics experts) to develop, trial and demonstrate more comprehensive and evidence-based assessment and diagnostic techniques.

Brief description:

These could include demonstrations of:

- Use of thermal imaging equipment (including plug-in units for mobile phones) to identify weaknesses in insulation, overheating engines, bearings and other components, partial blockages, excessively cold evaporators or overheated condensers of refrigeration equipment, and extreme conditions for animals.
- Use of ultrasonic detectors to pick up air leaks in vacuum and compressed air systems, vibrations in motors and drives, etc.
- Non-invasive energy and heat flow measurement products and techniques.
- Add-on modules would be developed for real time monitoring of energy meters to send real time data to 'the cloud', as well as use of other data streams such as flows of milk, ambient and process temperatures, energy pricing, etc, length of time between milk production and transport, etc. These data streams could be fed into improved data analytics to provide practical feedback to operators for process optimisation, support benchmarking of performance, early identification of emerging faults, etc.

Compilation of a comprehensive list of options, and maybe even a web-based tool to identify and explore potential applications of options.

Project outcome:

Outcomes could include:

- Hands-on experience of the value that can be captured using suitable tools.
- Development of a module that reads existing meters for electricity, gas, water etc and makes that available for real time analysis.

- Improved advisory resources, Standards and guidelines for operators, equipment manufacturers, installers and maintenance contractors.
- Improved training of auditors (and possibly certification) and government field staff.
- Improved point of sale information for equipment.
- Provision through loan schemes for farmers, auditors and contractors of diagnostic equipment which may be too expensive for them to buy for intermittent use.

Benefits (energy savings, productivity, carbon, adoption)

Many significant opportunities for energy saving and innovation are difficult to identify without high quality real-time data, often synthesised with data from multiple data streams. Energy waste is often difficult to identify without appropriate equipment such as thermal imaging, ultrasonic detection and equipment-level monitoring of energy and material flows and other factors such as environmental conditions.

Quality information, presented in an appropriate form, can be a very powerful tool to motivate, reduce perceptions of risk, and support improved management and operator practices.

Pilot D5: On-site vehicle energy use (a speculative project idea based on limited knowledge of present tractor technology and tractor use on dairy farms)

Project situation (problem/rationale/opportunity/potential):

High level data suggest that on-site vehicle use on dairy farms is 30% of total energy use. Experts consulted questioned this data. Since diesel and petrol are more expensive than electricity and gas, if the data are correct, this is potentially a major cost issue for dairy farmers. Emerging technologies for stock and pasture management, and vehicle technologies mean there may be significant potential savings and productivity gains from innovation.

Pilot proposed:

After clarifying the actual extent of on-site vehicle fuel use for typical dairy farms, a decision would be made regarding pursuit of the rest of the pilot project. If it is significant, the pilot would identify techniques for stock and pasture management that require less vehicle use, explore actual power and torque requirements for tractors used on dairy farms, then engage with Australian firms that adapt other vehicles (e.g. light trucks) to plug-in hybrid or electric drive.

Brief description:

Recent trends that could reduce on-site vehicle use on dairy farms include 'virtual fences', use of satellite (e.g. GISS) data to optimise pasture growth and grazing, and some forms of robotized milking. The impacts of these options for dairy would be analysed using existing dairy farms that use the approaches, and/or adapting data from other types of farms that are using these techniques.

If tractors on dairy farms have relatively low power requirements but high initial torque requirements, and are often used to drive farm machinery via Power Take-Offs, significant productivity gains and fuel savings may be achieved by using hybrid technology and replacing PTO use with electrically driven towed machinery. Relatively small batteries may be useful to boost existing engines and allow some downsizing of tractor engine size.

Project outcome:

Reduction in vehicle use would improve productivity and save fuel by applying emerging practices pioneered in other types of farming. Application of hybrid and electric technologies would improve efficiency and partially shift from diesel or petrol use to electricity, which could be sourced from renewable sources.

Niche markets for conversion of vehicles and machinery would be created. Lessons could be learned from the proposed facility for the Latrobe Valley in Victoria that will convert light trucks and other vehicles to electric and hybrid drive.

Benefits (energy savings, productivity, carbon, adoption)

These approaches could improve labour and overall productivity, cut operating costs, reduce vulnerability to imported diesel prices, and create niche business opportunities.

Other energy productivity measures from literature, but not specifically referred to in the above include:

- Improve Power Factor.
- Reduce peak loads on SWER lines (as line losses are proportional to current flowing – and SWER line losses can be very high (e.g. up to 50%).
- Replace rewind (and oversized) motors: rewind motors are less efficient, and oversized motors operate less efficiently than optimally sized motors.
- Electrify processes that now use gaseous or liquid fuels – with high efficiency electro-technologies that are more controllable, so processes and energy use can be optimised.
- Improve building thermal performance, create wind breaks.
- Refocus on higher value markets and alternative supply chains.

Pilot P4: Alternative sourcing and processing of feed

Project situation (problem/rationale/opportunity/potential):

The production of feed is a major contributor to carbon emissions from pork production. Some piggeries operate feed mills, which add 20 to 30% to site energy use. They can also increase peak electricity demand.

Waste food, organic effluents from industrial processes and dead animals create significant waste management problems. They can be used for energy and fuel production using biogas, pyrolysis and other processes. However, they can also contribute to food supply for pork (and other agricultural) production.

Even though energy is a significant element of input costs, the pork industry is relatively low in on-site energy and energy-related emission intensity compared with other meat production and supply chains.

DPI focuses on pork production in piggeries: this project therefore focuses on piggeries. However, a value chain perspective would include food production and processing (much of which is at other sites), pork processing (for meat sales and processed products such as bacon and ham) and the path to the consumer. Carbon accounting typically only considers emissions from on-site activities (scope 1) and purchased electricity (Scope 2). However, the voluntary National Carbon Offset Standard includes consideration of 'significant' off-site emissions. Increasing numbers of companies are adopting the NCOS approach, as it provides a form of certification of good practice regarding carbon management.

The graph of a Life Cycle Analysis below reflects greenhouse gas emissions rather than energy use, but it provides a useful perspective. Meat processing emissions (Table 9 in the same report), dominated by electricity use (half of final energy, almost three-quarters of primary energy), were comparable with emissions from energy and services on farms. Note that primary energy is the 'raw energy' from fossil fuels and renewable energy sources, while final energy is measured at the meter or fuel bowser. For Australian electricity, primary energy inputs are almost three times the final electricity supplied, due to large losses in power generation and powerlines, while losses for the other energy sources are much smaller. Energy Productivity is measured as Value Added per unit of primary energy, and primary energy is also a better indicator of carbon emissions and energy costs than final energy.

Land-use change (excluded from the graph) is estimated at 0.04-0.7 kg CO₂e, averaged at 0.38 (including soy bean production in South America).

Most of the feed production presumably appears in other parts of the agriculture sector.

Emissions from manure dominate the overall picture. Since these result from on-site activity, they are included in piggery site emission inventories. Reducing these emissions adds to the other benefits of biogas digestion for the piggery sector: production of relatively cheap (and price-stable) energy for use on site and potentially for export, as well as management of wastes, odour and health issues. And the biogas plant still produces useful fertilizer replacements.

Overview of greenhouse gas emissions from pork production from **BENCHMARKING THE PERFORMANCE OF AUSTRALIAN PORK WITH LIFE CYCLE ASSESSMENT 4C-117**

Report prepared for the Co-operative Research Centre for High Integrity Australian Pork

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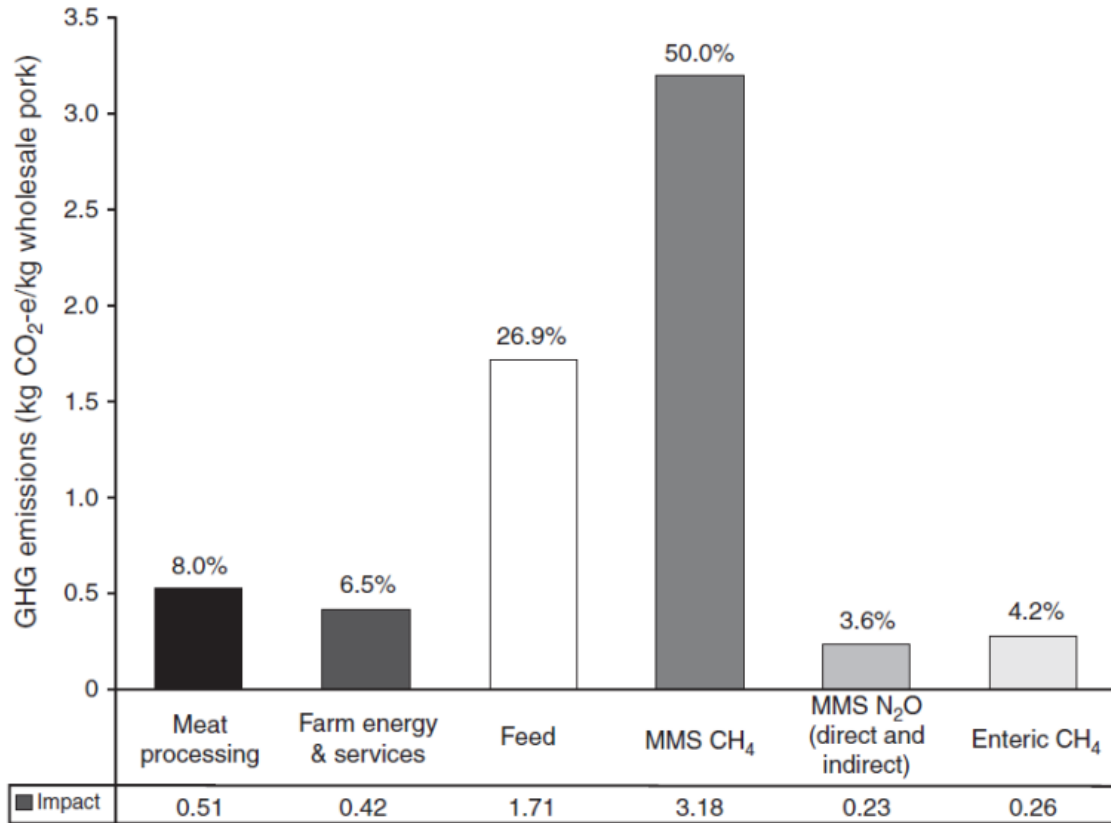


Fig. 6. Contribution to greenhouse-gas intensity (excluding land use (LU) and direct land-use change (dLUC)) per kilogram of wholesale pork.

Some piggeries have feed milling on-site, as shown in Table 6 from the same report. This can add 20-30% to site final energy use. Diesel and gas use, presumably for heat and some on-site vehicle use, comprise around 60% of final energy and 40% of primary energy, while electricity is 30% of final and 55% of primary energy. Truck fuel is a relatively minor factor.

Table 6. Feed-milling energy inputs per tonne of ration delivered to the pig farm

Input	Mean ± uncertainty
Electricity (kWh/t ^A)	32 ± 5.5
Diesel (L/t)	4.2 ± 2.3
Gas (MJ/t)	67 ± 49.7
Transport of commodities to feedmill (km)	85 ± 49.4

^AReported on an 'as fed' basis inclusive of moisture.

Pilot proposed:

- Improvements in feed mill electrical and heat efficiency and demand management have been proposed in the section on feedlots. A2EP has investigated opportunities in another project (See ARENA 'REALM' (renewable energy and load management for business) project report: <https://arena.gov.au/projects/realms-renewable-energy-load-management-businesses/>)
- The pork CRC has been funding research into use of organic wastes/effluent to grow algae that can be used for food and/or liquid fuel production.

Brief description:

See above.

Project outcome:

Reduce energy costs, increase utilisation of on-site renewable energy, increase potential for demand management to capture revenue from energy markets. Utilise organic 'waste' to reduce business input costs. Enhance reputation on climate action.

Benefits (energy savings, productivity, carbon, adoption)

See above.



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