final report

Project code: V.SCS.0001

Prepared by: I. O'Hara[1], K. Robins[2], G. Forde[1,3], B. Henry[1,4], P. Jenson[5], R. Speight[1,6], D. McNicholl[7]

[1]Institute for Future Environments, Queensland University of Technology
[2]Sustain Biotech Pty Ltd
[3]All Energy Pty Ltd
[4]Agri-escondo Pty Ltd
[5]Advanced Water Management Centre, University of Queensland
[6]Science and Engineering Faculty, Queensland University of Technology
[7]Meat and Livestock Australia

Date published: 10 June 2016

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 1961
NORTH SYDNEY NSW 2059

Research, Development and Adoption Strategy for Environmental Innovation within the Australian Red Meat Supply Chain

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

The purpose of this project was to develop a research, development and adoption (RD&A) strategy for environmental innovation within the Australian red meat supply chain. The strategy is aligned with the MISP 2020, which focuses on increasing profitability of the red meat industry in a sustainable manner, and sets the direction for MLA's Supply Chain Sustainability (SCS) Programme over the period 2016 to 2020.

Three programmes of RD&A activity are presented within the strategy, each providing an economic value proposition for improved management of energy, water, greenhouse gas emissions and waste streams. The three RD&A programmes are a) increasing productive efficiency and environmental performance using enhanced supply chain information systems; b) using biological processing systems to convert wastes from feedlots and red meat processing into animal feed; and c) driving adoption of technologies to improve water and energy management in the Australian red meat supply chain.

An investment of $13.3 million in the next 5 years in these programmes has the potential to make a significant contribution to decrease energy usage by 25%, water consumption by 22 – 36%, solid wastes from feedlots and processing plants by 50% and greenhouse gases by 7% in the feedlot sector. In addition, new market opportunities for the red meat industry in excess of $167 million per year for the industry are achievable, excluding the costs and contributions under Programme 3. This corresponds to a cost:benefit ratio for Programme 1 and 2 of 1:12.6.

Executive Summary

This document presents the 'Research, Development and Adoption (RD&A) Strategy for Environmental Innovation within the Australian Red Meat Supply Chain.' The strategy contains three RD&A programmes of activity over the period 2016 – 2020, which align to each Pillar contained in the Meat Industry Strategic Plan (MISP) 2020.

The aim of the strategy is to add value to waste generated by the red meat industry and to reduce energy and water consumption, greenhouse gas emissions and the volumes of liquid and solid wastes by 25%.

Each RD&A programme provides an economic value proposition to attract public, industry (levies) and private sector funding via MLA. Suitable metrics for outputs, outcomes and impacts that can be used to assess the success of the strategy are also identified.

RD&A strategy structure

VISION Economic value proposition for improved management of energy, water, greenhouse gas emissions and wastes within the Australian meat and livestock supply chain
Information platforms ● Feed products ● Water and energy efficiency
Environmentally sustainable, grow demand for red meat
GOALS
Value-add to wastes, reduce energy and water consumption, reduce greenhouse gas emissions
PROGRAMMES
1. Enhanced supply chain information systems 2. Wastes to enhanced feed protein 3. Improve adoption of energy and water management
IMPLEMENTATION & EVALUATION

Programme 1: *Increasing productive efficiency and environmental performance using enhanced supply chain information systems.* This programme presents two strategic opportunities to increase productivity, improve meat quality and environmental performance in an information-enabled supply chain.

The first project promotes practices that maximise weight-for-age and investigates improved environmental performance, particularly the reduction of greenhouse gas emissions, driven by eating quality objectives. It also presents an opportunity for producers to earn additional income by qualifying for carbon credits while increasing the number of carcasses that meet compliance and consumer expectations.

The second project proposes replacing days on grain with objective methods for judging carcase quality. The reduction in number of days spent on feedlots would decrease feed requirements, reduce greenhouse gas emission, reduce energy requirements and also decrease water consumptions on feedlots dramatically.

The additional advantages of an information-based supply chain have not been quantified but could be truly transformational. The initial platform would be developed to provide the necessary feedback along the supply chain from consumer, processors and producers on carcase quality, market prices and changing market specifications. This system would position the meat and livestock industry for future expansion of the IT platform into an Ag-relevant information platform, which integrates digital technology, real-time data acquisition, advanced analytics and assists farmers with planning and risk management.

Programme 2: *Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein.* This programme aims to develop processes that use waste from feedlots and red meat processing plants to produce animal feed in the form of high value protein feed supplements. These waste streams need pretreatment before they can be used for protein production. The programme proposes using advanced anaerobic digestion, which produces more biogas for power or heat generation and mobilises the nutrients necessary for protein production, as part of the pretreatment strategy. There are not many barriers to adoption as anaerobic digestion is highly scalable and suited to abattoirs (> 500 head/day) and feedlots (> 1000 head).

The second project is transformational and proposes producing high value feed protein from the products of anaerobic digestion. The valuable protein feed supplement produced represents a significant opportunity for reducing solid and liquid waste volumes, reducing feed costs on feedlots, reducing greenhouse gas emissions and is a source of additional income for processors. With appropriate choice of production strain, single cell protein can be produced with enhanced nutritional characteristics, which would contribute even more to increasing productivity and decreasing greenhouse gas emissions.

Programme 3: *Driving adoption of technologies to improve water and energy management in the Australian red meat supply chain.* This programme aims to enhance the adoption of innovative technologies to improve energy and water management across the industry. The programme proposes:

- Projects investigating new funding opportunities and new business models;
- Projects assessing feasibility and demonstrating the suitability of equipment and machinery that use renewable fuels and power sources; and
- New technologies increasing energy efficiency and decreasing water usage.

The total cost of fossil fuels used in the red meat industry is over $1.3 billion per annum and the technology to replace a large percentage of this fuel with sustainable alternatives like new, cleaner, lower cost liquid fuels, “green steam” generated by biogas, biomass or concentrated solar to displace grid and off-grid electricity and solar for stationary energy are now available. Successful implementation of even a small percentage of these projects would represent a large market opportunity for the red meat industry, contribute to a significant reduction in greenhouse gas emissions and promote red meat consumption through demonstrated environmental stewardship. Other projects to improve energy efficiency like waste-to-energy, power efficiency and process thermal efficiency opportunities could reduce costs in the industry by over $200 million per year.

Farms and feedlots use more than 90% of the total water used in the industry with red meat processing only use ~2% of the total water used in the industry per year. Measures to redesign livestock water supply systems and reduce water evaporation would lead to a 25 – 40% reduction in water consumption. Larger reductions are possible if suitable recycled water from feedlots are used for irrigation, cattle wash-down or dust suppression. Adoption of these measures are difficult as there is an uncertain value of water in this sector. There is also a potential to reduce water consumption by 50 – 70% in red meat processing sector with the implementation of advanced water recycling technology. This translates to a reduction of only ~1% of the total water consumption in the industry, but a cost saving of $18 – 25 million per year in processing.

An investment of $13.3 million in the next 5 years in these programmes has the potential to make a significant contribution to improving the environmental sustainability across the red meat industry supply chain by providing technologies with the ability to decrease energy usage by 25%, water consumption by 22 – 36%, solid wastes from feedlots and processing plants by 50% and greenhouse gases by 7% in the feedlot sector while generating new market opportunities for the red meat industry in excess of $167 million per year for the industry not accounting for Programme 3 R&D costs or contributions. This corresponds to a cost: benefit ratio for Programme 1 and 2 of 1:12.6. The programmes costs and benefits are summarised in the following table:

RD&A programmes for the Meat & Livestock Association from 2016 - 2020

<table>
<tr><td colspan="6">Enhanced supply chain information systems
Increase productive efficiency improve meat quality and environmental performance</td></tr>
<tr><td colspan="3">Promote practices to maximise weight for age

■ R&D cost: $280,000 over 1.25 years
■ Economic benefit: $1.6 million p.a. (2020)
■ Cost:benefit 1: 5.6
■ GHG reduction: 57,000 tonnes CO_2-e p.a.
■ Information-based supply chain providing feedback on carcase quality, market price, changing specifications</td><td colspan="3">Replace days on grain with objective method for judging carcase quality

■ R&D cost: ~$3 million over 4 years for domestic feedlot cattle or $4 million over 4 years including export cattle
■ Economic benefit: $29.4 million p.a. based on 5-day reduction on feed for grain-fed domestic cattle by 2020 or $50.4 million by 2023 including export cattle
■ Cost:benefit 1: 9.8 or 1:12.6 including export cattle
■ GHG reduction: 7% reduction for feedlot sector</td></tr>
<tr><td colspan="6">Waste to enhanced feed protein
Pre-treat waste from feedlots and red meat processing plants with advanced anaerobic digestion and use the products to produce high value protein animal feed</td></tr>
<tr><td colspan="3">Advanced anaerobic digestion

■ R&D cost: $1-2 million over 3 years
■ Economic benefit: $40 million p.a. (2020)
■ Cost:benefit 1: 20
■ Biogas produced can cover 20-100% of energy costs
■ Pretreatment for single cell protein production</td><td colspan="3">Enhanced high value protein animal feed production

■ R&D cost: $5 -10 million over 5 years
■ Economic benefit: $70 - 80 million p.a. (2025)
■ Cost:benefit 1: 8
■ Potential to decrease solid waste by 50%</td></tr>
<tr><td colspan="6">Improve adoption of energy & water management
Adaption & development of new technologies for increasing energy efficiency, reducing water usage and replacing fossil fuels with renewable fuels</td></tr>
<tr><td colspan="2">Support adoption of energy and water use reduction projects (multiple projects)

■ R&D cost: ~$1-3 million over 5 years
■ Economic benefit: $40 million p.a.
■ Cost:benefit 1: 10
■ Examples of benefits:
- Redesign livestock drinking supplies & storage - 22 – 36% reduction in water consumption in industry
- Implement advanced water recycling in processing sector - 1.0-1.4% reduction in water consumption across industry; $18-25 million p.a. savings in water costs</td><td colspan="2">Promote adoption through feasibility studies, case studies and demonstration projects (multiple projects)

■ R&D cost: ~$2-4 million over 5 years
■ Economic benefit: Dependent on projects funded
■ Cost:benefit - variable depending on projects funded</td><td colspan="2">Investigate new business models for adoption

■ R&D cost: $0.4 million for a 1 year project
■ Economic benefit: This project is an enabling study supporting the othe two projects in this programme
■ Identification of business models to drive improved adoption and programme co-funding</td></tr>
</table>

Table of Contents

1 RD&A strategy for environmental innovation within the Australian red meat supply chain

1.1 Introduction

The red meat industry is Australia's largest rural industry and recognises its duty of care to the environment in order for future generations to prosper. Under the auspices of the Meat Industry Strategic Plan (MISP) 2020, MLA invests in technology, practice change and educational programmes to reduce the environmental impact of red meat production, improve economic performance, and maintain the industry's social license to operate.

In addition to managing on-farm specific research, development and adoption (RD&A) activities, via the On-Farm Innovation and Adoption Business Unit, MLAs Value Chain Innovation Business Unit manages a Supply Chain Sustainability (SCS) research programme which spans beyond the farm gate. The SCS programme provides information, tools and technologies to fill existing and emerging technology, knowledge and capability gaps in the following areas along the red meat supply chain:

- Water use efficiency, reuse, and recycling;
- Energy use efficiency and renewable energy technologies;
- Mitigating greenhouse gas emissions; and
- Improved management of waste materials from reduction of the amount of waste generated, treatment, reuse or recycling.

Achieving positive outcomes in these areas delivers a win-win for the environment, through improved natural resource utilisation and reduced greenhouse gas emissions, and the economy through reduced operating costs for management of energy, water and wastes.

The purpose of this project was to develop a research, development and adoption (RD&A) strategy for environmental innovation within the Australian red meat supply chain. The strategy is aligned with the MISP 2020, which focuses on increasing profitability of the red meat industry in a sustainable manner and sets the direction for MLAs SCS Programme over the period 2016 to 2020.

The strategy encompasses the grass-fed production, grain-fed production, processing, and retail sectors. Realisation of environmental innovation opportunities along the red meat supply chain requires an economic value proposition for industry participants, which is a central component of this strategy.

Implementing this strategy will expand existing, and develop new opportunities that provide value propositions for the Australian red meat industry by increasing profitability, sustainability and global competitiveness along the supply chain.

1.2 Objectives and outcomes

The objective of the project was to develop an RD&A strategy to provide direction to MLAs Supply Chain Sustainability programme for the development of environmentally sustainable red meat supply chains over the period 2016-2020. The strategy is aligned with the MISP

2020 which focuses on increasing profitability of the red meat and livestock industry in a sustainable manner while protecting the environment.

The outcomes of the project are:

- Identification of high potential opportunities across research horizons and technology readiness levels; and

- Submission of an RD&A strategy for environmentally sustainable value chains for the Australian red meat industry.

These outcomes will enhance the red meat industry's ability to implement new product, technology and business models for environmental innovation in industry supply chains.

1.3 Development of the strategy

The strategy was developed through a three phase process as follows.

Phase 1 involved the compilation of baseline information on the current environmental performance of the red meat and livestock industry in four focus areas - wastes, water, energy and greenhouse gas emissions. This information was collated and compiled into a report for reference by project participants (Topical Background; Appendix A);

Phase 2 of the project involved generation, compilation and ranking of a broad range of new product, service and business model opportunities originating from a series of stakeholder workshops. This process resulted in 22 high potential opportunities which were down selected to three RD&A programmes. These programmes were developed to provide the Australian red meat industry with the tools and information to improve management of energy, water, greenhouse gas emissions and wastes, while growing demand for Australian red meat. Each programme was developed with a focus on the economic value propositions for the Australian red meat industry. The programmes were identified and calculated by:

- Analysing and collecting baseline information on resource use and a range of industry parameters;
- Talking to key industry experts;
- Identifying a wide range of potential new technologies and business models;
- Ranking using multi-criteria analysis;
- Quantifying the value propositions through identifying the business and market opportunities for the red meat industry, evaluation of process and technology, business models and supply chain aspects, and adoption enablers; and
- Testing assumptions and value propositions with key industry stakeholders.

Phase 3 involved the formulation of an RD&A Strategy for Environmental Innovation within the Australian Red Meat Supply Chain.

A detailed description of the project methodology is included in Appendix B.

2 Strategy overview

Applying new energy, water and sensing technologies, developing information platforms and using biotechnology to reduce energy, water, wastes and greenhouse gas emissions while increasing profitability and environmental sustainability is the basis of this strategy.

Three RD&A programmes are presented in the strategy, including:

1. Increasing productive efficiency and environmental performance using enhanced supply chain information systems;
2. Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein; and
3. Driving adoption of technologies to improve water and energy management in the Australian red meat supply chain.

The scope of these programmes is represented in Fig. 1.

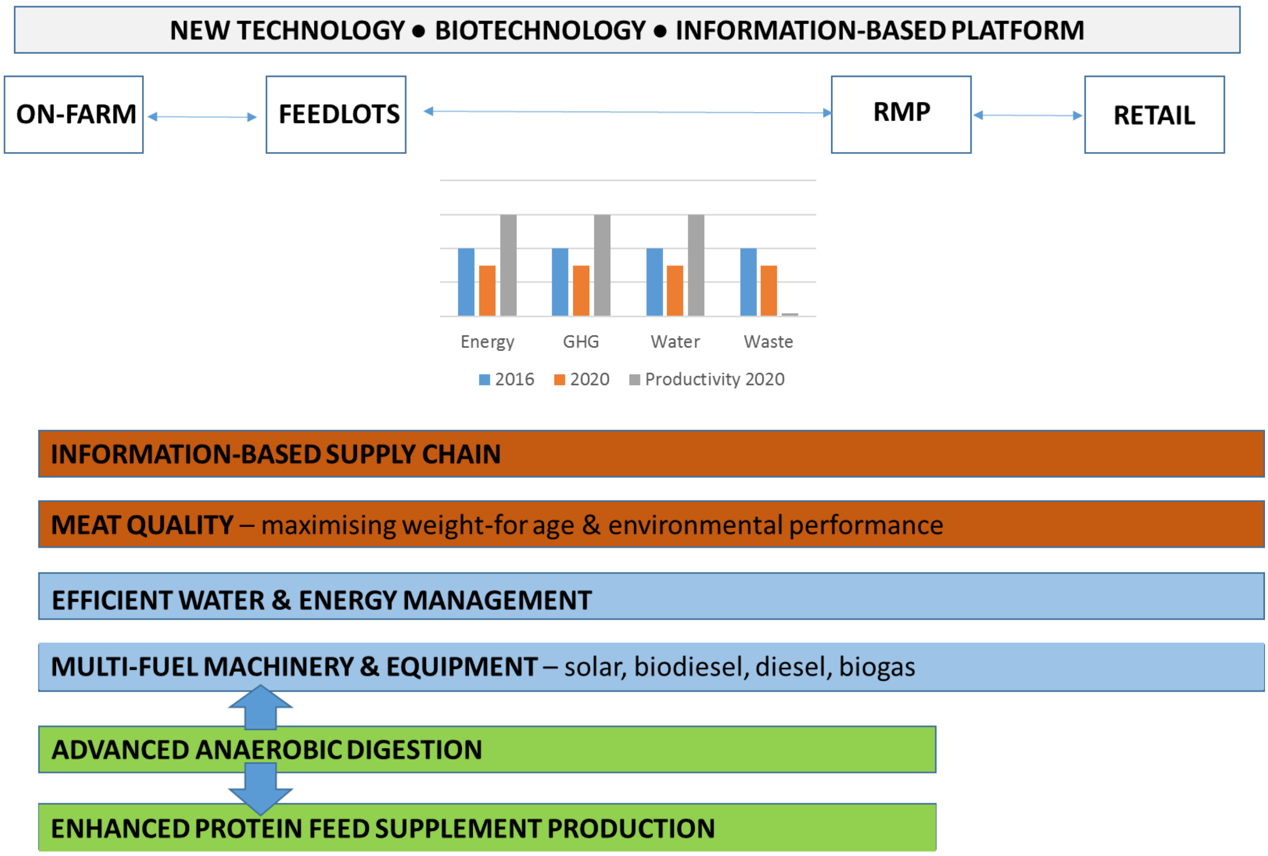


Fig. 1 Conceptual representation of the three RD&A programmes within the Strategy

<u>Programme 1:</u> *Increasing productive efficiency and environmental performance using enhanced supply chain information systems*

Programme 1 presents two R&D projects to increase productivity, improve meat quality and environmental performance through information-enabled supply chains. The first project investigates practices that maximise weight-for-age in beef feedlotting and improved environmental performance, particularly the reduction of greenhouse gas emissions, driven by eating quality objectives for beef production. The project is short term spanning 1.25 years and would cost ~$300,000 with a potential cost:benefit ratio of 1:5.6 (Table 1). It also presents an opportunity for producers to earn additional income through carbon credits while increasing the number of carcasses that meet compliance and consumer expectations (Table 2).

The second R&D project involves the development of objective methods for assessing the market readiness and predictive beef carcasse attributes of lot-fed cattle. This technology will replace the current days-on-grain criterion at feedlots which will enable feedlotters to send cattle to slaughter when the animal is ready, rather than rely upon the days-on-grain criterion in order to meet market specifications. Objective measure of the market readiness of an animal will result in decrease overall feed requirements (by avoiding over-feeding), reduce greenhouse gas emissions, reduce energy requirements and decrease water consumption in feedlots (Table 2). This 4 year project would cost ~$3 million. The market opportunity for this innovation in grain-fed domestic cattle (based on the calculation of 5 days less on grain) is around $29.4 million dollars with a cost:benefit ratio of 1:9.8 (Table 1). If the project is expanded to include export cattle then the project costs would increase by 33% but would generate an additional $21 million, which would be realised 3 years later due to the slower time for adoption by the export market. The cost:benefit ratio would increase to 1:12.6 with the inclusion of grain-fed export cattle.

The additional advantages of an information-based supply chain have not been quantified but could be truly transformational. Initially an information platform would be developed to provide the necessary feedback along the supply chain from consumers, processors and producers on carcasse quality, market prices and changing market specifications. This system would position the meat and livestock industry for future expansion of the information platform integrating digital technology, real-time data acquisition, and advanced analytics assisting farmers with planning and risk management. Individual components are already used in the industry, however there is limited connectivity along the supplychain that allows data interaction and analysis. Enhanced information systems will be a key driver in the success of the industry in the future. It is vital that a coordinated approach is taken to ensure the necessary protocols, industry standards, data storage and security are incorporated allowing the seamless expansion of the platform. Critical to its success is improved connectivity for data transfer and integration. Very significant gains in efficiency across the supply chain are possible from this programme.

<u>Programme 2:</u> *Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein*

Programme 2 is comprised of two R&D projects. The first project involves the development of advanced anaerobic digestion technologies for converting abattoir and feedlot waste into biogas for power or heat generation and nutrients for protein production (Table 2). This project would cost $1 – 2 million over 3 years and a potential additional market opportunity of $40 million compared to current covered anaerobic lagoon technology (Table 1). There are few barriers to adoption as anaerobic digestion is highly scaleable and suited to abattoirs (> 500 head/day) and feedlots (> 1000 head).

The second project is transformational and proposes producing high value feed protein from the products of the advanced anaerobic digestion technology. The project would cost $5 –

10 million over 5 years with a market opportunity of $70 – 80 million and an estimated cost:benefit ratio of 1:8 (Table 1). The valuable protein feed supplement produced represents a significant opportunity for reducing solid and liquid waste volumes, reducing feed costs in feedlots, reducing greenhouse gas emissions and is a source of additional income for processors (Table 2). With appropriate choice of production strains, single cell protein can be produced with enhanced nutritional characteristics, which would contribute even more to increasing productivity and decreasing ruminant greenhouse gas emissions.

Programme 3: *Driving adoption of technologies to improve water and energy management in the Australian red meat supply chain*

Programme 3 aims to drive adoption of innovative technologies to improve energy and water management. The programme proposes several projects:

- Investigation of new business models and funding sources to support enhanced adoption of innovative technologies through the red meat industry;
- Projects supporting feasibility, project development, and concept design of innovative water and energy use projects; and
- Projects supporting wider adoption through case studies, knowledge sharing, technology adaptation and demonstration projects for renewable energy, energy efficiency and water use reduction technologies.

There are a wide range of renewable energy, energy efficiency and water reduction technologies with the potential to contribute to cost reduction in the red meat industry. Often the adoption of these technologies is limited by lack of exposure within the industry to the technology and the risks associated with early stage adoption of technology with unproven benefits. This programme seeks to enhance adoption through providing business models, co-funding approaches to reduce the risks associated with early stage adoption and share the knowledge generated through case studies and demonstration projects. The economic benefits for individual projects is likely to vary (5 – 30% internal rate of return) and cost:benefit ratios of 1:4.6 – 29.7. The total cost of fossil fuel to the red meat industry is over $1.3 billion per annum and the technology to replace a large percentage of fossil fuel with sustainable alternatives such as renewable liquid fuels, biogas, biomass or concentrated solar technologies to displace grid and off-grid electricity and solar for stationary energy are now available. Successful implementation of even a small percentage of these projects would represent a large economic benefit for the red meat industry and contribute to a significant reduction in greenhouse gas emissions and demonstrate improved environmental stewardship (Table 2). Other projects to improve energy efficiency such as waste-to-energy, power efficiency and process thermal efficiency opportunities could save the industry over $200 million per year. Applying advanced water recycling technologies to waste water from abattoirs could save the industry $18 – 25 million per year while the redesign of water suppy and storage on farm and feedlots to reduce evaporation represents a possible 25 – 40% reduction in water consumption (Table 2).

Table 1 Estimated costs, timelines and market opportunity for the programmmes

	Budget ($ million)	Timeframe (years)	Economic benefit to 2020 ($ million p.a.)	Cost: benefit ratio
Programme 1: Increasing productive efficiency and environmental performance using enhanced supply chain information systems				
■ Improved environmental performance driven by adoption of practices for eating quality objectives	■ 0.28	■ 1.25	■ 1.57	■ 1:5.6
■ Objective assessment of days on grain: - for grain-fed domestic cattle - with export cattle included	 ■ 3 ■ 4	 ■ 4 ■ 4	 ■ 29.4 ■ 50.4[a]	 ■ 1:9.8 ■ 1:12.6
Programme 2: Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein				
■ Advanced anaerobic digestion	■ 1 - 2	■ 3	■ 20 - 40[b] (2020)	■ 1:20
■ Single cell proteins as high value animal feed	■ 5 - 10	■ 5	■ 70 – 80 (2025)	■ 1:8
Programme 3: Driving adoption of technologies to improve water and energy management in the Australian red meat supply chain				
■ Support adoption of energy and water use reduction projects (multiple projects)	■ 1 - 3	■ 3 - 5	■ 10 - 30[b]	■ 1:10
■ Promote adoption through feasibility studies, case studies and demonstration projects (multiple sub-projects)	■ 2 - 4	■ 3 - 5	Project dependent	■ Variable
■ Investigate new business models for adoption	■ 0.4	■ 1	■ [d]	■ N/A

Note: [a]although the realisation of market opportunity would take 3 years longer due to slower uptake by the export market; [b]increase in market opportunity from current $24 million with current conventional, covered anaerobic lagoon technology to $64 million with advanced anaerobic digestion technology using solid waste from red meat processors and feedlotters; [c]calculated on projects with an internal rate of return averageing 10%; [d]enabling study to support the activities of the othe two projects in this programme.

Table 2 Programme benefits for the meat and livestock industry by sector

Programme 1: Increasing productive efficiency and environmental performance using enhanced supply chain information systems

Industry	On-farm & Feedlot	Processing	Consumer
■ Engaging more customers due to demonstrated environmental stewardship from the industry ■ Access to consumer feedback allowing adaptation of meat quality to meet consumer expectations	■ Higher number of carcases meeting MSA compliance & consumer expectations ■ Optimised purchasing/selling of livestock and feed ■ 10 – 15% increase in productivity (on farm) ■ Lower production costs ■ Optimised selling times ■ Lower GHG emissions ■ 25 million tonnes CO_2 equivalent less emissions ■ Lower water & energy usage ■ Additional income from carbon credits	■ Higher number of carcasses meeting MSA compliance & consumer eating quality ■ Lower cost of production ■ Improved consistency of supply	■ Improved eating quality and rapid response to changing customer preferences

Programme 2: Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein

Industry	On-farm	Feeedlot	Processing	Consumer
■ Demonstrated environmental stewardship from the industry ■ Improved long term sustainability		■ Considerable value add to waste ■ Reduced feed costs ■ Increased productivity due to enhanced nutritional characteristics of advanced single cell protein ■ Reduced transport costs if produced and used locally	■ Reduced waste volumes ■ Reduced cost of disposal ■ Biogas for energy ■ Reduced energy costs ■ Usable recycled water ■ Reduced GHG emissions ■ Considerable value-add to waste ■ Additional income stream	■ Reduced environmental impact of red meat products consumed

Programme 3: Driving adoption of technologies to improve water and energy management in the Australian red meat supply chain

Industry	On-farm	Feedlot	Processing	Consumer
■ Practical renewable energy and water saving examples enhances “cleaner and greener”image of the industry	■ Reduce fossil fuel requirements and increase energy security by replacing with renewable energy sources ■ Reduce evaporation ■ Reduce GHG emissions ■ Reduce operational costs	■ Waste to energy: better waste management and reduces energy costs ■ PV solar for lower energy costs and improved animal welfare ■ Reduce water usage by recycling water ■ Reduce evaporation ■ Reduce GHG emissions ■ Reduce operational costs	■ Reduce fossil fuel use by replacing with bioenergy, solar energy and efficiency gains ■ Reduce water usage by recycling water ■ Reduce GHG emissions ■ Energy efficiency to reduce operational costs	■ Reduced environmental impact of red meat products consumed

Note: GHG = greenhouse gas; MSA = Meat Standards Australia

3 Programme 1: Increasing productive efficiency and environmental performance using enhanced supply chain information systems

This programme identifies two opportunities with the potential to deliver value for the red meat industry through higher productivity, meat quality and environmental performance in information-enabled supply chains. The projects are also intended to help position the industry to be able to assess and strategically plan future directions in supply chain digital information flows. Environmental benefits will include more efficient use of land, pasture, water and energy resources, but the focus in this programme is on mitigating greenhouse gas emissions associated with red meat. Mitigation benefit is calculated as a reduction in greenhouse gas intensity, i.e. emissions per kg red meat (kg CO_2-e/kg meat) which provides a practical measure of improvement in a way that does not limit growth in production.

The programme relies on expanded adoption and applications of existing and emerging technologies and data analytics with enabling systems platforms for real-time data flows. The magnitude of economic gains from productivity, efficiency and meat quality improvements depend on externalities such as export markets and implementation variables, e.g. National Broadband Network rollout and training programs, but are expected to be significant. For example, productivity growth on-farm alone may be in the order of 10-15% from adoption of digital information systems based on experience in other agricultural industries (Keogh, 2014). Increases in efficiency as a result of supply chain integration should provide financial returns on top of the estimated $59.4 million estimated to be possible with increased beef and sheep meat compliancy as a result of feedback of slaughter information from processors to producers (MLAa, 2016). Additionally, there is potential for new income streams from carbon credits with prices of $10-14 per Australian Carbon Credit Units (ACCUs = 1 tonne carbon dioxide equivalent) over 2015 and 2016.

In total the proposed programme is estimated to span 4 years, and for an investment of $3.28 million, to generate anticipated returns in the order of $31 million indicating an achievable cost:benefit ratio of 1:9.4. More details of the assumptions are set out in the supplementary information provided in Appendix C but key points are for a growth in meat quality compliance in association with reduced greenhouse gas intensity driven by practices that target higher weight for maturity, and that moving to objective assessment would mean that half of all grain fed cattle could meet market specs in five days less than currently allowed under requirements for set days-on-feed. The legacy of the programme has not been costed but will include a systems platform for information flows across the supply chain to deliver ongoing value. The cost:benefit ratio is conservative since benefits for sheep meat in the first project have not been included and impacts of objective assessment for grain-fed export cattle have also been excluded, (i.e. assessment was restricted to the domestic market due to the likely longer time for acceptance internationally).

A conservative approach has also been adopted in estimating industry wide greenhouse gas emissions reductions directly attributed to the programme. Substantial reductions in total red meat emissions will only be achieved through actions specifically at the farm stage since this accounts for approximately 80% of supply chain emissions through to retail. Measures developed for enteric methane reductions in the National Livestock Methane Program have the potential to achieve substantial mitigation and this programme does not seek to replicate that on-farm RD&A investment but rather to add to it through additional reductions achieved with innovative value chain strategies.

Productivity gains and lower cost of production in this programme with information-enabled supply chains will increase capacity of producers to invest in mitigation measures. The programme is estimated to directly deliver significant greenhouse gas reductions for some supply chain stages, e.g. an estimated 7% reduction for feedlot beef cattle in Project 2. The contribution to the industry wide full supply chain emissions is small (<1%) with scaling up to sheep and goats and including indirect effects providing additional contribution.

This programme centres on promoting enhanced information flows through application of digital information platforms and data analytics across the value chain. It builds on the elements of advanced technologies and data use implemented or now being piloted in discrete sectors of red meat supply chains. For example, meat processing is being transformed by automation and on-farm production is benefiting from remotely sensed data, including for pasture condition from satellites and drones and for live weight gain of animals from automated weighing platforms. Use of these data has the potential to be extended beyond linear decisions to change the way the red meat industry responds in near-real time to production, climate and market variables for economic and environmental benefits and to meet consumer expectations. In summary the two areas identified for development in 2016-2020 are:

Project 1: Improved environmental performance driven by meat quality objectives.

This project would incentivise producer adoption of practices that target improved meat quality compliance and which also reduce the greenhouse gas intensity of production through efficient live weight gain. Producers would be provided with opportunities to participate in Emissions Reduction Fund (ERF) carbon credit markets and the industry would benefit from higher participation in MSA with flow on savings of the costs of non-compliance. A preliminary estimate of the budget for this short-term project is $280,000 over 1.25 years, with an anticipated economic benefit of $1.57 million by 2020 to beef producers alone, representing a cost:benefit ratio of 1:5.6. The future total economic value for the red meat industry is expected to be higher but a conservative approach has been taken to calculating the benefit for two reasons: (1) there is currently no certified ERF flock management methods for sheep or goats; and (2) a baseline to 2020 projected from the current statistics for lambs (‘56 per cent of MSA lambs i.e. 3.2 million head were formally identified to consumers as MSA product in 2015 – up from 35 per cent in 2013’) was considered to introduce unacceptable uncertainty in the estimated benefit. However, the protocols develop for beef will provide a guide for other species to be able to realise benefits also.

Project 2: Objective assessment of days on grain

Australian grain fed cattle spend a minimum of 50 and in excess of 100 days in feedlots with the length of time determined by market specifications. In reality, from feedlot entry there is a range in performance on grain in terms of weight and fat level between individual animals that has implications for eating quality, profitability and environmental performance. This project proposes to build on existing and ongoing research to assess the value chain implications of moving from ‘days on feed’ as the basis for meeting market specifications for grain fed cattle, to objective assessment of individual animal attributes.

Data, information platforms and analytics needed to optimise management from producer to feedlot and from feedlot to processor will be examined in order to; reduce the cost of production; maintain or improve meat quality; and decrease feed, energy and water use per animal and associated greenhouse gas emissions.

If half of feedlot cattle are destined for domestic markets and time on feed could be reduced by 5 days from 70 to 65 days (without compromising easting quality), then savings in costs of feed would be around $29.4 million and reductions in greenhouse gas emissions of 78,400 tonnes carbon dioxide equivalent would be achieved. A very preliminary estimate of the budget for this project is $3 million over 4 years. With an anticipated economic benefit for domestic grain-fed beef of $29.4 million by 2020 from feed rations alone, this represents a cost:benefit ratio of 1:9.8. Acceptance for export markets would likely take longer but if included the cost:benefit ratio would be 1:12.6 (assuming 33% higher costs to extend the research) with wider acceptance and realisation of the returns likely to take at least three more years.

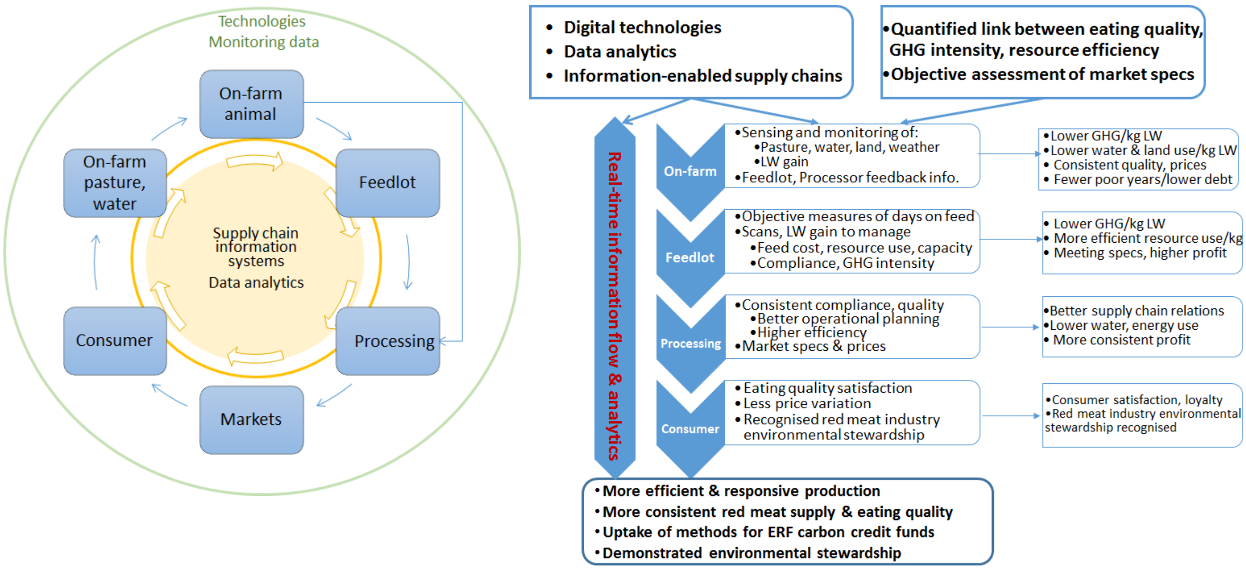


Fig. 2 Conceptualised information-enabled supply chain and information flows for Programme 1

Increasing productive efficiency and environmental performance using enhanced supply chain information systems	
Value proposition	The efficiency of production, profitability and environmental performance of the red meat industry will be improved through maximising the effective flow of information from applications of technologies, detailed data and analytics across the supply chain. • Incentivising adoption of practices that maximise weight-for-age as a key pathway to beef and sheep meat quality compliance through opportunities for additional income from carbon credits will increase adoption of the MSA system and contribute to promotion of the environmental performance of red meat value chains quantified as reduced greenhouse gas emissions per kg live weight. Potential industry benefits may be ~$1.57million from increased adoption of MSA (with reduced costs of non-compliance and down-grading) and uptake of Emissions Reduction Fund finance.

Increasing productive efficiency and environmental performance using enhanced supply chain information systems	
	• Investment in understanding requirements for information and analytical platforms and in quantifying the environmental impacts of replacing set 'days-on-feed' with objective assessment of compliance with grain-fed market specs will position the red meat value chain for major efficiency gains. Efficiency improvements will be possible through information-enabled supply chain feedback from processing analytics to feedlots to objectively optimise turn-off and from feedlots to producers to help meet optimal entry requirements for market segments. Carcase predictive systems based on slaughter data and animal characteristics will be informed by, and implemented through, the new and emerging precision livestock technologies such as CT scanning, high definition and hyperspectral cameras, X-ray imaging, and frequent automated weighing supported by parallel development of digital information systems.
Programme	1. ***Project 1:*** Improved environmental performance driven by eating quality objectives. *Background:* The major factor determining both eating quality and greenhouse gas intensity is higher weight for maturity (MLA 2016a), with a reasonable assumption that there is little difference between environmental impacts of compliant and non-compliant animals at processing. 1.1 Quantitative analysis of the greenhouse gas and resource use efficiency of management practices targeting high weight for age (daily weight gain on farm and feedlot) and MSA compliance (MSA Index) using a partial life cycle assessment approach. 1.2 Establish a 2016 baseline of MSA participation and compliance (e.g. for beef using data from MLAs 2015 Australian beef eating quality audit (MLA 2016a), data on daily live weight gain from 'walk-over-weighing' and current practices, ensuring coverage of grass fed, grain fed and hormonal growth promotants (HGP) pathways. 1.3 Define a set of recommended practices for eating quality, lower greenhouse gas intensity and lower cost of production through improved weight-for-age and promote uptake in MSA and MLA training programs. 1.4 Establish an information feedback system from processors to suppliers that includes linkages between carcase traits for grading and producer or feedlots records. 1.5 Develop a case for the Department of Environment to establish practices targeting MSA grading as an accepted basis for inclusion in the existing cattle and planned sheep 'Herd Management' methods, or developing a new certified method achieving reduced greenhouse gas intensity of meat under the Emissions Reduction Fund. 2. ***Project 2:*** Objective assessment of days on grain. *Background:* Markets define days on feed for 'grain-fed' beef, with a minimum of 100 days for export and commonly 60 or 70 days, respectively, for heifers and steers for domestic markets. A minimum of 50 days is critical to achieving the desired change in fat colour. This project will build on research being undertaken by the red meat industry to avoid down-grading of the carcase due to not meeting out-weight and level of fat specifications, and proposes evaluation of the potential for moving to a more objective assessment of readiness for slaughter. It is timely to examine this potential from the perspective of information system requirements and implications for environmental stewardship in the light of current and emerging technology and knowledge. While resolution of any barriers to acceptance of change in market specifications will also be critical it is important that the red meat industry proactively manage the opportunities for productivity, cost of production and environmental benefits. It is proposed that the first stage of this project assumes a minimum of 50 days on

Increasing productive efficiency and environmental performance using enhanced supply chain information systems	
	feed for the domestic market and 100 days for export grain-fed beef. 2.1 Collate and review data from feedlots on the relationship between days on feed and attributes that include entry and out-weights, nutrition, animal condition and fat scores, live weight gain and relate these variables to processor data for carcase traits, compliance and prices. 2.2 Develop relationships between daily live weight gain, entry weight, out-weight, cost of production and meat quality for MSA graded and non-graded cattle, initially for a regional study and single market segment, e.g. domestic. 2.3 Review any international programs that are using predictive relationships for target market based on animal characteristics such as height (or hip height) and width of the animal, fat scores, muscling, age (McPhee, 2016). Test the applicability of international predictive models to Australian cattle and specifically examine requirement for age as an input variable, technology development requirements and whether these can be met. 2.4 Pilot a program to test impacts on processing efficiency, feedlot resource use, costs and prices of flexible, objective assessment compared with standard set days on feed for information requirements and feasibility of setting up a platform to ensure efficient transfer of (1) carcase attribute information from the processor to feedlot; and (2) animal performance data from feedlot to producer to manage entry weight and animal selection for entry. 2.5 Use scenarios to quantify: (1) cost of production and benefit-cost; and (2) the greenhouse gas emissions and resource use efficiency associated with alternative assessment models. 2.6 Evaluate the outcome of this proof-of-concept stage. If successful, undertake a second stage which expands coverage, promotes adoption through relationships between processors and feedlots, evaluates provision of feedback to producers on feedlot entry and seeks approval for development of an ERF method and incorporates on-farm data from technologies such as sensors, walk-over-weighing platforms and automated data capture with Radio Fequency Identification (RFID) devices for herd management decisions. Earlier removal of low-performing individuals would provide improved herd efficiency and increased resource efficiency and lower greenhouse gas intensity (Gonzales et al., 2014).
Technology readiness	• Technology elements sufficient to initiate this programme are in place and new technologies or applications could be incorporated into the information platforms proposed. • Suitable protocols and formats for data and information transfer could be expanded across supply chains, e.g. based on experience with NLIS, Meat standards Australia and Livestock Data Link. Flexibility to enable mobile and satellite access where internet coverage is currently poor and to accommodate emerging communications (e.g. Sky Muster), and technology innovations (e.g. sensing, modelling, robotic) could be built into the protocols. • Some expansion of data analytics in red meat supply chains would likely be needed to fully implement Project 2. However, these would be explored in the initial proof of concept stage and no barriers are foreseen. • The second phase would develop regionally specific information products and capacity for national-scale and industry-wide analytics which could occur as a staged development linking technology and training for adoption.

Increasing productive efficiency and environmental performance using enhanced supply chain information systems

Adoption

- Case studies/proof-of-concept to prove effectiveness of information-enabled supply chains to demonstrate the increase in productivity, profitability, environmental sustainability.
- Marketing and articles in agricultural magazines/newspaper/social media (e.g. Facebook) of these case studies and on the results of adoption
- Free, subscription or buy access (with free trial period and training)
- Training programmes potentially through established MSA initiatives and MLAs new 'Profitable Grazing Systems' program being piloted in 2016 (MLA 2016b)
- Information packages and business case development to support decisions on options for aggregation and possible participation in the Emissions Reduction Fund.

Benefits

Economic

- Capacity to expand market share, through demonstrated environmental responsibility, data acquisition and analytics, and responding to consumer interest in sustainability and safety as well as delivering red meat with consistent high eating quality.
- Greater efficiency and value across the supply chain through increased adoption incentivised through carbon credit income of practices to maximise weight-for-age through understanding the links between drivers of eating quality for MSA grading and environmental outcomes (i.e. lower greenhouse gas intensity and high resource use efficiency).

Improved environmental performance driven by meat quality objectives

- For grass-fed beef cattle alone, Project 1 was estimated to deliver a cost: benefit ratio of 1:5.6 to 2020 (Table 3) for a modest investment of $280,000 over 15 months.

Table 3 Benefits of Project 1 for grass-fed beef industry

Variable	2016	2020 (without project)	2020 (with project)
MSA compliant beef carcases (million)	3.01	3.41	3.42
MSA complianht grass fed carcases (million)	1.58	1.80	1.81
Total price above non-MSA ($M)	186.4	211.9	212.9
Income from carbon credits	0	0	0.57

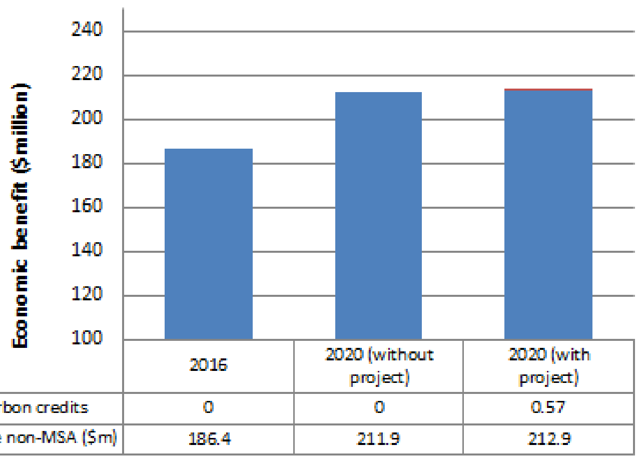


Fig. 3 Economic benefits

- As an indication of the conservativeness and scale, Paraway Pastoral Beef Herd Management Project sold 184,000 Australian Carbon Credit Units in the third ERF auction which at the average price would be worth $1.9 million, and Ramp Carbon (2015) estimated that approximately half of the payments, i.e. $330 million, in the first ERF Auction was potentially available to livestock.

Objective assessment of days on grain

- A sensitivity analysis of more objective assessment of the optimal time for slaughter than set days-on-feed was undertaken to determine the economic and environmental impacts. This analysis makes a number of assumptions as outlined in Appendix C and is intended only to be indicative.
- For short-fed steers, Table 4 indicates the impacts for cost of feeding, greenhouse gas emissions, water use and primary energy use per head for time on feed.

Table 4 Benefits of Project 2 for grain fed beef (a) short-fed and (b) long-fed. Baseline scenario is shaded green

Days on feed	50	55	60	65	70	75	80	
Cost for feedlotting ($/hd)	210	231	252	273	294	315	336	
GHG Emissions (kg CO2-e/hd)	560	616	672	728	784	840	896	
Water Use (L/hd)	35,770	39,347	42,924	46,501	50078	53,655	57,232	6
Primary Energy use (L/hd)	2,800	3,080	3,360	3,640	3920	4,200	4,480	

Days on feed	80	85	90	95	100	105	110	
Cost for feedlotting ($/hd)	240	255	270	285	300	315	330	
GHG Emissions (kg CO2-e/hd)	640	680	720	760	800	840	880	
Water Use (L/hd)	40,880	43,435	45,990	48,545	51100	53,655	56,210	6
Primary Energy use (L/hd)	3,200	3,400	3,600	3,800	4000	4,200	4,400	

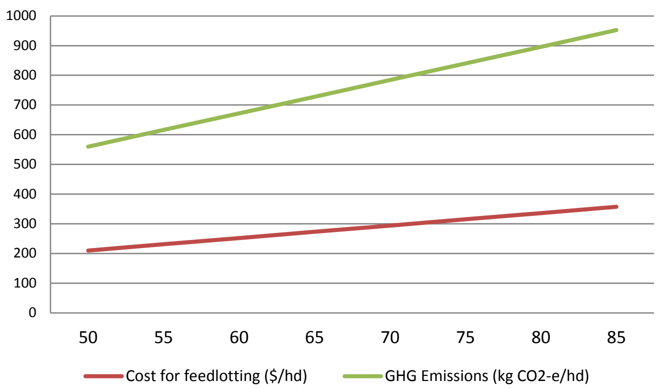


Fig. 4 Impact of reducing the time on grain from 85 days to 50 days as applicable to domestic grain-fed markets

- While this analysis is simplistic and should be considered preliminary only, it does indicate the economic and environmental importance of examining impacts of days on feed. If half the animals entering feedlots met specifications 5 days ahead of the

Increasing productive efficiency and environmental performance using enhanced supply chain information systems	
	'recommendation', it would save 7% of the costs and of the greenhouse gas emissions per kg weight. If 50 days on feed was sufficient to meet beef specifications then savings would be more than 28% of the levels for 70 days. Similarly, for long fed steers there would be a savings 0.5% of costs and of greenhouse gas emissions per kg steer. Extrapolating to an industry level and assuming that half of the cattle in feedlots were for the short-fed market and time on grain was reduced by 5 days, there would be a saving of \$29.4 million in feed rations alone across the domestic grain fed industry. A similar assumption for long-fed cattle would give \$21 million in savings making a total of \$50.4 million. Environmental • Estimated additional savings in greenhouse gas emissions from beef cattle from Project 1 were 57,000 tonnes CO_2-e/year. More efficient production (higher weight for age and shorter time to slaughter weight) would also deliver savings in water use and other farm inputs, and supply chain efficiencies through higher quality and consistency at the processor but these additional benefits weren't quantified. • Objective assessment against grain-fed specs for feedlot cattle has the potential to save over 78,400 tonnes CO_2-e/year associated with short-fed beef production and 56,000 tonnes CO_2-e/year for export markets when the impact is assumed to be equally split between domestic and export markets for cattle in feedlots and assuming that time on grain was reduced by 5 days. This represents an estimated direct greenhouse gas saving for the feedlot cattle of 7% based on national inventory figures. • Environmental stewardship of the red meat industry documented and recognised through monitoring and accounting for resource use efficiency and greenhouse gas intensity improvements from integrated use of improved information and technologies for management of climate variability and change.
Outcomes	• Australia's red meat industry positioned as a leader in use of digital technologies for higher efficiency and sustainability and rapid response to technology developments and changes in consumer tastes or interests. • Information-enabled supply chains achieve higher efficiency, lower cost of production, capacity to deliver more consistent meat quality and to respond rapidly to climate variables, markets and consumer preferences, and higher consumer satisfaction. • Marketing opportunities for MSA as environmentally responsible through demonstrated links between producing high quality red meat and environmental stewardship. • Access to additional income streams through quantitative analysis of greenhouse gas intensity of MSA graded beef and lamb. There is potential for processors to act as aggregators, although use of commercial aggregators is also an option.
Risks	• Confidentiality and commercial interests within the supply chain may make integration of information and actions to manage supply and quality more complex to achieve. *Risk considered low due to precedents such as Livestock Data Link.* • Research and quantified analysis fail to show statistically significant associations between environmental factors and eating quality factors or reveal unacceptable trade-offs between impacts, e.g. lower greenhouse gas intensity but higher energy and/or water use. *Risk considered low due to established relationship between weight for maturity and eating quality because of decreased extent of connective tissue*

Increasing productive efficiency and environmental performance using enhanced supply chain information systems	
	development in muscles. • Industry agreement on change from 'days on feed' to a more objective assessment of grain fed beef cannot be achieved or accepted by markets. *Risk is medium to high but the programme delivery of information systems and feedback for efficiency towards compliancy in carcase weight and fat specifications will provide a net benefit even if days on feed is retained as the metric.* • Policy changes that limit access to income streams from carbon credits for the improved agricultural or land management practices identified in this programme. *Risk considered medium despite bipartisan support for international emissions reduction targets.*
Customers	• Information-enabled supply chains will be able to respond more rapidly to consumer preferences, assisting retention of, and growth in, the red meat market segment relative to alternative proteins. This will build on the existing consumer satisfaction with beef eating quality which has increased from 30 to 36% from 2010-11 to 2014-15, and exploit the growth in satisfaction with MSA lamb with 6.8 million lambs graded in 2014-15. • Surveys indicate a growing community support for action on climate change (e.g., ABC Vote Compass 3.06.2016), and participation in ERF carbon credit trading will help demonstrate climate change mitigation responsibility. • Consumer support is likely to be enhanced by recognition of producers targeting MSA grading as delivering environmental stewardship benefits.
Measures	• Higher productivity growth year on year linked to increased information flows and uptake of technology and digital data for decision support in all sectors of the supply chain. • Market statistics showing recognition and support for 'environmentally responsible [MSA]' beef and lamb' • Lower rates of downgrading of grain fed beef carcases and higher feedlot profitability linked to objective assessment of time to slaughter. • Increase in carbon credit income (ACCUs) going to the red meat industry. • Survey statistics show higher consumer satisfaction with red meat and higher share of protein market.

4 Programme 2: Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein

Abattoir and feedlot wastes, including manure, paunch, and organics in wastewater, are treated through a variety of processes to enable cost effective disposal and minimise the potential for environmental harm. It is widely recognised that these wastes can be used to produce energy and displace fossil fuel use at feedlots and abattoirs. Converting wastes into energy reduces fugitive greenhouse gas emissions, which would otherwise be released into the atmosphere during conventional waste treatment, and avoids greenhouse gas emissions resulting from use of fossil fuel-derived sources of energy.

Waste-to-energy processes however only utilise some of the carbon component of abattoir and feedlot waste. Rapid advances in biotechnology are creating a range of other 'waste-to-value' options with higher revenue potential that utilise a broader fraction of the waste (that includes carbon in the form of protein, fats, starch, lignocelluloses, carbon dioxide and methane; and nutrients such as nitrogenous compounds, phosphate, vitamins, amino acids and trace elements such as metal ions).

Single cell (microbial) protein has significant potential to generate increased value compared to current practices for processing abattoir and feedlot waste. Single cell protein is composed of unicellular microorganisms such as algae, yeasts, bacteria or fungi that can contain more than 60% crude protein. These microorganisms may be used as a feed supplement and a substitute for protein-rich feed components such as palm kernel meal or cottonseed meal. Microbial protein production processes generally require some form of pretreatment of the waste or nutrient source to ensure the carbon, nitrogen, phosphorous and other nutrients are available for uptake by the microorganisms. There is currently an array of single cell protein production technologies at varying stages of development as well as the prospect of developing new nutritionally advanced single cell protein types. The technology of choice depends on the carbon source available (e.g. carbon dioxide, methane, or organic carbon derived from waste streams) and the preferred energy source for growth (e.g. light, hydrogen or directly from the carbon source). Economic production of single cell protein from abattoir and feedlot waste presents a market opportunity of $70-80 million p.a. to the Australian red meat industry, as well as the opportunity to reduce the reliance of current protein meals of varying cost and availability, through production of these supplements within the industry.

The use of biology for industrial processes is growing rapidly around the world as alternatives are sought for waste disposal and for the generation of energy, chemicals and materials from renewable starting materials. An example of such a process is the >10,000 tonne per year chemo-enzymatic process developed by Lonza for nicotinamide production using a waste product of the nylon industry as starting material. Significant recent developments in fundamental techniques such as genome sequencing, biological manipulation, catalysis and process engineering are making new processes more understood, more readily adapted and cheaper. The red meat industry produces a range of wastes or co-products that are amenable to biological processing.

This R&D programme contains a continuum of research towards value adding to abattoir and feedlot waste based on two main areas. The first project is based on advanced anaerobic digestion of liquid and solid wastes to reduce waste volumes, reduce waste odours, generate renewable energy (biogas), mobilise nutrients with the overall aim of developing anaerobic digestion technology as a platform for subsequent value-add processing. This research builds on past investment by the red meat industry by expanding the application of anaerobic digestion beyond covered anaerobic lagoons, with a focus on economical treatment of solid wastes. The anticipated budget for this area of research is in the order of $1-2 million over 3 years, with a market expansion opportunity from $24 million per annum (using lagoons) to $64 million per annum (with utilisation of anaerobic digestion of solid wastes by processors and feedlots) by 2020, representing a cost:benefit ratio of 1:20. The second project utilises the products of anaerobic digestion (or other pretreatments) and is focused on producing higher value animal feed supplements through advanced microbial protein technologies. This research is transformational and the anticipated budget for this area is $5-10 million over 5 years, with a market potential of $70-80 million per annum that could be realised by 2025, representing a cost:benefit ratio of 1:8.

There is a significant opportunity to increase the impact of the research investment and the breadth of technologies that are investigated through developing co-investment from other funding sources such as the Rural R&D for Profit Programme, the Australian Research Council Industrial Transformation Research Programme, the MLA Donor Company or other Research Development Corporations. This co-investment would more rapidly progress the development of the technologies and further improve the cost:benefit ratio for MLA.

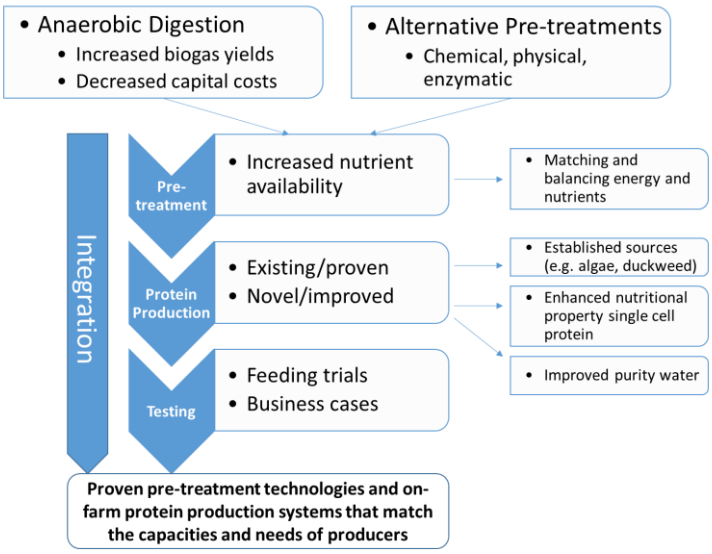


Fig. 5 Overview of outputs of the research program showing how the developed advanced pretreatment technologies, including anaerobic digestion, will be used to generate the optimised nutrients for single cell protein production. Existing single cell protein sources as well as new enhanced nutrition single cell protein will be evaluated, developed, produced and tested for commercial applicability. Both the individual research projects and the final production processes will be fully integrated.

Note: Abattoir wastewater and paunch solid waste contain very high carbon to nutrient ratios. In these streams, the production of microbial protein is nutrient limited and these streams are well suited to anaerobic digestion pretreatments where the excess carbon is converted to methane/biogas prior to further value adding processes.

Manure contains a lower carbon-to-nitrogen ratio and while anaerobic digestion is still a strong candidate for pretreatment and nutrient mobilisation, the subsequent microbial protein process may require additional carbon (such as carbon dioxide) to ensure full utilisation of the nutrients. Therefore, the optimal microbial strain and protein technology may be different for different waste streams.

Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein

Value proposition

- Feedlotters and red meat processors produce solid and liquid wastes that cost the industry an estimated $100-200 million in treatment and disposal each year.
- Biological waste processing systems can be adapted to feedlot and abattoir wastes to generate a variety of valuable products such as energy, fertiliser, and microbial protein. Currently, value is recovered through anaerobic lagoons, however this technology does not address the bulk of waste disposal costs and enables a small fraction of value recovery.
- Implementing new or improved biological processing technologies has the potential to reduce waste production and waste management costs and create revenue. Revenue potential is dependent on technology selection with examples shown in Fig. 6. In total, the carbon and nutrient components in abattoir and feedlot waste represent a value of ~$64 million p.a. if converted to energy, ~$40 million p.a. if converted to fertiliser and $80 million p.a. if converted to microbial protein. Importantly, the production of microbial protein can occur in conjunction with energy recovery (Figure 2) for a combined value opportunity exceeding $140 million.

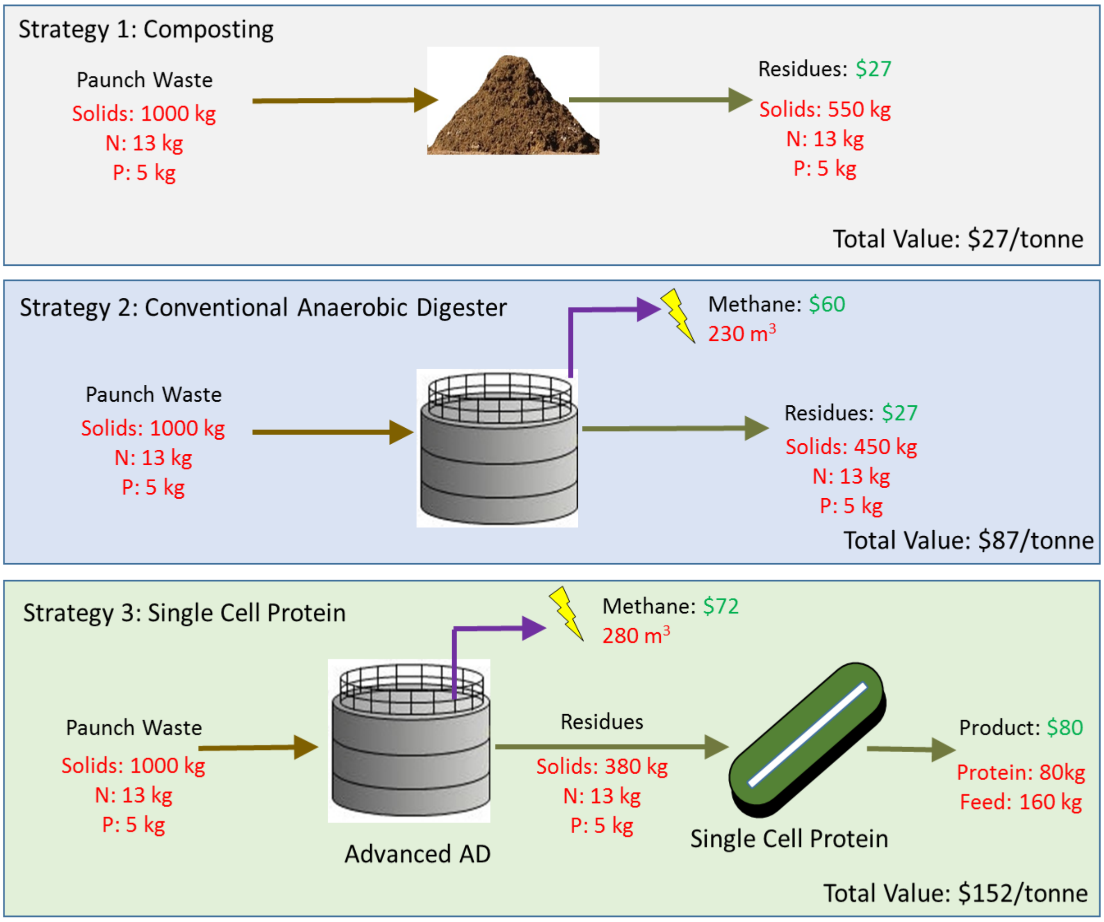


Fig. 6 Demonstration of the potential solid waste value when using current disposal methods, such as composting, or value add technologies such as anaerobic digestion and single cell protein production.

Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein

Programme

1. Advance the uptake of anaerobic digestion (AD) technologies in the red meat industry as a platform for value adding and waste-to-protein production through lower-capital solutions, increased biogas yields and nutrient recovery. These advances can be achieved by:

    1.1. Development of a detailed understanding of industry wastes (quality, location, sector/source and availability) specifically to inform pretreatment and single cell protein production process scale, process design, waste aggregation and process technology selection. This analysis includes waste aggregation opportunities from dedicated feedstocks and co-located industries to generate optimised substrates and should be integrated with the data being compiled through the ARENA (Australian Renewable Energy Agency) -funded Australian Biomass for Bioenergy Assessment (ABBA) project. Strategies to be evaluated would include:

    - Centralised off-site co-digestion – such as adding red meat industry wastes to existing infrastructure at water utilities or in other industries.
    - Decentralised on-site co-digestion using red meat industry wastes and imported wastes from local industries.
    - Decentralised on-site treatment using only wastes available at red meat facilities.

    1.2. Developing technologies to increase biogas yields from red meat industry anaerobic digestion - resulting in increased process-loading rates (reduced vessel size/capital cost) and increased biogas production. Research topics would include:

    - Development and optimisation of cost-effective pretreatment technologies (mechanical, chemical and enzymatic) and upgrading technologies that enhance biogas production and/or deliver low-cost microbial substrates to maximise value adding after anaerobic digestion (such as maximised single cell protein yields).

    1.3. Reducing infrastructure and capital costs through improved technology selection, plant engineering and alternative construction materials – with equipment engineered for the specific challenges of red meat processing wastes through the supply chain; and

    1.4. Increasing the value proposition of anaerobic digestion by developing market opportunities (e.g. fertiliser/soil amendment, feedstock for bio-crude production) for digestion residues not to be used in single cell protein production – and identifying competitive advantages of red meat supply chain wastes (i.e. solid wastes from meat processing plants contain low levels of heavy metal contamination and no human pathogens, increasing land application options and creating other re-use options).

2. Develop technologies for the production of enhanced, value-added single cell (microbial) protein using feedstocks derived from the anaerobic digestion/pretreatment platform (on feedlots of >10,000 head and red meat processing plants of >500 head per day). The realisation of this technology requires:

    2.1. Development and demonstration of existing waste-to-protein platforms on red meat supply chain wastes:

    - Selection of appropriate microbial strains for fermentation on red meat processing waste streams. Macro-algae and duckweed will also be considered

Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein	
	as production platforms. • Optimising organism growth rates, nutrient uptake and protein yields on manure, paunch solid waste and red meat processing wastewater. • Evaluating the composition and quality of the protein product. • Developing protein harvesting strategies and any downstream processing requirements. • Process design and optimisation and development of the business case. • This research builds on existing R&D to be lower risk and lower cost – with pilot and demonstration of technologies occurring in 2-5 years 2.2. Development of integrated microbial biotechnology and bioprocessing platforms co-producing single cell protein and enhanced feed productivity agents at low-cost and high-yields: • Identification of microbial compounds such as specific amino acids, vitamins, micronutrients, enzymes, or anti-methanogenesis agents that contribute to productivity gains in key livestock markets (i.e. in cattle, sheep, pigs, or chickens). • Identification of microbial strains with high potential to act as platforms to promote production of these enhanced feed-productivity agents. • Identification of ideal growth nutrient compositions from waste, including the potential for waste aggregate mixtures suitable for promoting growth of target microbial strains and production of enhanced feed productivity agents. • Microbial strain and production technology development as well as development of business cases and business models for these prospective technologies. • Develop and assess business model concepts to transform economic viability through the innovative integration of the developed microbial process technologies for the co-generation of enhanced feed protein with other valuable products; and • Demonstration of production technologies at pilot and pre-commercial demonstration scales with associated knowledge sharing activities. • This research has strong potential for impact but is at an earlier stage than technologies in section 2.1. The development period is likely 5-10 years, with a higher development cost. However, the value proposition is potentially much higher than figures presented below for crude protein alone.
Technology readiness	Anaerobic Digestion • Conventional anaerobic digestion is a commercially established technology that has been applied for treatment of manure and red meat processing wastes overseas, with multiple technology providers capable of supplying this technology in Australia. • More advanced anaerobic digestion technologies are being developed with some successful commercial applications in municipal sludge treatment and other industries. Applied research is required to adapt, optimise and demonstrate these technologies for the red meat supply chain, and to develop a robust business case for implementation. The timeframe for this research is expected to be less than 3 years and is largely applied research with a focus on optimisation and demonstration.

<table>
<tr><th colspan="2">Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein</th></tr>
<tr><td></td><td>

- Examples of technology providers with capacity to deliver anaerobic digestion technologies in Australia include, but are not limited to: Quantum Power, Wiley, ADI Systems Inc., Aquatec Maxcon Pty. Ltd., Trilogy Renewable Energy,

<u>Waste-to-Protein</u>

Single Cell Protein technologies are currently positioned at several different stages of technology readiness. For example:

- Some versions of algae based technologies are commercially available when using controlled synthetic media – but the technologies and economics are not optimised. Development for feedlot waste applications and red meat processing applications is required and should significantly improve economic potential.
- Solid-state fermentation technologies that both pretreat waste and generate single-cell protein cover a broad range of microbial strains applied to different wastes in different configurations. While some commercial versions exist, this technology could be significantly improved with better microbe selection or a more integrated process.
- Heterotrophic technologies such as purple phototrophic bacteria technologies are still embryotic and have been assessed on a basic feasibility basis only. These technologies appear highly suitable for red meat supply chain wastes, but still require fundamental R&D before progressing to pilot, demonstration and adoption.

Application of single cell protein technologies that incorporate productivity enhancing agents (such as specific amino acids, vitamins, micronutrients, enzymes, or anti-methanogenesis agents) are of potential high impact but are still conceptual or in early development stages.
</td></tr>
<tr><td>Adoption</td><td>

- Adoption can be enhanced by co-funding via industry partners and other sources such as ARENA or equity partners. This co-funding can reduce capital costs to the red meat industry and de-risk the deployment and operation of new technologies.
- Projects can be developed and de-risked through:
  a. Audit: understand current and future needs related to energy and feed.
  b. Set KPIs: understand what the goals are e.g. short list options with less than 5-year payback; 20% energy recovered through renewables; 25% waste reduction targets; 30% of feed protein produced onsite.
  c. Analyse efficiency options in terms of technical and economic viability.
  d. Standard approaches to project execution: funding, design, project management, construction, commissioning.
- Anaerobic Digestion processes are highly scalable and more than 20 RMP plants in Australia (covering >60% capacity) and more than 25 feedlots (covering >50% capacity) in Australia could benefit through implementing program outcomes.
- Initial expectations are for microbial protein processes to have a similar application range to anaerobic digestion processes; however, technology selection and optimised process designs may vary based on the size and location of the process.
</td></tr>
<tr><td>Benefits</td><td>

Economic

- Major sources of solid waste from abattoirs and feedlots include manure (>100 million tonnes p.a. – 10 million tonnes p.a. at feedlots) and paunch contents (0.2 million tonnes p.a.) from cattle alone. Energy value in the range of $50-70 per dry tonne ($5-
</td></tr>
</table>

10 per wet tonne) can be recovered using conventional anaerobic digestion. Capital costs are high, however, resulting in payback periods exceeding 10 years. These high capital costs restrict application to urban areas where high existing costs for waste disposal provide additional economic incentive. Advanced anaerobic digestion technologies have the potential to reduce payback periods by more than half through increasing biogas/energy yields (20-30%), reducing the size of process vessels (30-50%) and reducing volumes of digested product requiring transport offsite.

- If microbial protein (60% crude protein content) had a comparable value to meat and bone meal (50% crude protein content), the potential value recovery from 1 kL of red meat processing wastewater as protein could be $3-5/kL (compared to ~$1.5/kL methane energy and mineral nutrients) – however this process may be limited by nutrient availability. A value of $3/kL could be achieved by using a 2 stage process converting nutrients to microbial protein and converting excess carbon to methane).
- The potential value recovery from 1 tonne of paunch (dry weight) is $50-$70/tonne based on methane energy recovery. This value has the potential to increase 2-5 times using microbial protein technologies – and demonstrates the potential value on an integrated waste-to-protein strategy.
- Feed is a significant contribution to the costs of livestock production at an estimated 73% of cattle production costs of which protein supplements represents 6-13%. However, feed also contributes 55-65% of live pig production costs and 65-75% of poultry production costs creating a broad market opportunity for sustainable single cell protein feeds.
- Recent AMPC funded research on single cell protein included a feasibility study that estimated the production cost of purple phototrophic bacteria (a single cell protein) at approximately $100/tonne (however significant process development is required). For comparison, a summary of common animal feeds, protein content and costs are shown in the supplementary information in Appendix C. Importantly, competition between these markets drives up the cost of current protein based feeds (i.e. soy bean meal), suggesting strong market potential for waste derived single cell protein.
- Current technologies such as anaerobic lagoons allow a red meat processor with a capacity of 500 head per day to recovery energy-value in the order of $380,000 p.a. Through this program, the same processor could increase this figure to $980,000 p.a. by maximising value recovery from the 3,750 tonnes of solid waste and 320 ML of wastewater available onsite per year and producing 45,000 GJ energy and 800 tonnes of microbial protein.
- A feedlot with a capacity of 10,000 head will generate over 100,000 tonnes of manure p.a. (at full capacity), with the potential to produce 50,000 GJ energy and 1,800 tonnes of microbial protein at a combined value of $1,600,000 p.a.. This may offset feed costs or represent a revenue stream – depending on the protein end use.
- Single cell protein has seen values in the range of $300-600 per tonne, based on crude protein content. However, there is potential to significantly improve this value if productivity-enhancing agents (such as specific amino acids, vitamins, micronutrients, enzymes, or anti-methanogenesis agents) are successfully integrated into the technology.

Environmental

Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein	
	• Some feedlots and abattoirs generate enough waste (e.g. manure, paunch, wastewater) to offset 20-100% of on-site energy requirements, thereby reducing fugitive greenhouse gas emissions and those associated with the use of fossil fuels. • The combination of advanced anaerobic digestion technologies and single cell protein technologies would be expected to reduce volumes of paunch solid waste and manure solid waste at each installation to less than 50% of current levels – through conversion to value add products. This potential exceeds the KPI of a 25% reduction in waste volumes by 2020. • Enhanced weight gain (reduced time to full weight) using enhanced feed supplements or those designed to reduce bio-methanogenesis could have significant impacts on methane emissions over the lifetime of the animal. Less waste to non-productive uses (landfill) or pollution (water).
Outcomes	• Enhanced low-cost anaerobic digestion technologies. • Optimal use of waste streams to extract maximum value and generate ideal substrates for biological processes. • Identification, development and production of ideal microbes for use in feed or for the generation of valuable products. • Assessment of and integration of the latest biotechnological methods to improve feed characteristics leading to increased feed efficiencies and maximised revenues from waste processing. • Development of business cases related to the use of biological systems.
Risks	• Knowledge and understanding of how a technology will impact a specific operation. • Access to capital and strict payback criteria. • Fluctuations in energy/nutrient/feed values. • Public acceptance of waste-to-protein products in the red meat supply chain – misconceptions/perceived quality impacts. • Regulatory restrictions on the use of waste derived protein.
Customers	• Improved customer perception by demonstrating continued improvements in red meat environmental impacts. • Improved long term sustainability of the industry.
Measures	• Increased number of in-vessel anaerobic digestion installations, number of microbial protein installations, and proportion of businesses with waste management plans. • Reduction of giga joules of fossil fuels used (and overall energy cost) per kg of retail ready red meat for the whole supply chain life cycle. • Reduction of kg of solid waste (and overall waste management cost) per kg of retail ready red meat for the whole supply chain life cycle. • Reduced kL of water used (and overall water cost) per kg of retail ready red meat for the whole supply chain life cycle. • Development of a whole of supply chain cost and resource consumption model.

5 Programme 3: Driving adoption of technologies to improve water and energy management in the Australian red meat supply chain

Water and energy are key inputs to the red meat industry and their use can result in significant costs to industry and increase the industry's environmental footprint. The total estimated cost of fossil fuel energy consumed by the Australian red meat industry is ~$1.34 billion p.a. which includes $700 million per annum on farm, $280 million in feedlots and $350 million for red meat processing (GHD 2011, Wiedemann 2015, ABS 2016b). The cost of water for red meat processors is relatively well defined, at approximately $37 million per year nationally, and increasing (AMPC). However, the processing sector consumes just 2% of water used across the supply chain (Wiedemann 2015). In total, beef cattle, sheep and grain farming operations use over 4,000 GL of water each year (ABS 2015) with usage of approximately 550 L per kg retail beef and 450 L per kg retail lamb. The total cost of this water is difficult to quantify and this is because over 95% of water used in the red meat supply chain is used on-farm or at feedlots and much of this water is supplied through bores or surface water at little or no direct cost, however water remains a critical resource and and possible strategies to reduce water use are presented in this program.

This program includes a series of research, development and adoption activities with associated estimated program budget, timeframe, and cost:benefit ratios. These activities aim to drive adoption of new technologies to improve water and energy management in the Australian red meat supply chain. The activities include developing new business models to drive adoption of technologies, and promoting opportunities for new technologies through feasibility assessments, case studies, knowledge sharing and demonstration projects for the integration of renewable energy, energy efficiency and water use reduction technologies across the red meat supply chain. The impact of a 25% reduction in energy use intensity by 2020 relative to 2015 levels is summarized in Fig. 7. Red meat producers, feedlotters and processors will benefit from improved water and energy management options that will deliver cost savings, reduce environmental impact, improve security of water and energy supply, and contribute towards the industry's social licence to operate.

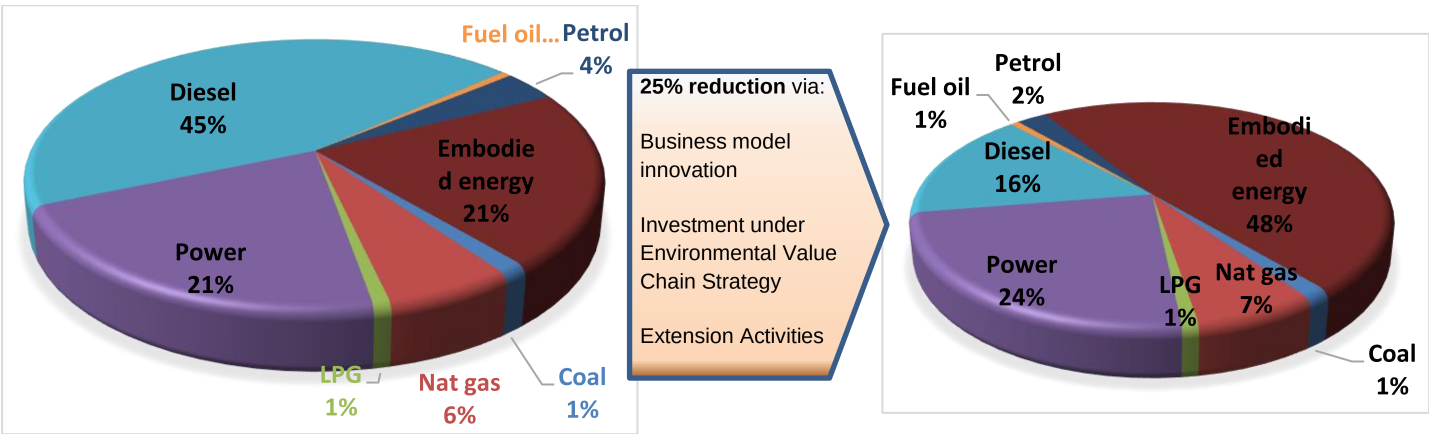


Fig. 7 Energy costs throughout the red meat industry value chain including beef, veal, sheep and lamb production for farm, feedlots and red meat processing through to retail ready product showing 2016 estimate ($1.34 billion p.a.) compared to a 25% reduction (Wiedemann 2015)

<table>
<tr><th colspan="2">New business models to increase adoption of water and energy efficiency technologies to reduce costs and improve environmental performance</th></tr>
<tr><td>Value proposition</td><td>Adoption of technologies to reduce water and energy use throughout the red meat value chain will provide practical case studies showing how the Australian red meat industry is improving its environmental sustainability. Innovation in reesource use efficiency will also provide a positive return on investment by reducing on-going energy and water costs.

While MLA may not directly fund the development of new energy and water technologies, due to the accelerating rate of technology innovation and advancement in this field there is a need to support the analysis, adaptation, deployment and adoption of these technologies in the red meat industry. Examples of promising technologies are provided below.</td></tr>
<tr><td>Programme</td><td>1. Support adoption of innovative energy and water use reduction projects into the red meat industry through the critical early stages of feasibility, project development, design, and application for third party funding (refer “Technology Readiness” section below for further information). These early stages of work are typically expected to cost around 1 to 5% of the Total Capital Investment (TCI). Assuming that MLA contributes 5% of TCI by supporting the early stages of project development, a project with a 5% internal rate of return (IRR) over 10 years will yield a net present value to the red meat industry that is approximately 4.6 times higher than the initial 5% TCI contribution. For projects with a 10%, 20% and 30% IRR, the benefit to cost ratio is around 9.6, 19.7 and 29.7 respectively. The early stages of work for new capital projects routinely take one to two years to complete.

2. Promote wider adoption through feasibility assessments, case studies, knowledge sharing, adaptation (to the red meat industry) and demonstration projects for the integration of renewable energy, energy efficiency and water use reduction technologies across the red meat value chain. The potential aggregation of a number of smaller demonstration projects into a larger project with co-funding from the Australian Renewable Energy Agency (ARENA; supports renewable energy technologies) should be investigated. Examples of higher priority opportunities to be promoted, in approximate priority order, include:

a. New liquid fuels: Displacement of liquid fuels (diesel, petrol, LPG, fuel oil); currently representing 49% or $660 million p.a. of the energy costs throughout the supply chain, with cleaner and lower cost fuels including liquefied natural gas (LNG), compressed natural gas (CNG), biogas, bio-CNG and renewable diesel.

As a specific example, a trial for the conversion of diesel powered farming equipment to displace 50% of diesel use with CNG and/or bio-CNG (biogas that has been ungraded and compressed with associated removal of carbon dioxide, moisture and other contaminants). A number of engines would need to be converted in order to complete appropriate statistical analysis (due to the high anticipated effect size, a sample size of 6 engines may be suitable for preliminary analysis). Costs are estimated at $150,000 to convert 6 engines with associated CNG / bio-CNG tanks, Data Logging hardware and software. A trial of 12 months would be suitable. Over 10 years, a cost:benefit ratio for individual engine modifications of around 1:3-1:4 may be realised.

b. Displace grid and off-grid electricity consumption, estimated to represent ~32% of annual energy costs or $423 million p.a., with biomass / biogas fired generation; PV solar; hybrid generation systems e.g. PV solar and multi-fuel engines (biogas, CNG, LNG, diesel); and/or power storage to increase</td></tr>
</table>

penetration of renewable energy technologies.

As a specific example, a large renewable energy boiler or waste to energy project at $15 million cap ex is estimated to cost between $200k and $750k to develop to "Final Investment Decision" readiness. By accessing 3rd party project funding (such as 20% funding of TCI via ARENA) a 4 to 15-fold payback to the processor on MLAs investment could be achieved during construction of the facility. Further benefits will be realised during the life of the project (such as outlined in section 1 above).

c. Feed lots: PV solar shading coupled with biogas cogeneration for power and steam (for grain flaking). Estimated to represent up to 21% of annual energy costs or $280 million p.a., excluding energy exporting opportunities (which could include biogas for fuel or power exported to grid). The manure at a feedlot is estimated to be able to create 120% of the power load of a feedlot, hence sufficient manure is available for economically viable waste to energy facilities, with efficient and financially viable collection being a critical area for consideration.

d. Solar for stationary energy:

    i. Displacement of fossil fuels for thermal heating (coal, natural gas, LPG and LNG-fired boilers), estimated to represent up to 21% of energy costs throughout the red meat supply chain or $286 million p.a., with concentrated solar thermal technology, bioenergy, and/or thermal storage.

    ii. Displacement of 12% of boiler fuels (coal, natural gas, LPG, fuel oil) and 17% of grid power with high efficiency simultaneous PV solar and hot water (Galvez 2016).This would contribute to energy cost savings of $75 million p.a. or 7% of entire value chain energy costs.

e. Energy efficiency:

    i. Waste-to-energy: biogas from anaerobic digestion for cogeneration to provide 40% of power and 11% thermal heating for red meat processors. Estimated to represent up to 8% of annual energy costs or $108 million p.a.

Note: Not all above Programmes are mutually exclusive – some overlap exists between the different opportunities (e.g. liquid fuels are used for transport, stationary power and for thermal heating).

f. Water efficiency (In priority order):

    i. Recycled Potable Water: Reduced consumption of fresh potable water at red meat processing facilities by 50-70% through the application of advanced water recycling technologies, saving $18-25 million p.a. in water supply costs and potentially a higher saving in trade waste disposal costs. AMPC is currently investigating strategic opportunities for water recycling and re-use at abattoirs and is well positioned to contribute to this activity.

        1. AMPC is currently investigating strategic opportunities for water recycling and re-use at abattoirs;
        2. The next step is to develop a cost model of the water recycling process specific to red meat applications and

New business models to increase adoption of water and energy efficiency technologies to reduce costs and improve environmental performance	
	factoring in wastewater quality, recycled water quality and technology selection. This model should be applied to 2-3 case study sites to identify the optimal treatment/reuse strategy, investment and cost/benefit. 3. The final step would be to progress outcomes above and drive adoption through technology demonstration. ii. Feedlot and On-farm: 25-40% of water consumption in the red meat supply chain is linked to losses from the livestock drinking water supply. Covering dams or redesigning water supply and storage infrastructure is a strategy to reduce evaporation of water supplies. This strategy has the potential to significantly reduce water consumption by the 25% targets as outlined in the MISP 2020, with strong environmental benefits. However, this activity is a low priority due to the uncertain value of water used by the red meat supply chain. The financial drivers are linked to establishing a value for water, presented below. iii. Feedlot and On-farms: Use of waste water (non-potable) from feedlots as alternative source of irrigation water, wash-down water and dust-suppression water, again this approach could reduce the environmental footprint of the red meat supply chain and contribute to water reduction targets in the MISP 2020, However, this activity is a low priority due to the uncertain value of water used by the red meat supply chain. The financial drivers are linked to establishing a value for water, presented below. 3. Investigate and develop new business models for adoption of water, energy and efficiency improvement technologies at broad scales across the red meat value chain. a. Investigate business models including third party services, aggregated purchasing, cooperative, alliance or other models to provide benefits at large scale. b. Investigate alternative approaches to capital requirements for adoption measures through equity funding, venture capital, superannuation funds and other investments in agritechnology and agribusiness. c. Investigate co-funding opportunities with government, the Australian Renewable Energy Agency (ARENA), Clean Energy Finance Corporation (CEFC) and others to implement water and energy efficiency measures.
Technology readiness	The technologies considered within this program are commercially available and have been utilised in other industries, but have not been implemented to any significant degree within the Australian red meat industry. Fig. 8 provides indicative information as to the technical readiness of some technologies considered within this program.

New business models to increase adoption of water and energy efficiency technologies to reduce costs and improve environmental performance

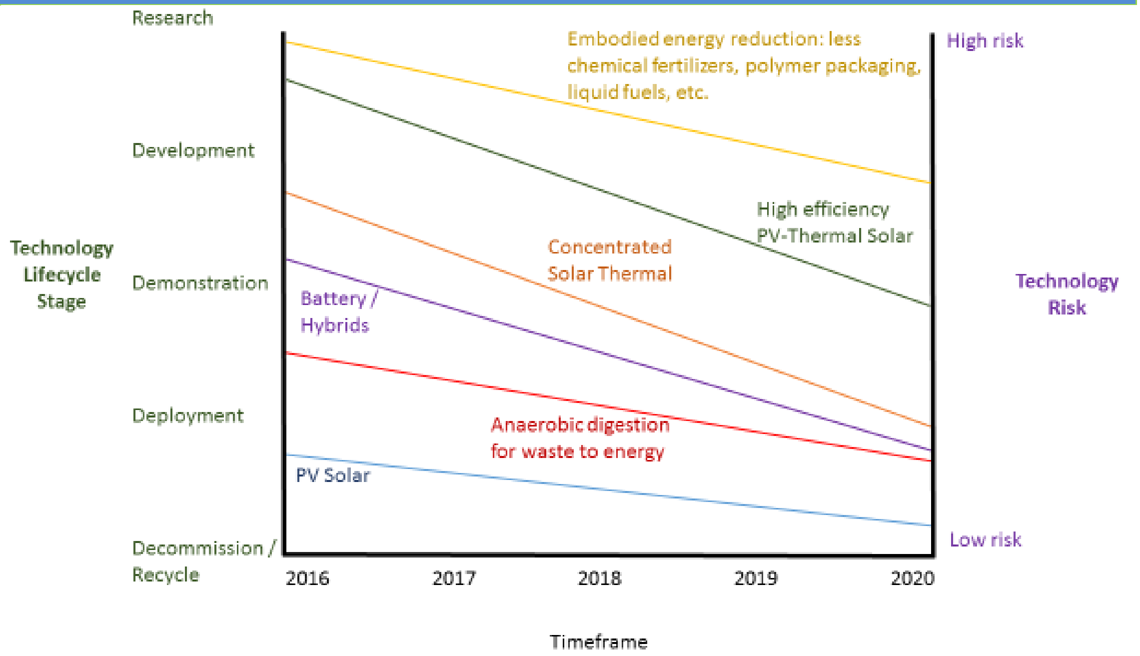
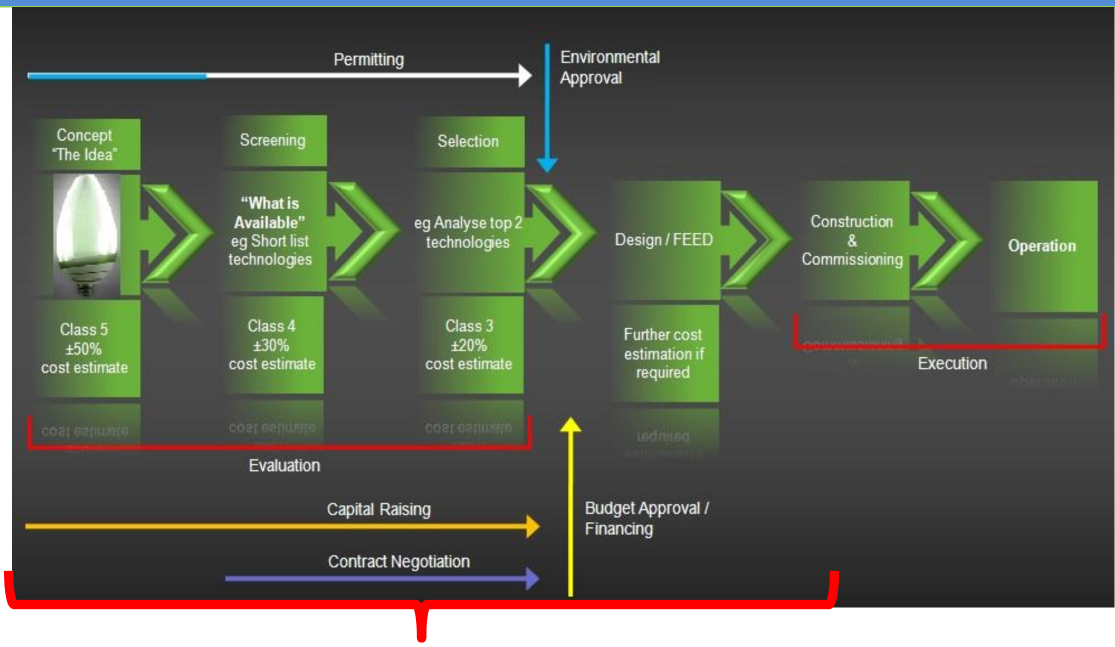


Fig. 8 Indicative commercial readiness for a range of technologies for the Australian red meat industry

- A key rate limiting step is the adaptation and then adoption of existing technologies into the red meat industry. New projects may take 6-12 months for concept development followed by detailed engineering assessments to take projects through to “Final Investment Decision”. A large scale demonstration project (potentially with co-funding from ARENA) will include: basis of design, technical specification, mass and energy balance, front end engineering design (FEED), council development application, state level EPA approval (may include air quality assessment, hazard and risk reporting, noise impact assessment, refuse and recycling assessment, and storm water contamination), HAZOP / risk register, safety approval, detailed design, capital and operating cost estimation. Estimated costs for project development works (studies, concept and engineering design, permitting) are in the order of 1% to 5% of total project costs, depending upon project complexity and environmental approval requirements.
- Fig. 9 shows a potential demonstration project and where early stage support for such projects could be provided by MLA / MLA Donor Company (MDC) and an example of an innovative business model is shown in Fig. 10.



MLA could support clean tech projects through the critical early stages of project development. These stages of work would be expected to cost around 1 to 5% of the Total Capital Investment.

Fig. 9 Project development lifecycle, showing where MLA can support technology adoption projects for the red meat industry

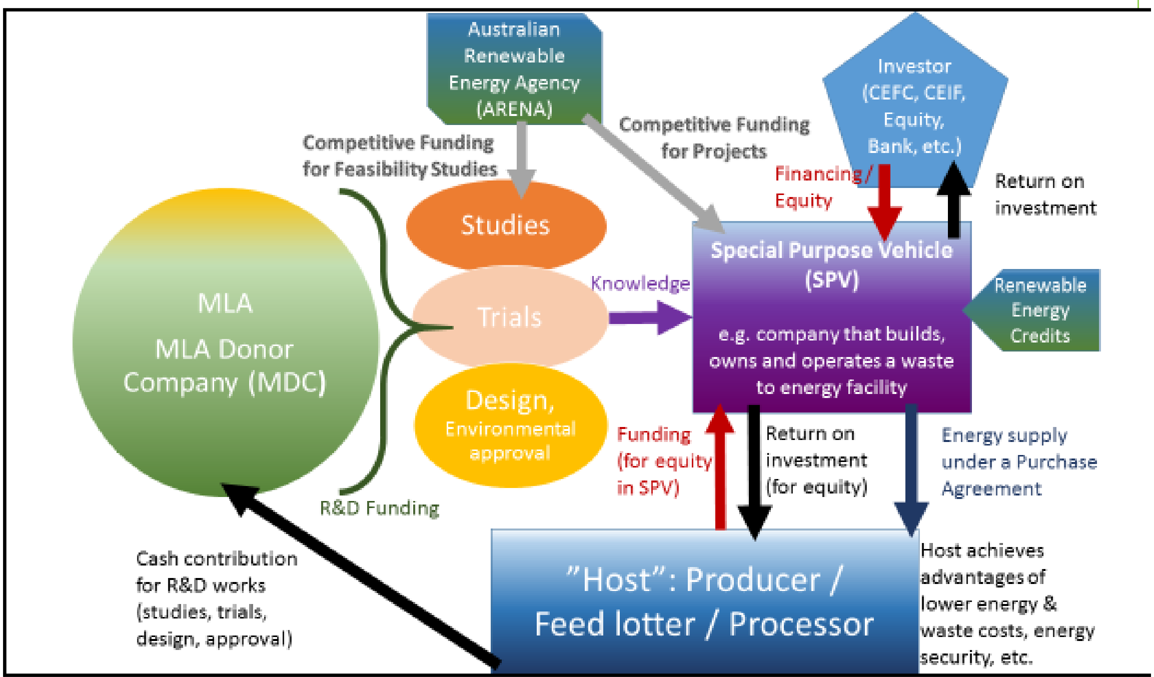


Fig. 10 Example of an innovative business model

Technology readiness of specific technologies include:

New business models to increase adoption of water and energy efficiency technologies to reduce costs and improve environmental performance	
	• 100% biogas, dual fuel and electrified vehicles are available from equipment manufacturers. • Solar energy opportunities offer the greatest area for innovative design targeting the entire life cycle of red meat industry. New offerings in pumping show costs an order of magnitude cheaper, with thermal heating 60% to 90% cheaper than fossil fuels. Thermal storage would need to be reviewed in detail. Short term feasibilty studies (e.g. over 3 months) are estimated to cost ~$20,000. • Energy efficiency: technologies exist for trials now. Short term feasibilty studies (e.g. over 3 months) are estimated to cost ~$20,000. • Water Efficiency: Water recycling technologies are commercially available and applied successfully in non-meat processing industries (e.g. Fosters Brewery, Yatala), poultry meat processing (e.g. Ingham's, Murarrie) and domestic red meat processing (Radfords Meats, Warragul). This area requires engagement with international regulators to develop an application process and facilitate application to export markets. R&D requirements are largely related to selection of "fit for purpose" process configurations, process optimisation and larger scale demonstration and would be suited to the MLA PIP program.
Adoption	• Adoption can be enhanced by co-funding from industry and other sources such as ARENA, equity partners or under build-own-operate schemes. This can reduce project capital costs to the red meat industry and de-risk the deployment and operation of new technologies. • Projects can be developed and de-risked through: ○ Audit: understand current and future energy needs ○ Set KPIs: understand what the goals are e.g. short list options with less than 5-year payback; annual 5% energy efficiency gain; 20% reduction in energy costs within 5 years ○ Analyse efficiency options in terms of technical and economic viability ○ Standard approaches to project execution: funding, design, project management, construction, commissioning. • Producers bear 53% of the energy costs, whilst feedlots represent 21% of the energy costs and processors 26% (Sandell 2013, ABS 2016a). Hence, adoption of energy efficiency and renewable energy solutions by producers will provide the greatest in-roads to energy use reduction. The anticipated adoption rates are difficult to predict, however, two scenarios have been modelled in order for the red meat industry to achieve a 25% reduction in energy use: ○ Scenario 1: 15% efficiency gain across stationary energy (thermal heating and power) and embodied energy; with a further 51.2% displacement of transport fossil fuels (achieved viarenewable fuels including compressed biogas; and biofuels). ○ Scenario 2: as per Scenario 1 above except that rather than transport fossil fuel reduction, 78.3% of power use otherwise obtained from the grid is sourced from renewable sources such as PV solar, waste to energy processes (e.g. anaerobic digestion biogas cogeneration).

<table>
<tr><th colspan="2">New business models to increase adoption of water and energy efficiency technologies to reduce costs and improve environmental performance</th></tr>
<tr><td>Benefits</td><td>
An estimation of the current energy costs throughout the red meat supply chain can be found in the supplementary information in Appendix C.

Some water and energy efficiency projects have the potential to deliver payback periods of months (reported returns on investment of >1000% (Taylor 2012), while large capital works (such as stationary energy equipment) will normally target returns on investment of 10 - 30%.
Where the return on investment is considered unacceptably low or the capital outlay too high, third party sources of funding may be available. Innovative technology coupled with innovative business models will increase the uptake of clean technologies. Potential funding partners and business models include:

The Clean Energy Finance Corporation (CEFC): requires returns of bond rate +3%. Equates to interest of ~4.79%. Clean Energy Innovation Fund (CEIF): just being created under a new CEFC Investment Mandate. CEIF requires a return of the bond rate + 1%. Equates to interest of ~2.79%
Other sources of equity including project finance, venture capital, superannuation funds and debt funding
Australian Renewable Energy Agency (ARENA): can provide grants for renewable power and heat projects that progress technology readiness and contribute to knowledge sharing objectives
Australian Government programs
Third party outsourcing models e.g. Build-Own-Operate-Maintain (BOOM) for a waste to energy facility with an associated power and heat purchase agreement

Economic Benefits of Water Efficiency

Feedlot and On-farm: There is currently limited information on the cost of water during the production stages of the red meat supply chain, however, water remains a critical resource and there is a need to ensure that is valued appropriately. The Australian Bureau of Statistics reports that the average cost of distributed water in the agricultural, forestry and fishing industries was $0.08/kL in 2013/14 and had increased 17% from 2012/13 (ABS 2015). Water trading prices in the Murray-Darling basin ranged from $0.15/kL to over $2/kL in December 2015, however data for other regions was not available at the time of reporting. Importantly, these statistics demonstrate that water used by the red meat supply chain is potentially valued at well over $80 million p.a. for beef production alone. There is increasing recognition of this value and increasing motivation for water efficiency.
A growing recognition of water value presents both economic risk and opportunity for the industry. It’s a risk for farmers and feedlotters that don’t pay for water directly or pay licences that are not linked to volume consumption: – if the cost of water or the water pricing structure changes, these businesses could have a much higher exposure to this new cost. This is an opportunity for farmers and feedlotters that have existing entitlements: - water allocations are in short supply in many regions, therefore if these producers can reduce water consumption, they may have left over entitlements to “trade” and thereby create a revenue stream.

Environmental benefits
</td></tr>
</table>

<table>
<tr><th colspan="2">New business models to increase adoption of water and energy efficiency technologies to reduce costs and improve environmental performance</th></tr>
<tr><td></td><td>Efficiency gains and clean technology reduce utility and/or resource costs whilst also reducing environmental impacts. Previous works have shown that many businesses can achieve a 15% efficiency gain for investments with payback periods of less than 5 years. As an example on the clean technology side, waste to energy, solar thermal and solar power systems are now able to provide a positive return on investment (ROI) in many applications
Technologies exist now for complete removal of fossil fuels use from the entire red meat industry and for processors to have completely closed loop water system. Due to disruptive technologies and incremental advances, solutions for energy, water and waste management are available that are resource and economically efficient.</td></tr>
<tr><td>Outcomes</td><td>Lower fossil energy uses across the value chain
Lower water use across the value chain
Increased knowledge of new technologies and their applications in the red meat industry
Experience in the application of new business models for improved adoption of renewable energy and water reduction technologies</td></tr>
<tr><td>Risks</td><td>Inertia in using the same utilities available now into the future
Being reactive when making equipment and technologies solutions (e.g. replacing like with like rather than having an improvement strategy)
Access to capital
Low priority compared to other capital works / core business
Knowledge in understanding how a specific technology will impact a specific operation</td></tr>
<tr><td>Customers</td><td>New and innovative technologies provide evidence of environmental improvements in red meat industry operations
Consumer sentiment is improved by showing and explaining actions that have been taken rather than high level or distant goals
Strategic programs of work and trending energy and water use throughout the supply chain will ensure that red meat remains competitive in terms of the cost of production compared to other sources of protein and has a knowledge base to react or adapt to changing business conditions and customer requirements.</td></tr>
<tr><td>Measures</td><td>GJ fossil fuels (and overall energy cost) per kg retail ready red meat for whole supply chain life cycle
kL water (and overall water cost) per kg retail ready red meat for whole supply chain life cycle
Overall Equipment Efficiency (OEE), a function of equipment availability, performance and quality
Whole of supply chain cost and resource consumption model
Investment in new energy and water efficiency measures throughout the industry</td></tr>
</table>

6 Conclusion

The purpose of this project was to develop a research, development and adoption (RD&A) strategy to guide environmental innovation within the red meat supplychain.

The two milestones were achieved with the completion of two reports:

- Milestone 1 interim report, “Environmental value chain in the Australian red meat industry: Current status and perspectives (V.SCS.0001), which completed milestone 1 of the project; and
- The final report, “RD&A strategy for environmentally sustainable value chains in the Australian red meat industry” which completes milestone 2 of the project.

The milestone 1 interim report collated background information on the current environmental performance of the red meat and livestock industry including the four focus areas - waste, water, energy and greenhouse gas emissions.

This final report details the process of identifying high value new products opportunities, service applications and service opportunities and the ranking and down selection of these opportunities to three programmes to inform the RD&A strategy for environmental value chain in the Australian red meat industry. The business cases for these three programmes were developed to provide direction to research, development and adoption activities undertaken within the MLA Supply Chain Sustainability Programme up to 2020. It focuses on increasing profitability of the red meat and livestock industry in an environmentally sustainable manner.

The three R&D programmes are:

1. Increasing productive efficiency and environmental performance using enhanced supply chain information systems;
2. Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein;
3. Driving adoption of technologies to improve water and energy management in the Australian red meat supply chain;

This report has identified three programmes that present high value products opportunities, service applications and service opportunities and promote environmental sustainability acorss the red meat supply chain. MLA should consider investment in these programmes to further their Environment Value Chain Innovation Programme.

7 Bibliography

ABS (2015). "4610.0 – Water Account, Australia, 2013-14." Retrieved 21.12.2015, from http://www.abs.gove.au/ausstats/abs@.nsf/mf/4610.0

ABS (2016a). "Livestock and Meat, Australia." Retrieved 29.05.2016, from http://www.abs.gove.au/ausstats/abs@.nsf/mf/7218.0.55.001

ABS (2016b). "Meat produced." Retrieved 27.05.2016, from http://www.abs.gove.au/ausstats/abs@.nsf/mf/7218.0.55.001

AMPC. "Fact Sheet: Recycled water opportunities in sustainable food production and manufacture", from http://www.ampc.com.au/site/assets/media/Factsheets/Climate-Change-Environment-Water-Waste-Energy-Sustainability/CSIRO-Recycled-Water-Opportunities-in-Sustainable-Food-Production-Manufacture.pdf

Galvez, J. (2016). "Made in IBM Labs: Collaboration aims to harness the energy of 2,000 suns." Retrieved 24.04.2016, from https://www-03.ibm.com/press/uk/en/pressrelease/40908.wss

GHD (2012). "Industry environmental sustainability review 2010." from http://www.ampc.com.au/reports/ENV_2011_Industry-Environmental-Sustainability-Review-2010

Gonzales, L.A., Charmley, E., Henry, B.K. (2014). "Modelling methane emissions from remotely collected live weight data and faecal new infrared spectroscopy in beef cattle." Animal Production Science **56**: 1980 - 1997

Keogh, M.A. and Henry, M. (2014). "The applications of digital agriculture and big data for Australian agriculture." Farm Institute, Sydney Australia, from http://www.farminstitute.org.au/publications-1/research-reports/the-implications-of-digital-agriculture-and-big-data-for-australian-agriculture

McPhee, M., Walmsley, B., Oddy, H., Andrews, T., Gudex, B. (2016) "Enhancing BeefSpec systems for improving market compliance of pasture fed beef in southern Australia – B.SBP.0111" from http://www.mla.com.au/Research-and-development/Search-RD-reports/RD-report-details/Productivity-On-Farm/Enhancing-BeefSpecs-systems-for-improving-market-compliance-of-pasturefed-beef-in-southern-Australia/3224

MLA (2016a). "2015 Australian beef eating qulity audit." from https://www.mla.com.au/files/c4d98c5b-8547-4bf9-bea2-a5e900b4e4f3/

MLA (2016b). "The next big thing for red meat production." Retreived 23.05.2016, from http://www.mla.com.au/News-and-events/Industry-news/The-next-big-things-for-red-meat-production

Sandell, G.R., Szabo, P.M., Baillie, C.P., Woodhouse, N.P., Schmidt, E. (2013). "North-east farming futures R&D support: Increasing the knowledge and adoption of energy saving initiatives amongst farming enterprises in Western Australia." From National Centre for Engineering in Agriculture, Publication 1005089/1, USQ.

Taylor, A. and Jamaludin, S. (2012). "Innovative APC boosts LNG train production." Retrieved 01.01.2012, from http://www.hydrocarbonprocessing.com/Article/2959324/Innovative-APC-boosts-LNG-train-production.html

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

Wiedemann, S.G., McGahan, E.J., Watts, P.J. (2010). "Scoping Life Cycle Assessment of the Australian lot feeding sector – B.FLT.0360." from http://www.mla.com.au

APPENDIX A
TOPICAL BACKGROUND

TOPICAL BACKGROUND

1. OBJECTIVES

The objective of this project is to develop a strategy to provide direction to Meat & Livestock Australia's (MLA) research, development and adoption (RD&A) activities regarding the development of environmentally sustainable Australian red meat value chains over the period 2016-2020. The strategy will be aligned with the Meat Industry Strategic Plan (MISP) 2020 report, which focuses on increasing profitability of the red meat and livestock industry in an environmentally sustainable manner. The strategy will:

- Provide direction to MLAs RD&A activities that span the whole red meat supply chain (production, feed lotting, processing, wholesale, retail, and transportation between these segments in the supply chain) to further develop key opportunities to improve environmental performance and generate new products, and revenue opportunities for the Australian red meat industry;
- Identify at least three opportunities for supply chain and business model innovation, within new or existing supply chains, that provide an economic value proposition for improved management of energy, water, greenhouse gas emissions and waste and how improved management in these areas can best be positioned to customers and consumers to grow demand for Australian red meat.

The first phase of this project is the development and collation of baseline information on current environmental performance of the red meat industry.

2. INTRODUCTION

The Australian red meat and livestock industry is one of the most important industries in Australia and contributes about $7 billion to Australia's gross domestic product (GDP). It directly employs about 200,000 people on-farm, in meat processing works and in wholesale and retail outlets, not including employment in service and related industries. The Australian meat and livestock industry also contributes extensively to the nation's social and environmental objectives (RMAC 2015).

The distribution and intensity of goat, sheep and cattle farming in Australia is contingent on the climate, geography and soil fertility. Farmland in Australia covers an area of 406 million hectares with the largest areas being farmed in Queensland followed by Western Australia, New South Wales, South Australia and the Northern Territory (see Table 1).

Table 1 Area of farmland in Australia

	Total	Qld	WA	NSW	SA	NT	Vic	Tas	ACT
Area ('000 ha)	406,269	139,933	89,313	58,303	52,823	51,871	12,290	1,701	34
%	100	34.4	22	14.4	13	12.8	3	0.4	<0.1

Source: (ABS 2015a)

Livestock production in Australia is carried out in the following zones (OECD 2013):

- Pastoral
- Wheat-sheep
- High rainfall

The majority of agricultural land in Australia is used for beef and sheep production (ABS 2013) with goat farming making up a small but increasing percentage (see Table 2).

Table 2 Proportion of farmland dedicated to cattle, sheep and goat farming in Australia

	Cattle	Sheep	Grain-fed sheep & cattle	Goats
Proportion of total farmland	58%[a]	32%[b]	-	negligible
Number	24,349,000[c]	69,942,000[c]	11,552,000[a]	3,600,000[d]

Source: [a](MLA 2015a); [b](ABS 2015a); [c](ABS 2015b); [d](MLA 2014)

The size of the national sheep flock and cattle herds in 2014 – 15 are shown in Table 2. These numbers represent a decrease of 4% in sheep numbers and 7% in beef cattle numbers compared to the year before (ABS 2015b). Three years ago the Australian beef herd was the largest in 30 years and now it is the smallest in 20 years. This is due to poor seasons and insufficient rainfall particularly in Queensland and also increased overseas demand (LiveCorp 2015). The number of grain-fed beef and sheep are increasing with increasing export demand. In 2012 there were 11.6 million cattle and sheep produced on feedlots (ABS 2013). In 2014 – 15, 2.8 million grain-fed cattle were marketed, which corresponded to about 29% of all adult cattle slaughtered (MLA 2015a). Increasing demand from Asia and the Middle East is fueling the growth in demand for Australian red meat. In these countries the main drivers for this increase are population increase, the rise of the middle class and Australia's reputation for high quality product and health & hygiene standards. In the coming years, growing export markets will see an increase in the numbers of sheep and beef cattle exported which is likely to impact considerably on the size of the national herd and flock in Australia.

The domestic market for goat meat is small but increasing due to changing dietary trends and changing demographics in Australia. Currently, Australia is a relatively small producer of goat meat but it is the world's largest exporter. In 2014-2015, 2.12 million head of goats were slaughtered (MLA 2015c). The domestic market consumed about 10% of this meat with the remainder being exported. Australia exported 34,354 tonnes goat meat in 2014 – 2015 with the major customers being the US and Taiwan. The main driver of growth in the Australian goat meat industry is the growing US market. There is also a large market for live export. In 2013 the number of live goats exported were about 91,000 with the majority airfreighted to Malaysia.

3. INDUSTRY PERSPECTIVES

3.1 Global perspectives

Historically, the Australian red meat sector has been able to compete in the global market for a variety of reasons (see Table 3) despite its unpredictable climate, high production and processing costs, high transport costs and high regulatory burden.

Table 3 Advantages and disadvantages of the Australian red meat industry from a global perspective

Advantages	Disadvantages
Availability of large areas of pastoral land	Transport within Australia expensive
Livestock BSE and foot & mouth free (unique position)	Unpredictable climate conditions (drought, flood, fires)
One of the best traceability systems in the world	High employment costs
High quality products supplied to >100 countries	High regulatory burden
Variety of products	Uncertainty of investment
Long shelf-life	High processing costs
High health & hygiene status	Increase in number of bilateral and regional agreements hindering access to international markets
Adoption of latest technology in red meat processing plants	High cost of protecting biosecurity status
Transport costs to Asia low	

Source: (AMIC 2015)

Table 4 benchmarks Australia's agricultural industry with four competitor nations – Canada, the US, the EU and Brazil. The following section describes some of these issues in more detail.

Australia has very large expanses of agricultural land, which is approximately the same as the US (World Bank 2013)**.** On one hand, this gives Australia a huge competitive advantage considering we have only about 10% of the population of the US to feed. On the other hand, there are also disadvantages such as insufficient transport infrastructure to adequately support the industry and insufficient labour to fulfil the industry demands.

Labour is expensive in Australia compared to Brazil and the US and, as in the US, Australia's farmers are aging with few incentives for young people to stay on the land (OECD 2013, Zeigler 2015, OECD 2015a). Canada has a mismatch in skills between labour supply and demand but are addressing this problem through training and re-skilling programmes and immigration policies (OECD 2015b).

The economy of Australia is stable and robust compared to the EU, the US and Brazil but still transitioning from the end of the mining boom (OECD 2013, Zeigler 2015, OECD 2015a)**.** The red meat and livestock sector is well positioned to expand and, at least in part, help to address this decrease in GDP caused by the decline in the mining sector. Driving this expansion is the currently thriving export sector. Economically Canada has similar problems to Australia as it also depends highly on the mining sector to boost economic growth. The US and the EU are still recovering from the Global Financial Crisis (GFC) with the EU struggling with the large debts of some of its member states. Brazil has successfully transitioned from the high inflation rates of the 1980s and 1990s but the risk of high inflation, deterioration of fiscal performance, rising household debt, and global uncertainty remains.

In Australia, Canada, the US and the EU credit is generally available and sufficiently capitalised (OECD 2013, OECD 2015b). In Australian interest rates are at an all-time low but it is critical that credit is made available for innovation in order increase productivity and the environmental sustainability of the industry. Canada has implemented a special agricultural credit programme, which lowers the cost of credit to farmers. However, Canadian farmers have insufficient access to venture capital. The US is expecting a tightening in credit availability in the first quarter of 2016 (Kauffman 2016). Brazil, however, has high interest rates and credit is scarce, which has a large impact on the ability of the industry to modernise and stay competitive (OECD 2015a).

Taxation is another important aspect, which impacts on the ability of the industry to compete. **In Australia the agricultural industry is operating with a degree of uncertainty due to the on-going discussions around tax reforms** (OECD 2013). The Canadians and the Americans have lower taxation rates than Australia (USDA , OECD 2015b). In Canada, farmers are taxed on a corporate rate, whereas, in the US the farmers are taxed as individuals. In both countries faster depreciation of investments in machinery, equipment and other eligible capital investments is possible. The taxation and credit burden in the US and EU is lessened by high level of subsidies. As in most developing nations Brazil’s agricultural industry struggles with the complexity and high level of taxation (OECD 2015a).

Agricultural infrastructure is comprised of irrigation, energy, transportation and pre-harvest and post-harvest storage. It supports on-farm production, effective trading and exchange and adds value, e.g., agro-processing & packaging facilities, transport by roads and rails with bulk storage that move product more rapidly from farm-gate to processing facilities and on to wholesalers. Infrastructure is one of the keys to competitiveness. **In infrastructure, Australia lags behind competitors both in coverage and quality** (Australian Government 2015). This is partly due to its large land mass and low population density. Canada, despite its large land mass, has less of a problem with infrastructure as it has more than six times less agricultural land than Australia and the farming and population is concentrated in the south of the country (OECD 2015b). Brazil’s standard of infrastructure is well below its competitors and has huge gaps, especially in the area of roads and rail (Garcia-Escribano 2015). Large tracts of roads are unpaved. The US has a high level of freight activity but it is critical that its infrastructure and transport is maintained and modernised (Zeigler 2015). US port terminals are aging and they are not equipped to handle modern large ocean cargo ships that transport large containers. The terminals are outdated characterised by insufficient infrastructure, poor connectivity to rail and highway networks and inefficient operation. Labour disputes also hamper their efficiency. Even navigable waterways, which were traditionally a low cost means of transport, need to be upgraded and repaired as do road and rail infrastructure. Investment to modernise and upgrade agricultural infrastructure as a whole is a necessity but the low level of funding by governments is hampering progress in this area.

Greenhouse gas emissions in Australia have been stable over the last 20 years (OECD 2013). Brazil, Canada and the US have seen a substantial increase in their greenhouse gas emissions over the last 20 years (US EPA 2013, Environment Canada 2014, OECD 2015a). However, in the case of Canada these levels have remained stable from 2005 – 2012. If emissions are broken down into the contribution per sector it can be seen that, whereas the amount of emissions from on-farm fuel use and crop production has increased, the emissions from animal production has decreased by 18% over this period (Government Canada 2013). The EU has successfully decreased their emissions by 25%. This reduction can be attributed to the reduction in livestock numbers and the success of their regulatory policy, which has successfully led to the implementation of more efficient farming practices and better manure management strategies and a reduction in the use of nitrogenous fertilisers (Eurostat 2015a). Brazil is globally the 5th largest producer of greenhouse gas emissions and the agricultural sector is the dominant source.

Energy use in the agricultural sector, as a percentage of total consumption, is quite low in Australia, the EU and the US but this is quite misleading unless total energy consumption is considered (Eurostat 2015b). If the real amounts are considered, Australia has by far the lowest consumption followed by Canada and Brazil (OECD 2013, OECD 2015a). The EU and US have very large energy consumption corresponding to about ten times the energy consumption in the Australian agricultural industry (Eurostat 2012a, Beckman 2013). This is due to the high intensity of farming in the EU and the high degree of mechanisation and the large number of livestock and grain fed cattle in the US. In the EU about 53% of the total energy consumption is derived from oil with the exception of the Netherlands (which uses gas), Sweden (with a high level of renewable energy) and the UK & Norway (electricity). It is also interesting to note that both the US and Brazil produce a large amount of bio-energy from renewable resources. The US produced 54.3 billion litres of bio-ethanol from corn and 4.7 billion litres of biodiesel from soybeans, corn oil and animal fat and Brazil produced 26.5 billion litres of bio-ethanol from sugarcane and 3.4 billion litres of biodiesel in 2014 (REN21 2015). This is an interesting example of the effectiveness of government policy and mandates in influencing environmental sustainability and supporting a new industry that benefits farmers and offers employment to a large number of people.

Table 4 Benchmarking the Australian agricultural sector to competitor nations - Canada, USA, EU and Brazil

Country	Australia[a]	Canada[b]	US	EU	Brazil[c]
Agricultural land (2011, '000 km^2)[d]	4097	626	4113	1879	2750
Population (2012, million)[d]	23	35	314	504	197
Farm labour	High cost	Supply & demand mismatch	Cheap and flexible[e]	Expensive	Cheap
Education levels of farmers	Well-educated	Well-educated	Well-educated	Well-educated	Low but improving
Economic stability	Stable	Stable	Recovering	Threatened	Risk of instability
Domestic credit	Efficient, sufficiently capitalized	Low cost	Available but tightening[f]	Access to credit easing	Costly, long term credit scarce

Taxes	Uncertainty	Low	Low[g]	Low with subsidies	High & complex
Agricultural regulations	Inefficient and burdensome	Need improve-ment	Only meat processing highly regulated	Encourages greener farming practices	Restrictive, complex
Infra-structure	Lags behind competitors	Relatively good	Needs modern-isation[e]	Highly networked	Significant gaps
Infrastructure investment (% GDP)[e]	2.7 (calculated from[h,i]	4.0	<2.0	5.0	2.5[j]
Agricultural GHG emissions (% change)	-3% (1990 – 2010)	+15% (1990 – 2012)[k]	+17[l]	-25% (1990 – 2012)[m]	+50% (1990 – 2011)
Total energy use (2012, million toe)[n]	128.3	251.1	2140.6	1685.8	281.7
Energy use in agriculture (% total) consumption)	2.7 (2008 – 10, incl. forestry)	4 (2010)[k]	< 2.0[o]	2.0 (2010)[p]	4.9 (incl. forestry)
Total freshwater resources (billion m, 2011)[c,d]	492	2,850	2818	1505	5,418
Water use in agriculture (% total consumption, 2011)[b]	53.3	6.7 (2009)[q]	40.2	25 (excl. Turkey)[r]	54.6
Running cost RMP plant[s]	100	-	50	-	50

Source: [a](OECD 2013); [b](OECD 2015b); [c](OECD 2015a); [d](WDI 2013); [e](Zeigler 2015); [f](Kauffman 2016); [g](USDA); [h](Australian Government 2015); [i](Wiki 2016); [j](Garcia-Escribano 2015); [k](Environment Canada 2014); [l](US EPA 2013); [m](Eurostat 2015a); [n](Eurostat 2015b); [o](Beckman 2013); [p](Eurostat 2012a); [q](Statistics Canada 2012); [r](Eurostat 2012b); [s](AMIC 2015)

Australia's water resources are very limited compared to the US, the EU, Canada and Brazil (World Bank 2013). We use over 50% of our water resources for agricultural activities but this corresponds only to a slightly higher water usage than Canada, which has the lowest agricultural water usage of the countries compared (OECD 2013). By far the largest water resources are in Brazil and they use more than ten times the amount of water that Australia uses in its agricultural sector. The US also uses large amounts of water but this is less than half that of Brazil. The EU uses 50% more water than Australia and most of this is used for irrigation (Eurostat 2012b).

Australia struggles with cost pressure associated with meat processing with costs twice as high in Australia compared to the US and Brazil (AMIC 2015).

3.2 Stakeholders

The following section provides a brief introduction to the stakeholders involved in the red meat industry. Due to the complexity of the stakeholder landscape in Australia (see Figure 1) only the key stakeholders relevant to this strategy are identified.

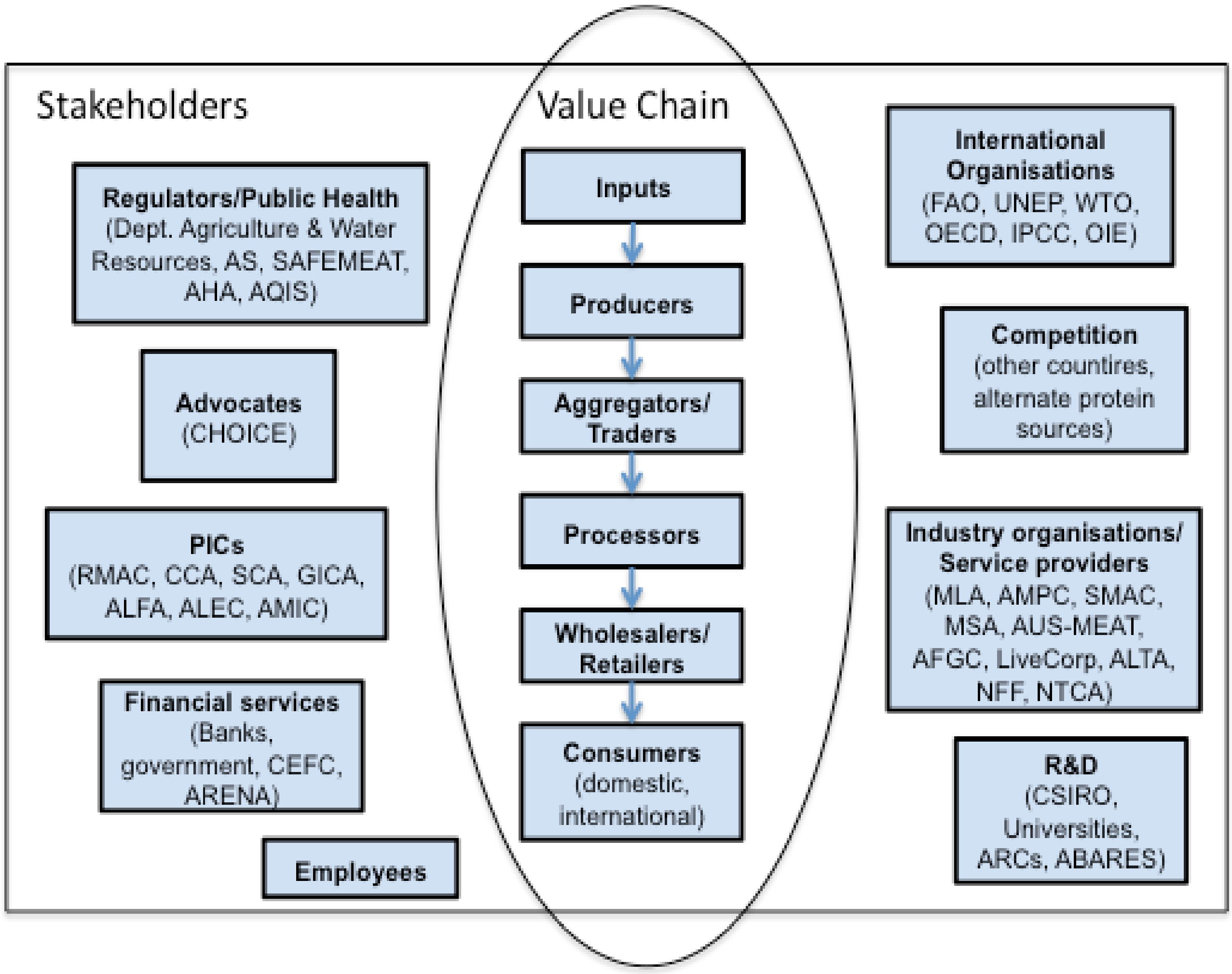


Figure 1 Overview of red meat & livestock industry stakeholders

(see Appendix 1. Abbreviations for explanation of abbreviations)

Commercial value chain stakeholders covers producers of grass-fed and grain-fed livestock, grain preparation plants, red meat processors, aggregators, traders, wholesalers, retail, exporters and consumers from the red meat industry.

Producers are the property operators that produce beef, sheep and goats in Australia. The producers can be large corporate or family-owned businesses. The largest properties are cattle stations, which are usually owned by pastoral companies, e.g., Anna Creek Station, SA owned by the S. Kidman & Co Ltd which covers an area of 23,677 km^2 (S. Kidman & Co Ltd). Anna Creek Station is the largest cattle station in the world. Grain-fed cattle and sheep are grass-fed and then finished on feedlots. Feedlotters supply the majority of their livestock to the export market with a small percentage used for the domestic market.

Aggregators help move livestock by rail or road from the farms to the meat processing facilities, sale yards and airports or shipping terminals for live export. They also distribute meat from the processors to wholesalers, retailers and shipping terminals for export.

Traders facilitate the sale of the "product" along the supply chain. Today there are many methods of sale which include (AMIC 2015):

- Sale yard auctions are the traditional method of livestock sale and offer wider competition but incurs higher costs from transport and sale yard costs;
- On-farm sale saves costs on selling, handling and transport;
- On-line auction allows for electronic online web-based sales;
- Forward price contracts set future prices and reduce price uncertainty; and
- Over the hook reduces handling and transport costs and reduces price volatility.

Red meat processing facilities are responsible for the slaughtering and first steps in the cutting of meat for distribution to wholesalers. It is estimated that the four largest meat-processing companies in Australia (JBS Australia, Kilcoy Pastoral Company, Teys Australia and NH Foods Australia) slaughter about 45 – 55% of total livestock.

Most meat is delivered from the meat processing plants to **wholesalers** where boning and cutting of the meat into saleable portions is undertaken. The meat is then sold to **retailers (**supermarkets, butcher shops, delicatessens), restaurants and institutions (aged care facilities, hospitals). **Consumers** buy the meat products and it is critical that their food safety and hygiene concerns, increased awareness of nutrition and the newest food trends feedback through the whole supply chain.

Peak industry councils (PICs) represent the industry sector(s) on a national basis. These councils provide leadership and define strategy including responsibility for developing the MISP 2020. They also provide advice to the government on the red meat and livestock industry. The red meat industry PICs include:

- Red Meat Advisory Council (RMAC) which consults with the Minister for Agriculture and Water Resources on industry issues and provides leadership on red meat industry matters. It covers PIC participation costs, coordinates maintenance of MISP and support of industry relationships;
- Australian Meat Industry Council (AMIC) representing the meat processing sector;
- Australian Livestock Exporters' Council (ALEC) representing the live export sector;
- Australian Lot Feeders' Association (ALFA) representing the feedlot sector;
- Cattle Council of Australia (CCA) representing the grass-fed cattle sector;
- Goat Industry Council of Australia (GICA) representing the goat sector;
- Sheepmeat Council of Australia (SCA) representing the sheep meat sector (excluding wool).

Research and development corporations (RDCs) are levy and federal government funded and provide research, development, extensions and marketing services to their corresponding industry sector. The Australian red meat industry RDCs include:

- MLA was established by CCA, SCA, ALFA, and GICA as a producer-owned service company. It delivers R&D, marketing and other functions to the beef, sheep and goat sectors of the red meat industry. As shown, its levy paying members number nearly 50,000 (see Figure 2).

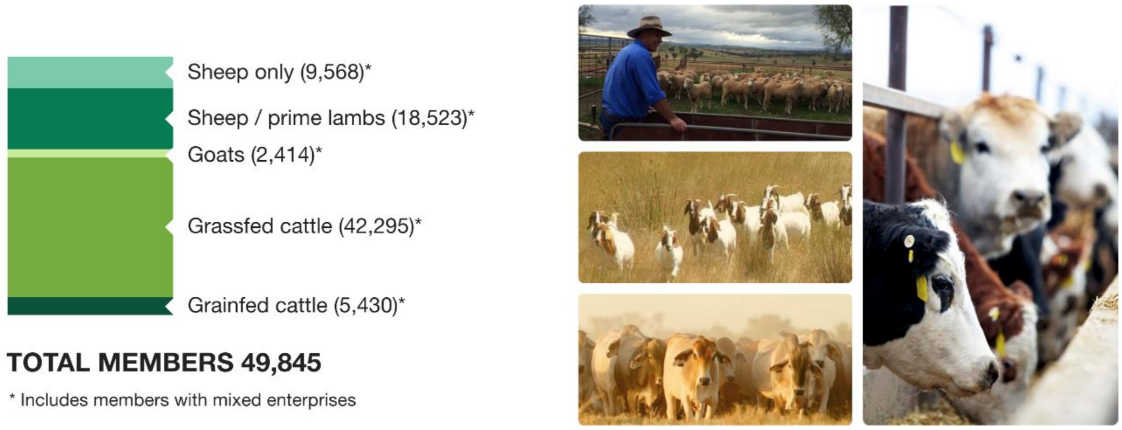


Figure 2 MLA membership breakdown

- Australian Meat Processors Corporation (AMPC) is the research and development corporation servicing the processing sector in Australia.
- LiveCorp is the research and development corporation servicing the live export sector in Australia.

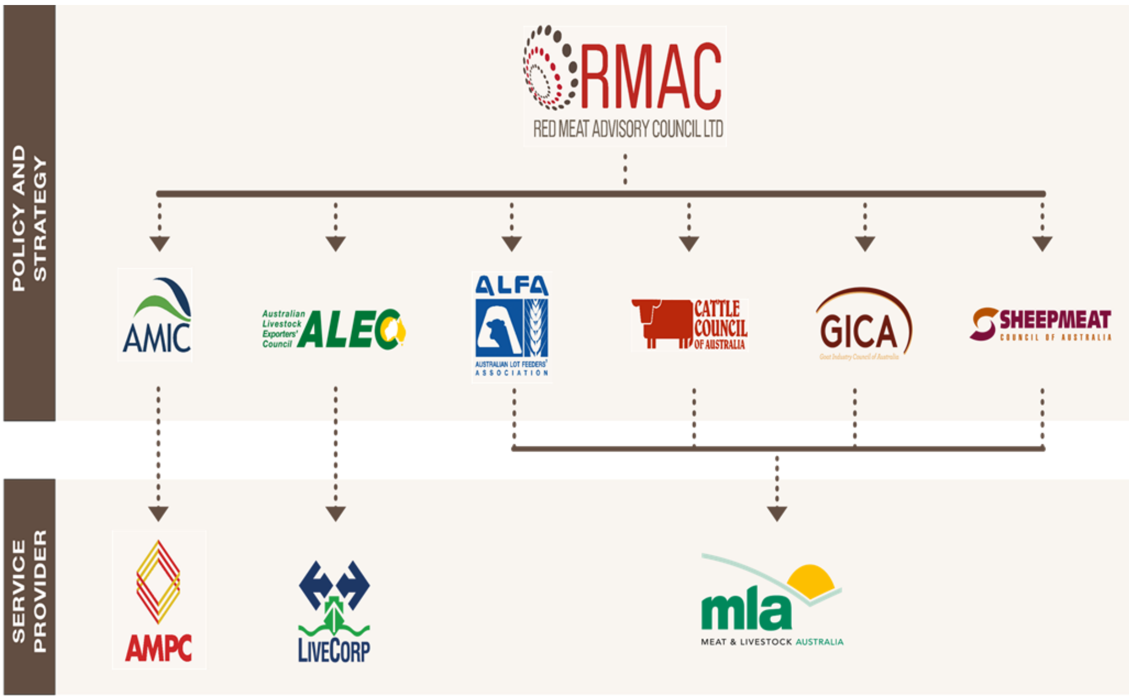


Figure 3 Structure of Peak Councils and RD&E Service Providers (MISP, 2020)

Other important organisations providing a range of R&D and quality assurance services include:

- AUS-MEAT Ltd is a joint venture funded by MLA and AMPC. The joint venture maintains national industry standards for meat production and processing
- SAFEMEAT is a partnership between Australian Government, state/territory governments and industry to ensure the integrity of the Australia's red meat industry. SAFEMEAT oversees and promotes programs and systems that ensure the delivery of safe and hygienic product
- Animal Health Australia is a partnership between the Australian Government and the state/territory governments, major livestock industries and other stakeholders to strengthen Australia's animal health system and maximise confidence in the safety and quality of Australia's livestock products in domestic and overseas markets

Research and development organisations (RDOs) are important stakeholders that identify, prioritise and provide funding for innovation across the industry. RDOs assist the industry adopt better practices and new technologies and minimise environmental impact, develop user-friendly software for data acquisition and forecasts that support industry competitiveness. In Australia, research and development is typically carried out by:

- Universities and Research Institutes
- Cooperative Research Centres (CRCs)
- CSIRO
- State Government Departments
- Companies

Government Department stakeholders include the Department of Agriculture and Water Resources, the Department of Environment and the Department of Health. The Department of Agriculture and Water Resources determines national policy in the agricultural sector. Through this department, regulations and programs are initiated to address industry standards, best practices, food safety, hygiene standards, biosecurity, animal welfare and product traceability. The Department of Environment is focused on enhancing Australia's environmental sustainability and the Department of Health focuses on the health and hygiene aspects of the industry.

Financial services are important stakeholders who provide access to credit, banking and insurance services.

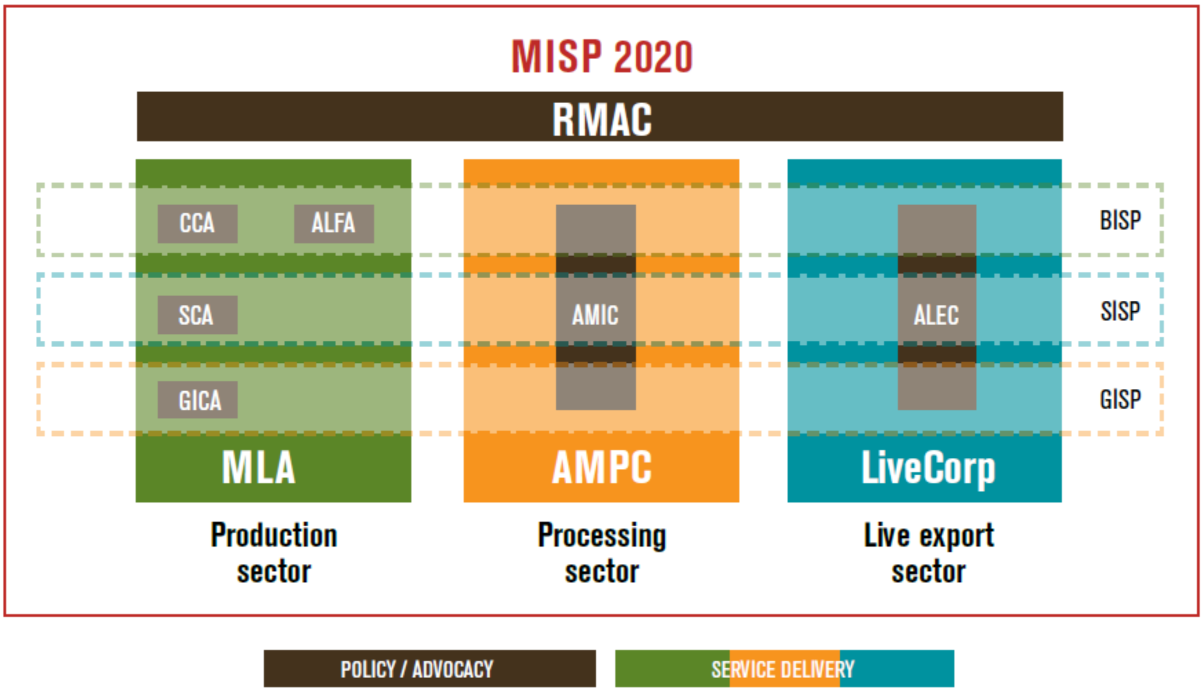
3.3 MISP 2020

As caretakers of around half the continent's landscape, Australian red meat and livestock producers have a vested interest in continually improving sustainable farming practices. Indeed, greenhouse gas emissions intensity has been reduced by 14% over the last 30 years while red meat production levels have increased by more than 70% over the same period. In addition, the industry has achieved a 42% reduction in emissions associated with vegetation protection and tree planting and a 65% reduction in water use (RMAC 2015).

3.3.1 Integrated strategic plan structure

The Meat Industry Strategic Plan (MISP) frames the overarching strategic priorities for Australia's red meat and livestock industry, comprising the production, processing and live export sectors of Australia's beef, sheep meat and goat meat supply chains. This strategy has been built with the direct input of major red meat and livestock co-investors including levy payers, Federal, State and Territory Governments, CSIRO, the University sector and agribusiness (including pastoral houses, financial and service industries).

As a whole-of-industry strategy, the priorities identified in MISP are cross-sectoral. MISP defines the 'what to do' in terms of these priorities. The strategic and operational details specific to each supply chain or sector cascade into MISP's component strategies e.g. the Sheep meat Industry Strategic Plan (SISP) and Beef Industry Strategic Plan (BISP), and in the operating plans of the industry's service companies.



ENTITY	CORE FUNCTION	SECTOR		
		Live Export	Production	Processing
RMAC	Cross-sector policy/advocacy		Red meat and livestock	
CCA	Sector policy/advocacy		Cattle (grassfed)	
SCA	Sector policy/advocacy		Sheep (meat)	
ALFA	Sector policy/advocacy		Cattle (grainfed)	
GICA	Sector policy/advocacy		Goat (meat)	
AMIC	Sector policy/advocacy			Red meat
ALEC	Sector policy/advocacy	Cattle / Sheep / Goats		
LiveCorp	Sector service delivery			
MLA	Sector service delivery			
AMPC	Sector service delivery			

Policy/advocacy Service delivery Joint programs

Figure 4 Organisational responsibilities under the MISP (RMAC 2015)

Table 5 Policy and strategy context to the Environmental VCI Strategy (RMAC 2015)

Pillar identified in RMAC's Meat Industry Strategic Plan (MISP) 2020: - Consumer and community support for the red meat industry	**KPI -** Consumer and community support index (to be developed by RMAC)
Priority: - Stewardship of environmental resources	**KPI** – Maintenance or increase in community support for the industry's environmental stewardship practices
Imperatives: 1) Minimising industry impact on the environment	**Objectives:** - Participate in global partnerships to conduct R&D that provides technical solutions to convert 25% of the energy lost in methane emissions into gains in animal productivity by 2030 with demonstrable progress towards this goal by 2020 - Develop new methodologies under Carbon Farming Initiatives to capture revenue from carbon credits of $30 million by 2020 and $80 million by 2030
2) Sustainable management of the natural resource base	- Alignment of NRM practices with community expectations - R&D results in savings in industry costs due to weeds and feral animals of at least $50 million by 2020 and $150 million by 2030
3) Adapting to climate variability	- R&D into improved livestock and pasture genetics, and improved climate forecasting, provides technical solutions to mitigate 80% of the potential productivity falls due to climate change (-3.5% by 2020 and -5.2% by 2030), particularly in the southern beef and sheepmeat industries
Actions to be taken by MLAs VCI Business Unit: 1) Conduct R&D and develop new technologies & business models to reduce GHG emissions along the supply chain; 2) Conduct R&D and develop new technologies & business models to increase efficiency or reduce waste along the supply chain; 3) Maintain the security of supply and increase the usage efficiency of water and energy throughout the supply chain.	**KPIs:** 1) Identify and deliver by 2020 five new technologies or business models to reduce GHG emissions through the supply chain; 2) Provide the tools and resources for industry to achieve a 25% reduction in waste by 2020 relative to 2015 levels; 3) Provide the tools and resources for industry to achieve a 25% reduction in water and energy use intensity by 2020 relative to 2015 levels.

3.4 A related Australian industry perspective: The Australian Dairy Industry

According to the ADIC website the national dairy herd numbers 1.74 million cows with a total milk production of 9.73 billion litres. Dairy farming and manufacturing employ 39,000 people with more than 100,000 people employed indirectly through related services. Most of Australia's milk production occurs in the south-east of the continent although all states have dairy industries. The main export markets are South-East Asia, Japan, China, Africa, the Middle East, Mexico and Russia. Australian exports account for 34% of total milk production with a value of $2.88 billion. The average herd size is 284 cows and produce 25 – 40 litres of milk each day. About 70 – 75% of feed requirements come from grazing with the remainder coming from supplementary feed made up of grain, hay and silage.

The Australian Dairy industry has developed the following sustainability measures:

- Whole-of-industry Sustainability Framework to reduce environmental impact, increase earning capacity across the industry and improve community well-being and animal welfare
- Industry sustainability reporting system to meet stakeholder requirements
- Unilever Project (a system of continuous improvement measured against Unilever Sustainable Sourcing Requirements)
- DairySAT (DairySelf-Assessment Tool), an environmental self-assessment tool and action-planning tool for dairy farmers in Australia
- Fert$mart, a tool for fertilizer and soil management

The Australian Dairy Industry Sustainability Framework Progress Report was established in 2012. It contained 11 targets and 41 performance measures. In terms of environmental impact reduction by 2020 the report targeted the following areas:

- Improvement of nutrient, land and water management
- A reduction of the intensity of water usage in dairy manufacturing by 20%
- A reduction on greenhouse gas emissions by 30%
- A reduction of waste to landfill by 40%

The latest 2015 Progress Report (ADIC 2015) shows that with regard to environmental sustainability considerable progress towards the following targets have been achieved (baseline 2011):

- The amount of waste sent to landfill has declined by 46% (e.g., through recycling of silage wrap)
- The number of farmers with nutrient plans is about 58%, which is on track to achieve the 2020 target of 80%
- Water recycling on farm has increased from a baseline of 50% to 75%
- Emissions from dairy manufacturing have decreased by about 15%

4. REGULATORY AND ENVIRONMENTAL PERSPECTIVES

Increasing environmental sustainability in the red meat and livestock industry makes sound economic sense for several reasons:

- The Australian public is becoming increasingly concerned about environmental sustainability in the agricultural industry with many people willing to pay more for greener products
- Increased efficiency and productivity leads to less wastes and lower operating costs
- Value-adding to wastes from the industry increases profitability and/or reduces costs

The primary responsibility for the affairs and strategic future development of the red meat and livestock industry lies with the industry itself (DAWR 2016). However, the regulatory environment is inefficient and the cost of compliance is high. Reducing the regulatory burden on farmers could lead to earlier adoption of new, imported technologies and products (OECD 2013). Key environmental regulations pertaining to the industry are briefly discussed in this section.

The Department of Agriculture and Water Resources administers the Australian Meat and Livestock Industry Act of 1997 and its Regulations of 1998. This Act sets out the industry's structural arrangements.

There are several Acts and Regulations that specifically impact on environmental sustainability:

- Water Amendment Act 2008 and its Regulations provide for the Murray-Darling Basin Authority to provide arrangements for meeting critical human water requirements from Basin water resources, while still ensuring that the resources are managed in a sustainable manner
- Quarantine Act 1908 protects animal, plant, human health, while maintaining market access for Australian agricultural exports (Department of Agriculture and Water Resources (2016)
- Biosecurity Act 2015 has brought together policy, biosecurity research and programme areas for animal, plant, food and quarantine. The Act commences on 16th June, 2016 and replaces the Quarantine Act1 1908. It will be co-administered with the Department of Health
- The Environment Protection and Biodiversity Conservation Act 1999 (DE 2016) is administered by the Department of Environment. The Act aims to protect and manage important flora, fauna and ecological communities and heritage sites

Each State Government in Australia has also enacted legislation and established environmental protection agencies to ensure protection of the environment.

Environmental policies in Australia frequently use market-based instruments to promote environmental sustainability (BDA Group and CSIRO 2007). Federal, state and territorial governments have used tax concessions, subsidies and grant schemes to encourage land conservation. For example, grant schemes have been established for:

- Landcare and Bushcare
- Salt Action
- Murray Darling Basin Commission
- Greening Australia

With the success of the BushTender plot in Victoria and the Environmental Services Scheme Pilot in NSW there has been a shift from government to consider the environmental outcomes that should be achieved from these schemes in order to measure their success.

The following section describes some of the policies and programmes that incentivise farmers to implement environmentally sustainable farming practices in other countries including Canada, EU, US and Brazil.

In **Canada** (Schmidt 2012) environmental sustainability as applied to industry is called Ecological Goods and Services (EG&S). Until 2011 EG&S had not been a primary focus of Canadian Agricultural Policy. The five-year national agriculture and food policy framework, Growing Forward 2 was ratified in 2012 by the federal, provincial and territorial governments.

This policy is designed not only to assist growth and prosperity but also to put more emphasis on EG&S policies and thereby address environmental sustainability in the industry.

Recent changes in the **EU** common agricultural policy (CAP) in 2013 have shifted the focus to greener farming practices (EU 2014). The changes have effectively decoupled farm support from production-based targets. They now target specific areas contained in CAP, which has effectively reduced incentives for increasing farming intensity. There are two mechanisms that are used to achieve environmentally sustainable targets in the agricultural industry (Schmidt 2012):

- Cross-compliance
- Agri-environmental measures (AEM)

Cross-compliance mandates that eligibility for government support is dependent on farmers meeting minimum environmental management requirements, while AEM is a voluntary programme. Payment is made to farmers who commit to adopting environmentally friendly farming techniques for a minimum period of 5 years. To be eligible for payment these techniques must exceed environmental standards in the areas of landscape, biodiversity, water, soil, nitrates or pesticides. For example, the nitrate directive has led to a measurable reduction in the use of nitrogenous fertilisers (Eurostat 2015a).

In the **US** the Environmental Protection Agency (EPA) is responsible for enforcing environmental regulation while the United States Department of Agriculture (USDA) is responsible for agri-environment programmes (Schmidt 2012). The US policies focus on achieving specific environmental targets but give farmers the freedom to choose the actions to achieve these goals. Unlike Europe, the US policy views the natural environment to be of greater value than agricultural production but the influence of the farm lobby on US Congress limits government efforts to direct agricultural policy towards greater environmental sustainable measures (Baylis 2008). The food-processing sector in the US is extensively regulated by state and federal agencies. The USDA FSIS is the major agency for the meat and poultry sector. US Food law covers the whole supply chain for a food product (NDSU 2015).

The growth over the past two decades in **Brazil's** agricultural industries has been driven by productivity improvements, new technologies and broad economic reforms but there is still scope for policy to target productivity increases and sustainability balanced with policies aimed at reducing poverty. Government policy and industry initiatives are becoming more focused on the sustainability of agricultural development in Brazil. Deforestation has been on the political agenda for a long time but more recently air and water pollution and climate change are receiving more attention and will become important in the future. In 2013, a National Plan for Agro-ecology and Organic Production was initiated to coordinate policies around environmentally-friendly agriculture and organic food production. There are now other important regulations protecting genetic resources, recycling of wastewater, control of water quality and disposal of toxic chemicals. Brazil is unique in the area of energy sustainability as renewable energy accounts for about 42% of the country's total energy supply. This provides an example of how strong economic drivers and government support can lead to environmentally sustainable outcomes (OECD 2015a).

The EU has successfully implemented measures to reduce environmental emissions while increasing productivity with the help of uniform legislation concentrating on positive externalities while the US and Australia have concentrated more on negative externalities. The EU has increased farm efficiency and productivity and improved farm management practices, which have contributed to emissions reduction. Over time, Australia, the US and Brazil are likely to continue to strengthen their environmental sustainability legislation.

5. CONSUMER AND CUSTOMER AWARENESS OF ENVIRONMENTAL ASPECTS

Traditionally, product price, freshness and quality were the most important considerations for consumers when purchasing their groceries. While today this is still the case, this landscape is changing as consumers become more affluent, informed and demographically diverse. New aspects like animal welfare, environmental sustainability, nutritional value, organic production and greener brands, functional foods, and different cuts of meat, however, are having a large influence on the consumer’s choice of product.

Food safety and traceability are also growing in importance particularly with the continuing emergence of food scandals like the recent horsemeat contamination of beef in the UK and the contamination of baby milk with melamine in China.

6. SUPPLY CHAINS IN THE RED MEAT INDUSTRY

A good understanding of the meat and livestock supply chain in Australia is necessary in order to develop a RD&A strategy to add value to waste from the industry and concurrently reduce energy and water usage and greenhouse gas emissions.

A supply chain model of the red meat industry is shown in Figure 5. The model shows the roles and flows of goods between producers, transporters, traders, processors, wholesalers, retailers and exporters.

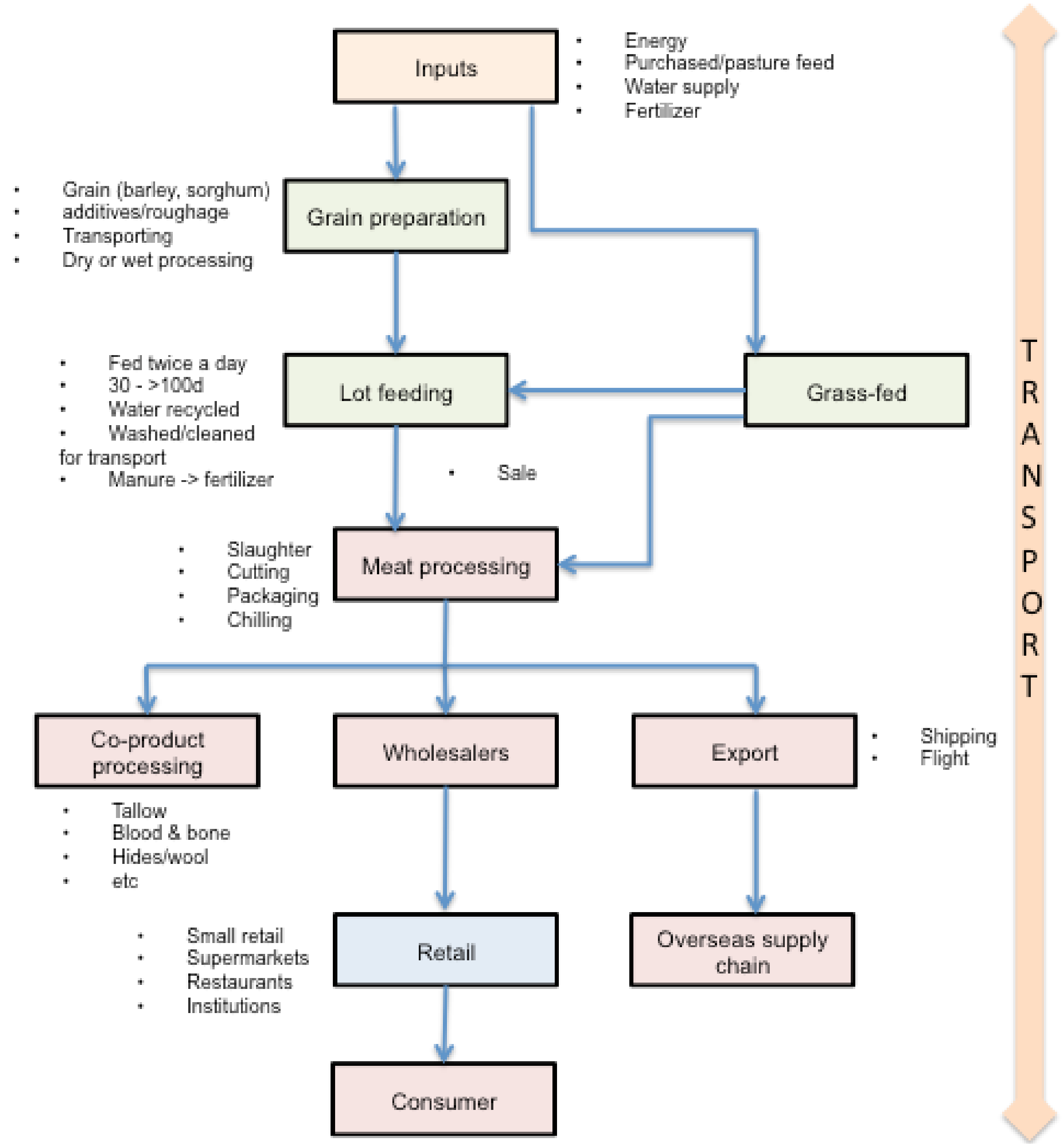


Figure 5 Australian red meat industry supply chain

The first step in the supply chain is the on-farm production of livestock. Large cattle and sheep stations are found in the pastoral zone of Australia. This area occupies desert and semi-arid areas of Australia with low rainfall and less fertile soil. The stations are mostly unfenced, large corporate or family-owned farms with low to medium stocking densities. Properties in the sheep-wheat and high rainfall zones are usually smaller family-owned businesses with medium to high stocking densities. Winter cropping and livestock grazing characterize the sheep-wheat zone and most of Australia's sheep flock is produced here, whereas, the high rainfall zone is ideal for producing prime beef and lambs.

Grain-fed cattle are mainly produced for export although the domestic market is growing. Most of the **feedlots** in Australia are located in Queensland and New South Wales with smaller numbers in Victoria, South Australia and Western Australia. Cattle are usually grain-fed in Australia in feedlots although there are also small numbers of sheep fattened in this manner (MLA 2012). Feedlots are usually located close to cattle and grain supplies. In 2012, there were approximately 700 accredited feedlots in Australia.

A typical feedlot consists of pens with shade cloth where the cattle (or sheep) from grass-fed farms are confined for fattening on grain for a period of between 100 – 400 days before slaughter and/or export. The cattle are fed special, high protein mixes of grain, straw, oil and feed additives. Molasses can also be added to increase feed palatability. The grain is usually pretreated to improve starch availability and enhance its digestibility, which increases feed efficiency (MLA 2011a). The grain can be dry-rolled, steam flaked or reconstituted and the main equipment required for processing are boilers for the production of steam or heat and hammer mills or roller mills for grinding or rolling the grain. Storage facilities and feed mixing equipment are also part of the feedlot system. Water supply is an important component of the feedlot design as it is used for cattle drinking water, cooling the cattle, reducing dust and washing the cattle and vehicles. The feedlots are located where drainage and capture of run-off is possible. The waste water is collected in holding ponds and the solid waste, mostly manure, is bulldozed into stockpiles for composting. The combined waste is typically applied to land and crops as a fertiliser.

The aggregators and traders are an important link in the supply chain. Aggregators help move livestock by rail or road from the farms to meat processing facilities, sale yards and airports or shipping terminals for live export. They also distribute meat from the processors to wholesalers, retail companies and shipping terminals for export. Traders facilitate the sale of the "product" along the supply chain.

The **red meat processing plants** depend on high throughput and low margins (AMIC 2015). Red meat processing facilities are located all over Australia particularly outside of urbanised areas. The following factors are important in location of a red meat processing facility:

- Hub for livestock transport
- Workforce availability
- Water availability
- Near grazing properties
- Distribution network for domestic and export markets
- Environmental rules and regulations

The red meat processing sector has been able to maintain its competitiveness by the adoption of the new, more efficient technologies and its ability to provide products meeting the specifications of >100 countries while maintaining quality, high standards of hygiene and food safety and traceability over the product life cycle. The industry continues to face considerable pressures to maintain its production capacity in Australia, which is leading to amalgamation in the industry. Over the last 25 years, many smaller meat processing plants have either closed or been bought by big corporations. In this way, the sector benefits from increasing economies of scale.

The red meat processing sector produces beef, sheep or goat meat and **co-products** that are used in other industries. The co-products include hides, which are used in the leather industry; wool in the case of mutton/lamb; edible offal which is used for human consumption or pet food; blood and bone which is rendered to produce blood and bone meal and blood meat; and fat that is used to produce tallow.

The next step in the supply chain is the **wholesalers** where boning and cutting of the meat into saleable portions is carried out. Wastes from the wholesalers include bone and fat, which are rendered to produce meat and bone meal.

Another important trend in the industry is the growing number of vertically integrated companies, which allow increased control of the supply chain (grass-fed and feedlots production of livestock, meat processing and export) and the opportunity to differentiate by brand. This business model allows companies to control product to meet customer specifications and allows for a larger degree of flexibility, consistency of quality and supply, traceability over the whole product life cycle, improved efficiency and reduced overhead costs (Beef Australia 2015). Examples of vertically integrated companies include JBS Australia, Teys Australia, Cargill Australia, the Australian Agricultural Company and Australia Company Choice.

The second last step in the supply chain that is relevant to this project is retail. **Retailers** vary greatly in size and type of business. Margins are usually low and supply chain efficiency is key (supermarkets and butcher shops, restaurants and institutions) with the **consumer**s at the end of the supply chain.

Export and its accompanying international supply chain are not being considered in this project.

7. ENVIRONMENTAL VALUE CHAINS IN THE RED MEAT INDUSTRY

7.1 Environmental value-chains in the red meat industry

The ideal approach to environmental value chain optimisation in the meat and livestock industry is the management of environmental impact over the whole life cycle (Pesonen 2001). This necessitates control of whole supply chain by the main stakeholders in the supply chain, the producers and processors; better communication between each step in the supply chain; and cooperation through the supply chain. Environmental value-chains (see Figure 6) in the red meat industry are required to maintain productivity, profitability while accommodating the following factors:

- Volatile weather patterns
- Diverse farming zones
- Attitudes to farmers, who are often resistant to change and unaware of supply chain factors
- The need for faster and more efficient transport to reduce loss and waste of "product"
- Low margin, high volume meat processing plants and retail landscapes

- High level of food waste in retail sector
- Changing consumer tastes and preferences including changing demographics
- Expanding global markets

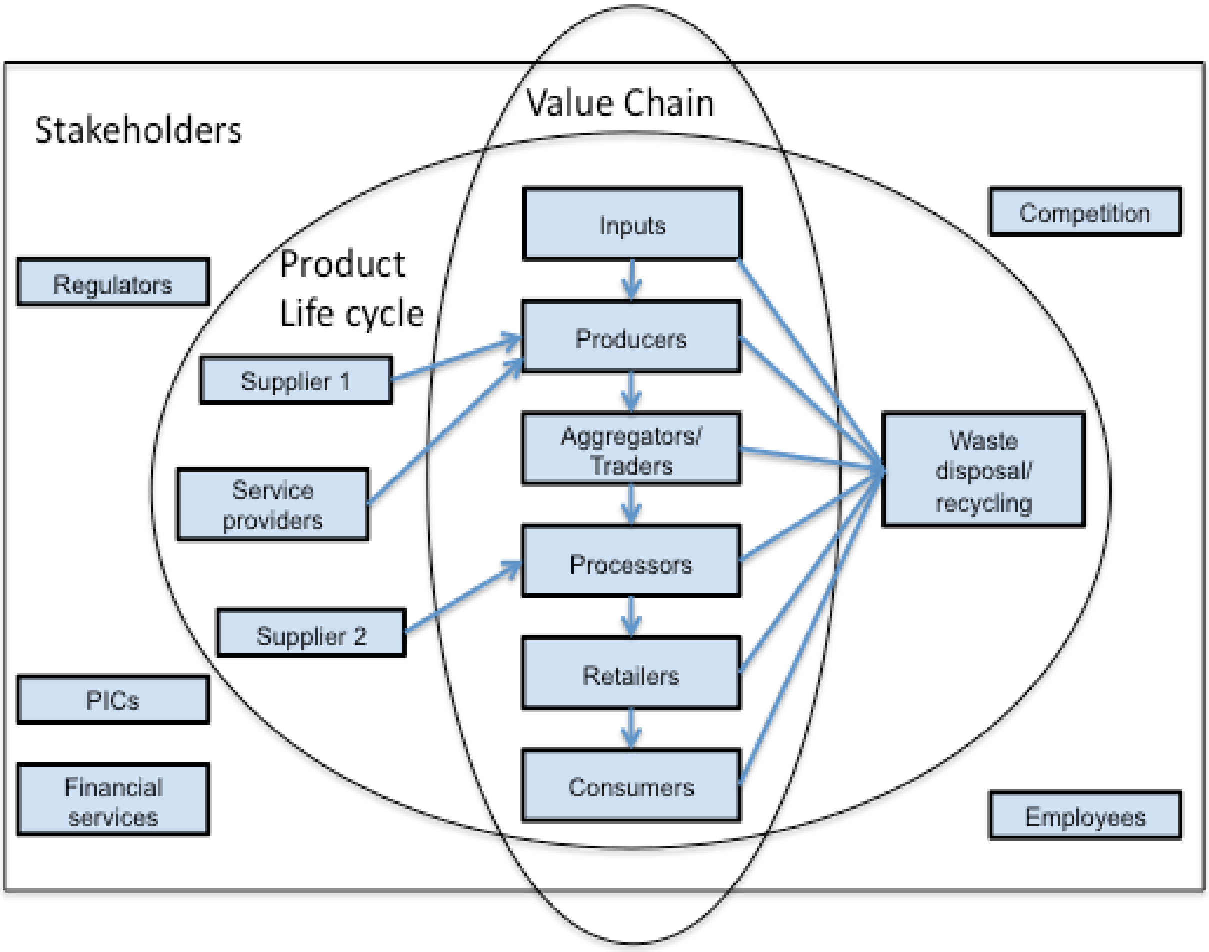


Figure 6 Australian red meat industry value chain

The environmental value chain requires innovative capacity and can only evolve successfully in a supportive regulatory environment. The environmental performance of the industry needs to be communicated to the stakeholders. The implementation of an environmental management system, e.g., ISO 14001 can be an effective means of accomplishing this goal.

The whole industry will benefit from a healthy environmental value chain that promotes renewable resources, secures the existing resources for the future, reduces emissions and adds value from industry waste or reduces operating costs by recycling water or the production of renewable energy.

The following sections will outline the baseline information on the current environmental performance of the red meat industry in relation to energy, greenhouse gas emissions, water and wastes.

7.2 Focus Area: Energy

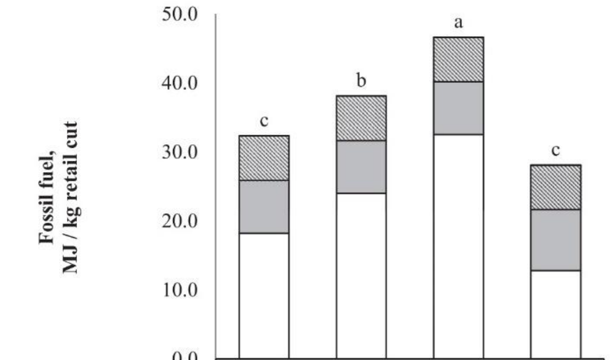
7.2.1 Introduction to energy in the red meat industry

A fourth industrial revolution is occurring due to digital and data advancements (World Economic Forum January 2016). History has shown that industrial revolutions are not distributed evenly hence businesses need the right infrastructure and partnerships in place as no company on its own can have all the answers. Energy is a key sector that will be dramatically disrupted by such industrial advancements: smart meters, smart grids, data sharing between multiple stakeholders in the supply chain, grid parallel and island mode energy options, and energy storage.

As an example, consider a regional feedlot that requires steam for its grain feed flaking operations and power for milling, pumps, feed augers and other equipment. The steam can be provided via waste heat from a cogeneration engine with a wood chip fired booster boiler. Power can be provided by biogas generated from a portion of the available manure, with PV solar (which provides advantages of reduced heat stress) and flow cell batteries supplementing the power from the cogeneration engine. In times of high power demand or excess steam availability, the high-pressure steam from the wood chip boiler can drive a back pressure micro-turbine. Smart design can mean that in times of excess power, water is pumped into a header tank via a large, high efficiency pump thereby reducing site-wide pumping energy requirements. To achieve this, an Energy Management System (EMS) with oversight of the flows of energy throughout the facility is required. Sensing enables automated and remote asset management thereby reducing travel time for diagnosing and maintaining equipment thereby reducing unscheduled downtime, which also enables remote staff to monitor the performance of the facility.

7.2.2 Current status of energy in the red meat industry

The total energy demand for the red meat life cycle is presented in Figure 7 below (European Commission Joint Research Centre 2010) calculated in terms of mega joules (MJ) of energy per kg retail cut. Previous works list goats as being similar to sheep from the perspective of environmental impacts per kg meat produced (European Commission Joint Research Centre 2010).



	Beef grass	Beef MF	Beef LF	Lamb
Warehouse	0.03	0.03	0.03	0.03
International transport	6.43	6.43	6.43	6.43
Meat processing	7.66	7.66	7.66	8.85
Farm & Feedlot	18.24	24.00	32.54	12.81

Figure 7 Contribution of supply chain elements to fossil energy consumption, per kg of retail ready Australian beef and lamb exported to USA

Grass refers to grass-fed, MF refers to medium fed grain (115 days), LF refers to long-fed grain (330 days). Different letters on bars indicate significant differences ($P < 0.05$) between cases assessed using comparative Monte Carlo analysis i.e. there is a statistically significant difference in the fossil energy consumption between the different finishing options for beef (Wiedemann 2015a).

Farm based energy represents the largest energy demand at 39 – 56%. As presented in Figure 8 using beef as an example, energy demand is composed of indirect uses (fertilizer and feed at 42% of farm energy), diesel (47.1% of farm energy), petrol (7.3% of farm energy), and power (3.6%) (Wiedemann 2015b). **Grain finishing**, with its additional inputs for producing, transporting, flaking and milling the feed, **increases the overall energy requirement for MF feedlots** compared to grass fed by around **32%** whilst for LF the increase is 78%. The life cycle boundary for this assessment is presented in Figure 9.

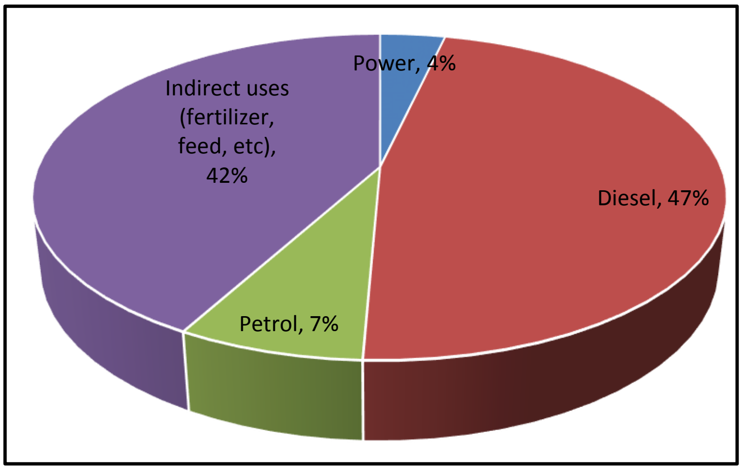


Figure 8 Percentage contribution of different energy uses to on farm energy demand for grass-finished beef production in eastern Australia (Wiedemann 2015a)

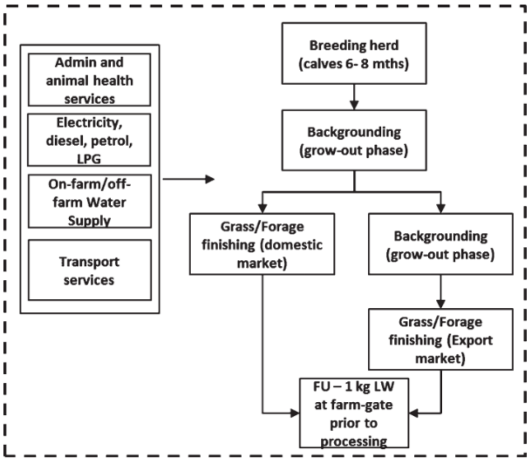


Figure 9 Life Cycle Assessment system boundary for grass-finished beef production in eastern Australia to estimate on farm energy demand (Wiedemann 2015a)

Meat processing contributes to 16 – 32% of energy demand (with Figure 11, Figure 10 and Figure 12 showing a more detailed breakdown) and international transport contributing 14 – 23% of energy demand.

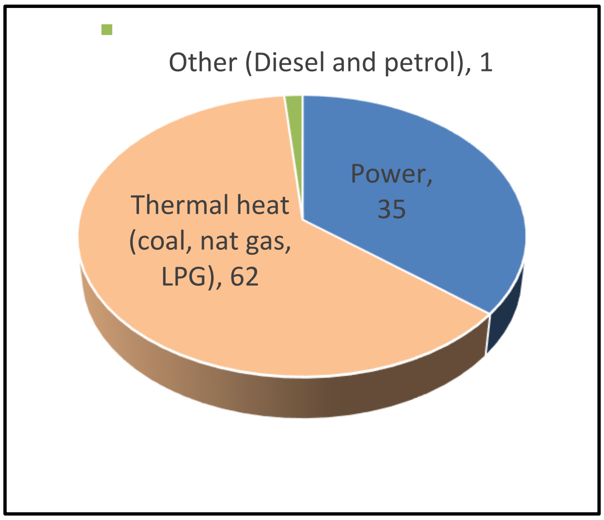


Figure 11 Different fuel sources for a "typical" 625 head per day facility

Thermal heat represents 62.7% of the facility's energy requirements, power represents 35.8% and other (such as diesel and petrol for transport) represents 1.5% (GHD 2011)

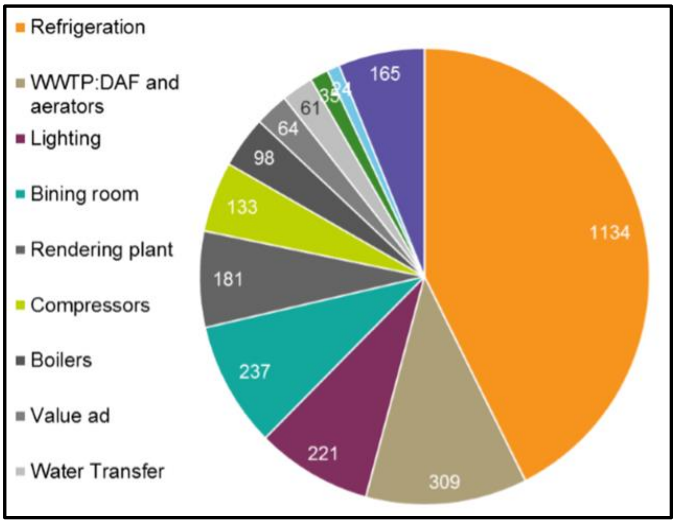


Figure 10 Main source of power load for a "typical" 625 head per day facility, reported in megawatt hours per annum (MWh pa)

Refrigeration represents the largest and, quite often, 24/7 load for meat processing facilities.

The above plant data provides high-level energy sink data, but does not provide the full energy picture - **power and thermal loads are non-homogenous and vary dramatically during the day and between different days**. This has very large implications on the technology selection and associated scale for efficiency and on-site generation options. Figure 13 shows a power load for a "typical" 625 head per day processing plant on a 2-shift per weekday (green line) compared to the weekend average (blue line). Hence, the scale of an economically viable PV solar array or co-generation engine (e.g. sized to meet the minimum weekend demand) would be different to a system required for complete off-grid or island mode operation (i.e. to meet the maximum weekday power load). The thermal load is also non-continuous (see Figure 14) with the main steam thermal load (and hot water generation via render vapour condensation) associated with the rendering operation and the hot water demand driven by the cleaning operations.

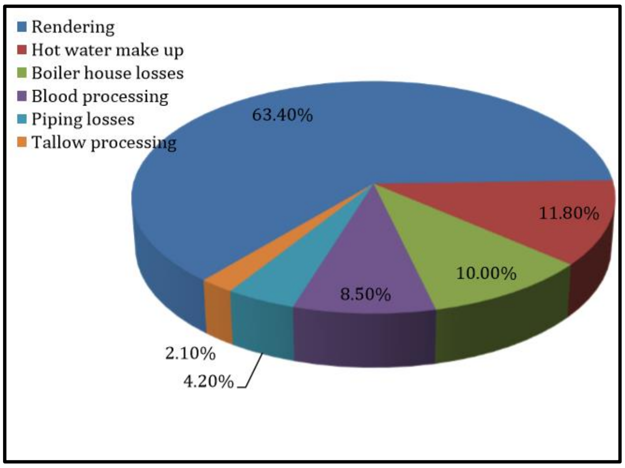


Figure 12 Summary of approximate thermal loads in a "typical" meat processing facility

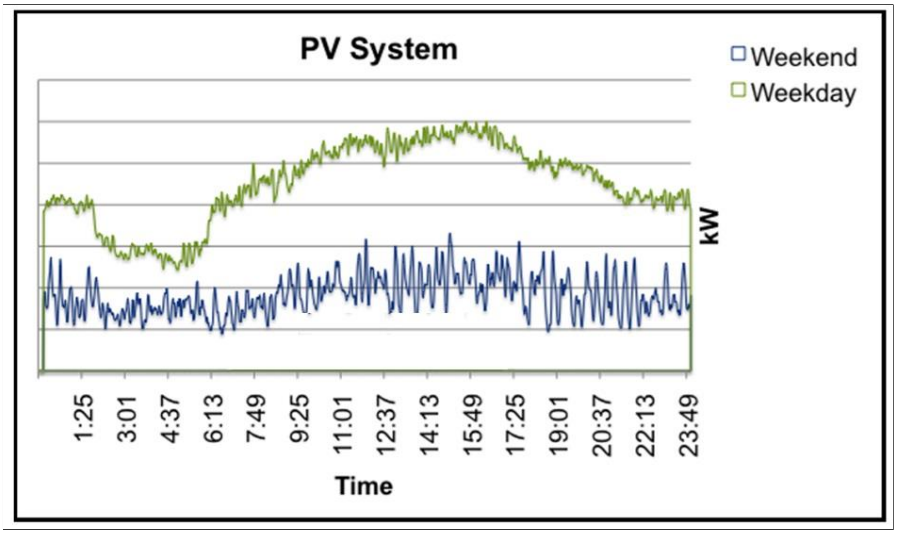


Figure 13 Power load for a "typical" 625 head per day processing plant running a 2-shift per weekday operation (green line) compared to the weekend average (blue line)

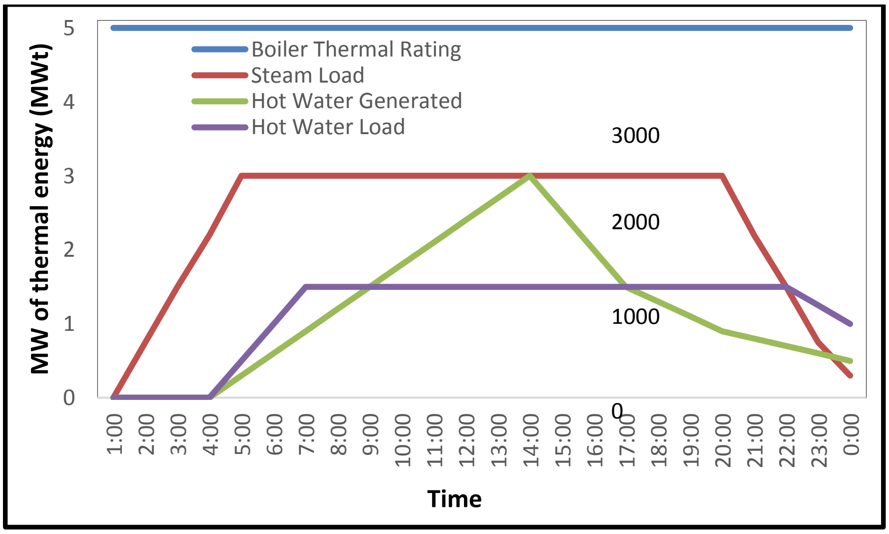


Figure 14 Representative meat processing plant thermal profile for a "typical" 625 head per day processing plant for an operational day running a 2-shift operation

Due to the complexity and variability between different businesses and sections within the red meat industry supply chain, it is proposed that specific case studies be used to identify, assess and illustrate opportunities for supply chain, value-chain and business model innovation that provide an economic value proposition for improved environmental performance in energy for the Australian red meat industry.

7.2.3 Current and emerging trends in energy innovation

Presented in this section are technologies that are commercially available in Australia, however, are not currently widely used through the Australian red meat industry.

Internet of things:

- Sensing and web enabling more devices so that more useful data can be collect and utilized for optimized decision making. 4.9 billion sensors are currently connected to the web. With estimates at 50 billion in 5 years' time[1], this equates to a compound increase of 59% year on year for the next 5 years.
- "Energy Internet": decentralized and multi-demand, multi-generation hubs that increase efficiency, reduce transmission / distribution costs and even out supply/demand mis-matches. As a simple example, a meat processing facility may have excess power generation capacity during evenings and weekends that it can trade or sell with a co-located cold storage facility that has thermal storage capabilities; the cold storage facility may have excess low grade heat that can be used for boiler water and hot water make-up preheating and in waste water treatment plants.

Increased speed in task completion and decision making: for example

[1] www.virgin.com/entrepreneur/tech-trends-are-transforming-way-evergy-business-works, accessed 10 March 2016.

- Turning a motor off or turning the speed down via Machine-to-Machine (M2M) communication or automation.
- Automated or scheduled energy procurement reviews.
- Automated or remote equipment monitoring and maintenance to maximise efficiency and availability.

Increased connectivity and bespoke data analytics: for staff, management, clients, customers and suppliers. For example, automated email, web and/or mobile platform real time information to increase engagement and customer loyalty and bring the customer closer to the business by creation of a community.

"Behind the meter" innovation, where efficiency (representing ~60% of opportunities) and generation (represents ~40% of opportunities) examples are provided below.

Efficiency examples include:

- Energy Management Systems (EMS) for M2M plant optimization and motor / combustion control.
- For boilers: oxygen trimming, economizers, combustion air / make up water pre-heating with low-grade heat, blow down heat recovery, stream traps / condensate return.
- Ammonia de-superheaters / heat recovery from compressors and fridges.
- Fuel swapping (such as diesel with compressed natural gas or biogas).
- Motor size and type optimization (multi-speed, variable speed drives).
- Flow cell batteries for storage of power for industrial facilities.
- Power factor correction.
- Voltage optimisation (also known as voltage correction) - most electrical equipment manufactured for Australia is designed to work most efficiently at 220V to 230V, any incoming power that is higher than this level is wasted energy and shorten equipment lifespan. The payback period is typically between 1 to 2.5 years. Voltage optimization is ideal for inductive loads (e.g. motors and lighting) especially if these are not loaded at 100% of their capacity for 100% of the time.
- Compressed air audit.
- Lagging (or lagging repair) of heated and cooled process lines.

Generation examples include:

- Waste to energy e.g. anaerobic digestion of volatile solids into biogas to off-set power and/or thermal heat.
- Optimization of motor-energy source combinations e.g. oversizing of remote area water pumps to run off PV solar during daylight.
- Integrated power, heating, cooling and water treatment facilities. For example, IBM's "Sunflower" or High Concentration Photo Voltaic Thermal (HCPVT) systems create PV power, hot water at 95 ^{o}C, potable water via permeable membrane distillation systems and cooling via adsorption chillers. This achieves an 80% efficiency (as opposed to current commercial panels of around 20% efficiency or less).
- Integration of multiple power sources (e.g. PV Solar, biogas engines, diesel gen sets, turbines, batteries) via an Energy Management System (EMS) to minimize generation costs and enhance energy security.

7.2.4 Critical aspects for future Energy innovation development

Energy Strategy: The flow diagram below (Figure 15) shows an process model for how a business could implement an energy strategy. Concept development deals with creating a common language through the business (e.g. kWh, GJ, $, see Appendix 2 for Energy Conversion factors) and "buy-in" from all critical areas: procurement, treasury, maintenance, engineering, CEX-level.

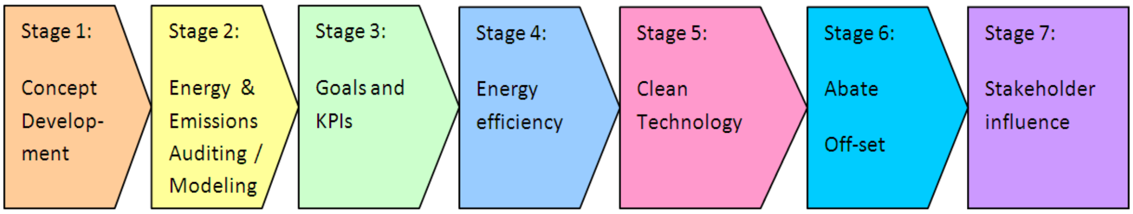


Figure 15 Energy strategy process

Auditing and modelling is required to obtain full and accurate data on the current, historical and anticipated energy loads and generation levels. Setting of goals and KPIs is a critical stage that must be completed with buy-in from all levels of the business. As an example, a business may aim to reduce its energy intensity (e.g. MJ per $ revenue) by a set amount (e.g. 1% per annum reduction through to 2020), or increase the share of on-site renewable energy to a sustainable level (e.g. 3% by PV solar, 30% by bio-energy. The level of engagement in energy strategy is impacted by the time scale, complexity and/or level of energy maturity within the company or facility, as detailed in Figure 16. This strategy needs to be review and updated periodically.

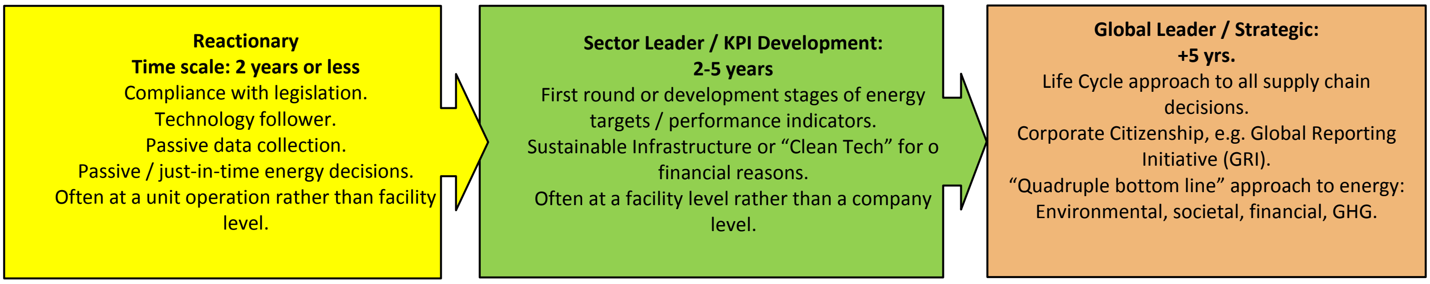


Figure 16 Energy strategy time scale and complexity

Rapidly changing legislative and incentive environment. Specific example: Record high Large-scale Generation Certificates (LGCs, see Figure 17). The closing price at 9th March 2016 was $78 / MWh. It is anticipated that a LGC undersupply could drive the price higher due to a predicted shortfall in 2018[2] - spot prices for LGCs have soared past the nominal shortfall penalty of $65 and exceeded $80 in Jan 2016. Some forward trades beyond 2017 have traded only a few dollars off the tax-effective level of the shortfall penalty of $92.86.

[2] http://greenmarkets.com.au/resources/insight-ret-wont-be-met-in-2018, accessed 14 March 2016.

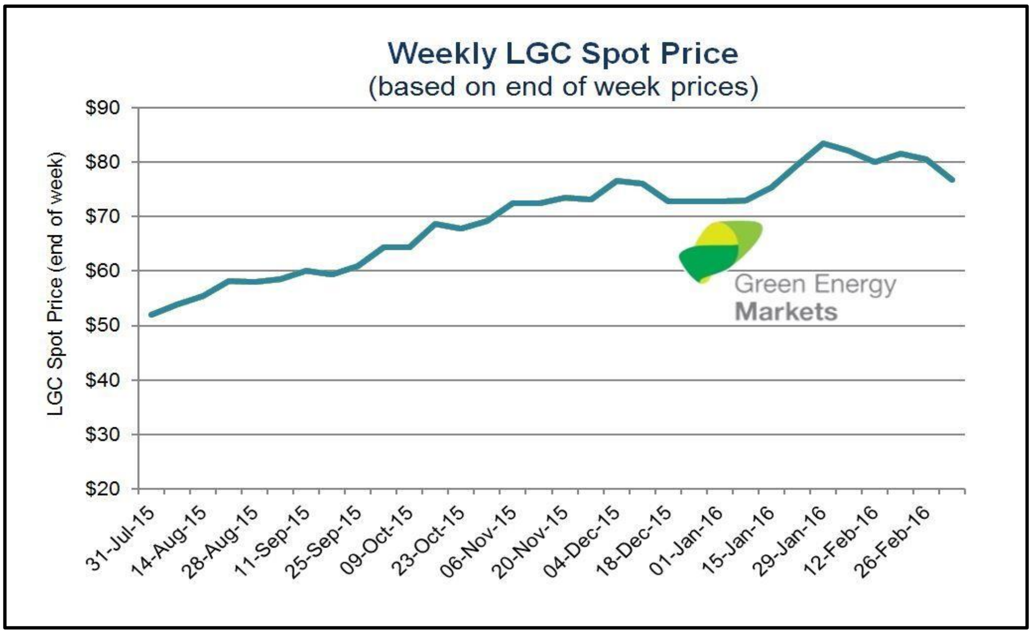
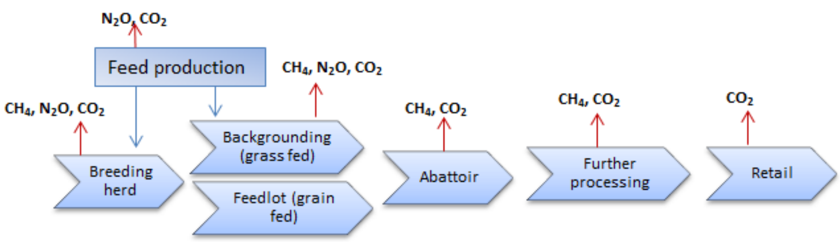


Figure 17 Large-scale Generation Certificates (LGCs) price trend from July 2015 to early March 2016[3]

7.3 Focus area: Greenhouse Gas Emissions

7.3.1 Introduction to greenhouse gas emissions in the red meat industry

Greenhouse gas (GHG) emissions occur at all stages of the red meat supply chain (Figure 18. The greatest contribution to greenhouse gas emissions of beef, sheep meat or goat meat occurs at the farm production stage (Lieffering 2012, Wiedemann 2015d) with life cycle assessment (LCA) studies showing that **more than 90% of total emissions for Australian beef and lamb** exported to the US **occur at the livestock production stage** (Wiedemann 2015a). Greenhouse gas emissions for New Zealand export beef and lamb through to consumption was similarly found to be dominated (around 90%) by the on-farm stage of the supply chain (Lieffering 2012). Animal production has, therefore, been the focus of evaluation of GHG mitigation for red meat supply chains but it is important in analysing cost-effective abatement strategies to consider the potential reduction in terms of practical implementation, efficiency gains and innovation across the supply chain.



[3] http://greenmarkets.com.au/ resources/lgc-market-prices, accessed 10 March 2016.

Figure 18 Simplified diagram of the stages of the red meat supply chain with major GHG emissions.

GHG emissions include carbon dioxide, methane and nitrous oxide, which are commonly expressed in mass of carbon dioxide equivalence units (kg CO_2-e). Livestock farming contributes around 18% of total anthropogenic global emissions each year, i.e. about 6 billion tonnes CO_2-e (Herrero 2016), and domesticated ruminant livestock - cattle (*Bos taurus, Bos indicus*), sheep (*Ovis aries*) and goats (C*apra hircus*) are attributed with the majority largely due to methane emissions from enteric fermentation. Nitrous oxide and methane from dung and urine also contribute to ruminant GHG emissions.

Overall, the livestock sector includes 20 billion animals, supports 1.3 billion farmers and retailers, and contributes up to half of the total economic value of agricultural production. Consumption of meat, milk and eggs is projected to grow up to 70% by 2050 for an expanding population, mostly in the developing world (Alexandratos 2012) where auxiliary products and services of livestock are also important. The international agreement reached at the 21st Conference of Parties of the UNFCCC in Paris in December 2015 confirmed global climate change action for the period to 2030 and there is both policy and community expectations of contributions from all sectors of the economy. Recent studies have indicated that the global livestock sector can maintain the economic and social benefits it delivers while reducing emissions significantly, potentially by as much as 2.4 Gt CO_2-e every year[4]. However, some studies have suggested that as little as 0.2 – 0.6 Gt CO_2-e yr^{-1} of the potential mitigation is achievable cost-effectively based on a price of US$50 per t CO_2-e yr^{-1}. The challenge for the red meat sector is achieving the identified mitigation potential in the context of growing demand for high quality protein, with the constraints of cost of both increasing production and mitigation. Australia’s climate change target calls for a reduction in greenhouse gas emissions of 26-28% below 2005 levels by 2030, strengthening the existing commitment of 5% below 2000 levels by 2020. The principal instrument under current legislation is the Direct Action policy under which $2.55 billion dollars has been committed over 5 years to the Emissions Reduction Fund (ERF) with the aim of achieving least-cost abatement through a reverse auction purchase of emission reductions from new projects operating against an approved carbon credit method. ERF opportunities exist for the red meat industry but for most projects greater potential economic return has been shown for the associated productivity or efficiency gains than for carbon credit income.

7.3.2 Current status of greenhouse gas emissions in the red meat industry

7.3.2.1 Emissions from animal and feed production

In Australia’s 2013 National Inventory Report (NIR 2015) to the UNFCCC, the agriculture sector represented 16% of total annual greenhouse gas emissions and the livestock sector directly made up approximately 70% of the agricultural total through enteric fermentation and manure (Figure 19).

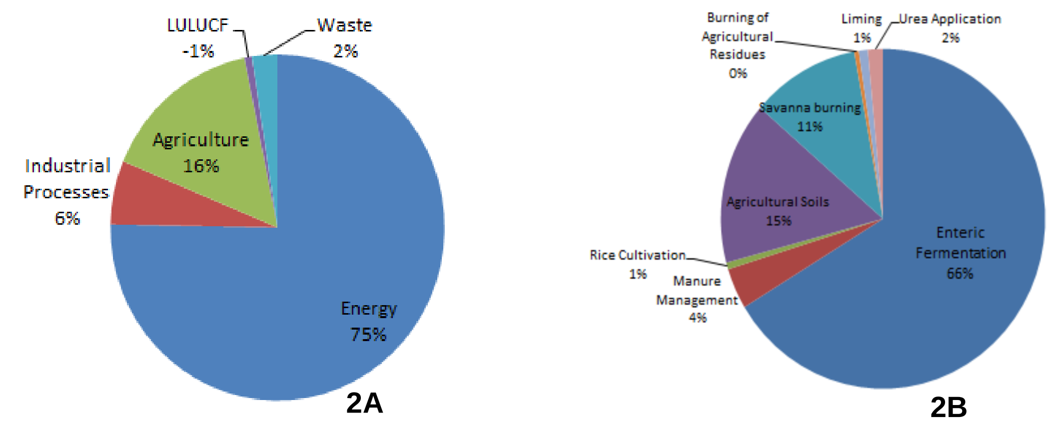


Figure 19 Greenhouse gas emissions as reported in Australia's National Inventory Report to the UNFCCC totalled 549,446 Gg ('1000 tonnes) CO_2-e in 2013 (NIR 2015), showing national emissions by sector (2A) and agriculture (80,024Gg CO_2-e) by sub-sector (2B)

Levels and trends since 1990 (
Figure 20) reflect changing animal numbers, industry structure and climate variations:

- **Cattle and sheep** accounted for **77% and 22%,** respectively, of **total 2013 enteric methane emissions**;
- **Feedlot cattle produced 97% of the total manure management emissions**;
- **Total enteric methane from beef cattle rose by 19%** from 1990 to 2013;
- **Greenhouse gas emissions per head in feedlots decreased** from 1990 to 2013 as the number of animals turned-off (Domestic+Mid-fed+Long-fed) increased 2.6 fold while total emissions rose 2.2 times);
- **Emissions from managed goats have high uncertainty** and are **minor** relative to cattle and sheep. However, introduction of the meat RSA Boer has led to productivity improvements and lower time to slaughter weights. Boer cross kids reach 34 kg LW at 5 months compared to 15 kg at the same age (Jones 2012).

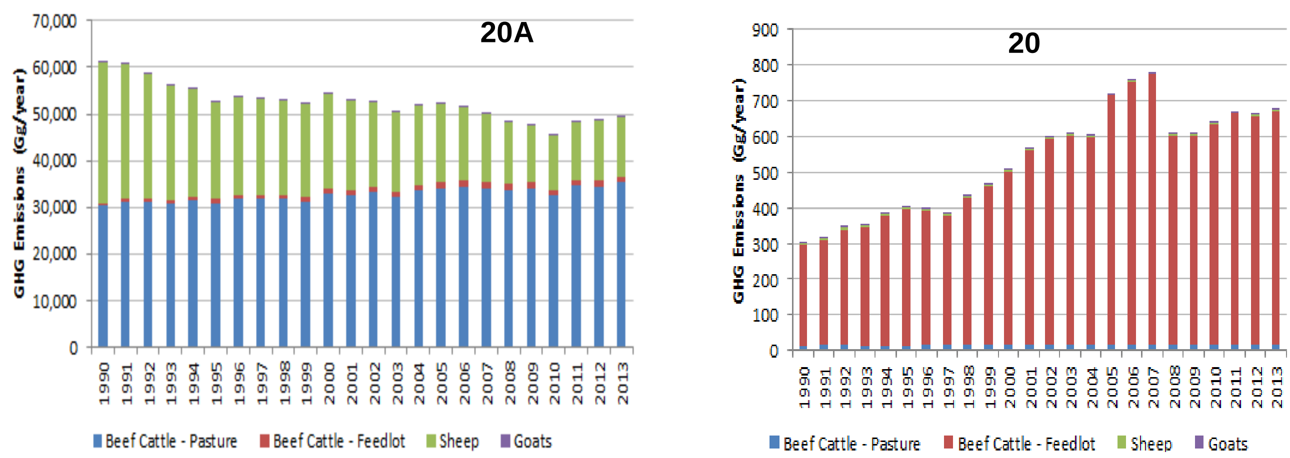


Figure 20 Greenhouse gas emissions (GgCO_2-e/year) for 1990–2013 for beef cattle (pasture-fed and feedlot reported separately), sheep and goats as reported in Australia's NIR(NIR 2015). 18A**: Enteric methane emissions;** 18B **Manure management**

emissions. *Note*: (1) Sheep emissions are the total for meat and wool producing animals

Expressing red meat emissions as greenhouse gas intensity (kg CO_2-e/kg meat) enables evaluation of the effectiveness and economic feasibility of strategies for mitigation while supporting industry growth and profitability. MLA-funded research used an LCA approach to quantify improvements from 1980 to 2010 in the greenhouse gas emissions intensity for the cradle to farm-gate stage for Australian beef production (Wiedemann 2015d). For the animal production stage, greenhouse gas intensity is affected by feed quality, animal feed conversion efficiency (dry matter intake, DMI, and daily weight gain, ADG), reproductive efficiency and mortality (Fig. 21). Between 1981 and 2010, the greenhouse gas intensity of Australian beef dropped by 14%, from 15.3 to 13.1 kg CO_2e/ kg LW, despite increase in production of over 50%. Factors most significant in changes in greenhouse gas efficiency included heavier slaughter weights, increases in daily growth rates in grass-fed cattle, improved survival rates and greater numbers of cattle being finished on grain. Overall, finishing on grain resulted in higher LWG and, hence, fewer days of greenhouse gas emissions per kg cwt at slaughter and lower greenhouse gas emissions per kg product. greenhouse gas emissions per animal were generally higher where slaughter weight was greater.

The study also showed that the decline in greenhouse gas intensity for beef occurred in the first two decades of the analysis period (Figure 21) with a small increase following for 2000 to 2010. This points to the importance of managing for climate variability since lack of gains from 2000 to 2010 in part reflected the influence of the 'Millennium drought' but also to potential further gains with better management. This challenge is important in the context of expected long- term growth in cattle numbers, demand for beef, and projected future increased climate variability.

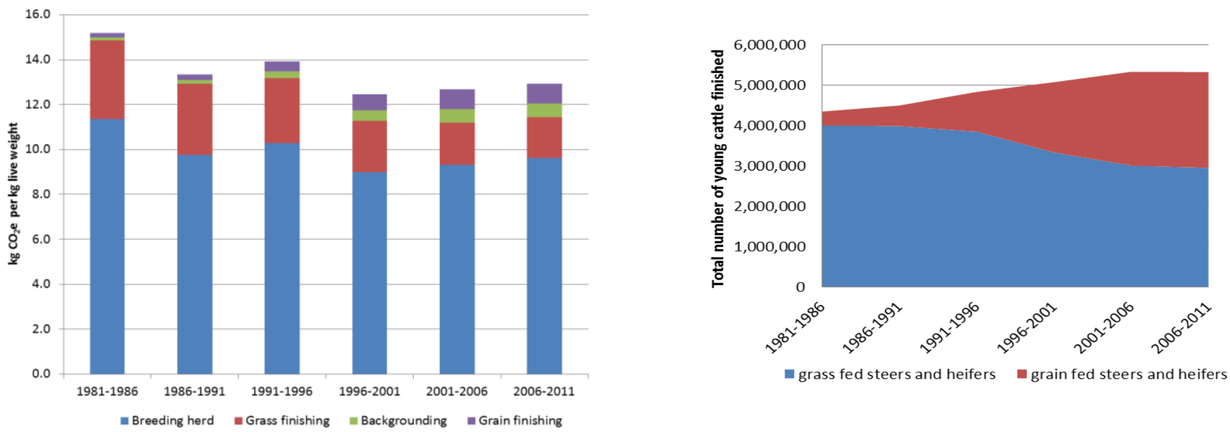


Figure 21 Change in the total GHG intensity of beef production 1981-2010 by herd production stage (19A) and change in relative number of young cattle finished on grass and grain (19B).

Assessment of changes in **emissions intensity of sheep meat** production in Australia is more complex due to the need to allocate GHGs between sheep co-products, primarily wool and meat. Nevertheless, using a simple calculation of the ratio of emissions from the national flock to sheep meat production indicated that **emissions intensity in 2013 was**

approximately half that in 1990. Data for goats are highly **uncertain**, but the NIR emissions data indicate that **GHG intensity of goat meat fell from 10.4 to 2.5 kg CO_2-e/kg CWT from 1990 to 2013**.

In terms of environmental sustainability, it is noted that the GHG intensity benefit of increased grain finishing must be balanced against the impacts of growing feed grain and preparing feed rations. These processes result in greater agricultural land occupation, loss of soil organic carbon and higher fossil energy use (Figure 22). There was a seven-fold increase in agricultural land occupation for beef production (albeit from a very low base) and approximate doubling of fossil energy demand (from 6.311 MJ/kg LW in 1981), both contributing to GHG emissions increases through (1) soil carbon loss; and (2) energy emissions, although minor compared to enteric methane change.

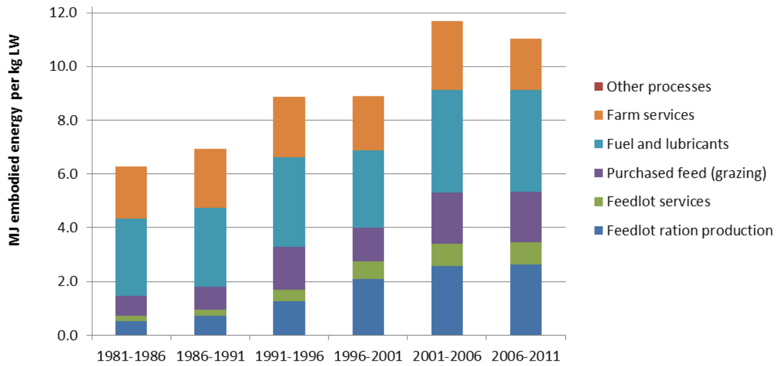
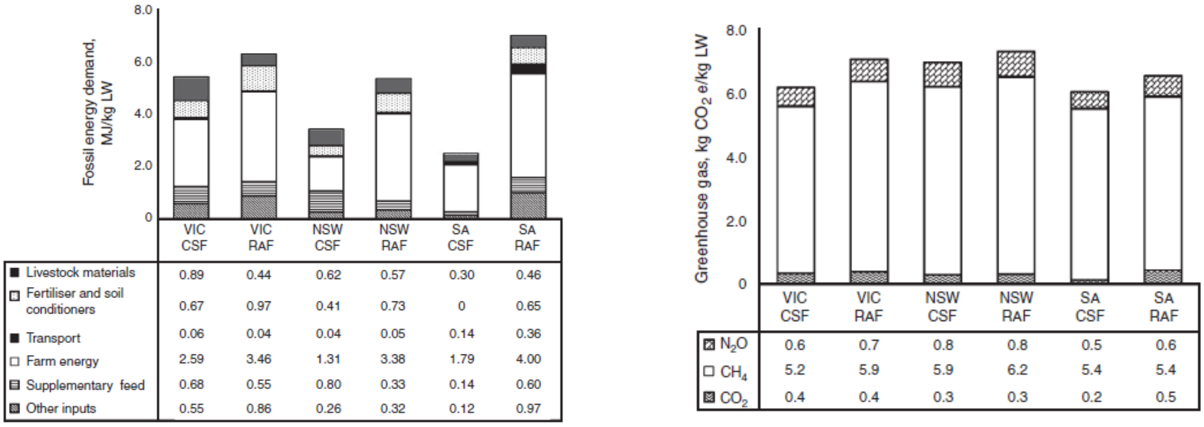


Figure 22 Trend in relative contributions of farm and feedlot processes to energy demand for beef production 1981 to 2010

7.3.2.2 Emissions from energy use

The above discussion focuses on direct livestock emissions due to their dominant contribution to the total GHGs from red meat supply chains. However, **fuel and electricity use are significant across the value chain representing major resource inputs** for which rising costs influence overall profitability of the industry as well as **contributing to GHG emissions**. **Major areas of energy use** and related GHG emissions include **on-farm** energy and **diesel fuel** use, energy for refrigeration **(including at the retail stage),** and energy for **production of steam and hot water**. Less significant amounts of energy are used for lighting, ventilation, motors and pumps. Of total supply chain GHG emissions from energy use, 67% is related to electricity use.

At the red meat processing stage, variations in contribution to GHG emissions occur as a result of differences in factors such as refrigerated product mix and installation of value-added meat processing facilities. Variation in fossil energy use is illustrated for export lamb production in case study and regional averaged data in Figure 23 (Wiedemann 2015c). As shown for beef production there is a need to balance higher inputs and costs for intensive production with associated GHG and other environmental impacts. Because of the dominant contribution of enteric methane, variation in GHG at the farm level is markedly less than that for fossil energy use. MLA reports that the red meat industry has been successful in reducing electrical and thermal energy emissions by 12% per tonne HSCW since 2003 to an average emission of 0.554kg CO_2-e/kg HSCW (~0.305kg CO_2-e/kg LW).



	VIC CSF	VIC RAF	NSW CSF	NSW RAF	SA CSF	SA RAF
Livestock materials	0.89	0.44	0.62	0.57	0.30	0.46
Fertiliser and soil conditioners	0.67	0.97	0.41	0.73	0	0.65
Transport	0.06	0.04	0.04	0.05	0.14	0.36
Farm energy	2.59	3.46	1.31	3.38	1.79	4.00
Supplementary feed	0.68	0.55	0.80	0.33	0.14	0.60
Other inputs	0.55	0.86	0.26	0.32	0.12	0.97

	VIC CSF	VIC RAF	NSW CSF	NSW RAF	SA CSF	SA RAF
N_2O	0.6	0.7	0.8	0.8	0.5	0.6
CH_4	5.2	5.9	5.9	6.2	5.4	5.4
CO_2	0.4	0.4	0.3	0.3	0.2	0.5

Figure 23 Fossil fuel energy demand and GHG emissions (excluding LULUCF) per kg LW at the farm gate for lamb produced from case study farms and regional average farms from Victoria, NSW and SA (Wiedemann 2015e)

7.3.3 Current and emerging trends in GHG mitigation strategy innovation

Global investment indicates a significant potential to reduce GHG emissions from livestock (Gerber 2013). Several global studies focus on increasing feed quality and animal welfare and survival in the context of climate variability and change in developing country production. However cooperative research is making progress in areas such as manipulation of rumen microbial populations, including potential development of a vaccine against methanogens (for example http://www.nzagrc.org.nz/current.html).

Targeting the dominant source of emissions from agriculture, Australian government and industry funding has been directed to research aimed at reducing methane emissions from livestock. Commencing in 2009 two major research programs coordinated by MLA (Reducing Emissions from Livestock Research program (RELRP) and National Livestock Methane Program (NLMP)) have developed practical options for Australian livestock producers to lower GHG emissions while maintaining or increasing productivity and profitability (Table 6). This research has also provided the scientific basis for development of ERF methods to enable producers to participate in carbon credit revenue opportunities. Parallel programs have invested in research on manure management, nitrous oxide emissions from cropland and pastures, and soil organic carbon and vegetation management. These programs provide further options for reducing net livestock emissions through managing dung and urine in feedlots, fertiliser applications in feed production, and sequestration of carbon in rangelands.

Enteric methane represents a loss of dietary energy from the production system, which, **if captured, could increase live weight gain in ruminant livestock**. Objectives under the MISP 2020 Priority, *Stewardship of Environmental Resources,* is to convert 25% of the energy lost in methane emissions into gains in animal productivity by 2030 and to develop new methods under the ERF to capture revenue from carbon credits of $80 M by 2030. These goals are consistent with, and assisted by, objectives for sustainable natural resource management and adaptation to climate variability. In addition to reducing emissions, the GHG profile of red meat production can be improved through offsetting emissions from livestock and farm operations by sequestrating carbon in biomass and soils possibly with additional ERF revenue. Good examples already exist of producers achieving carbon neutrality or better (Doran-Browne 2016) through good management and restoration of degraded grazing lands.

Table 6 Summary of potential GHG emissions change and productivity implications for practices identified in the NLMP coordinated by MLA. The potential for carbon credit methodology development and species/regional relevance is shown (MLA 2015d). Opportunities for sheep will also likely apply to goats with potentially higher gains due to lower baseline management

Strategy	Estimated GHG impact	Productivity impact	ERF potential (GHG reduction)	Potential for species/region
Practices available now				
BMP for feed utilisation & reproductive performance	-3%	20%	Approved (286 kt CO_2-e)	Cattle
BMP for feed utilisation & reproductive performance			In preparation	Sheep
Leucaena in pastures	-20%	22%	Very high (112 kt CO_2-e)	Beef cattle, N Australia
Native shrubs in pastures	-4%	5%	Medium (12 kt CO_2-e)	Sheep, SW Australia
Grape marc feeding	-10%	0%	Low (145 kt CO_2-e)	Sheep, spring/autumn Dairy/Cattle in feedlots
Nitrate (for urea) in dry season	-6%	0%	Approved (363 kt CO_2-e)	Beef cattle, N Australia
Practices requiring R&D				
Marine red macro-algae	-60%	8%	High (3296 kt CO_2-e)	Cattle, Sheep
Plan bioactive compounds	-25%	3.50%	Medium (1373 kt CO_2-e)	Cattle, Sheep
Beef cattle genetics	-6%	0.80%	Low (487 kt CO_2-e)	Beef cattle

A gap analysis undertaken as part of the NLMP summarised opportunities and research investment required to achieve potential productivity gains and methane emissions reduction (Figure 24) (Black 2015). Australian participation in international research can accelerate benefits for red meat production and mitigation.

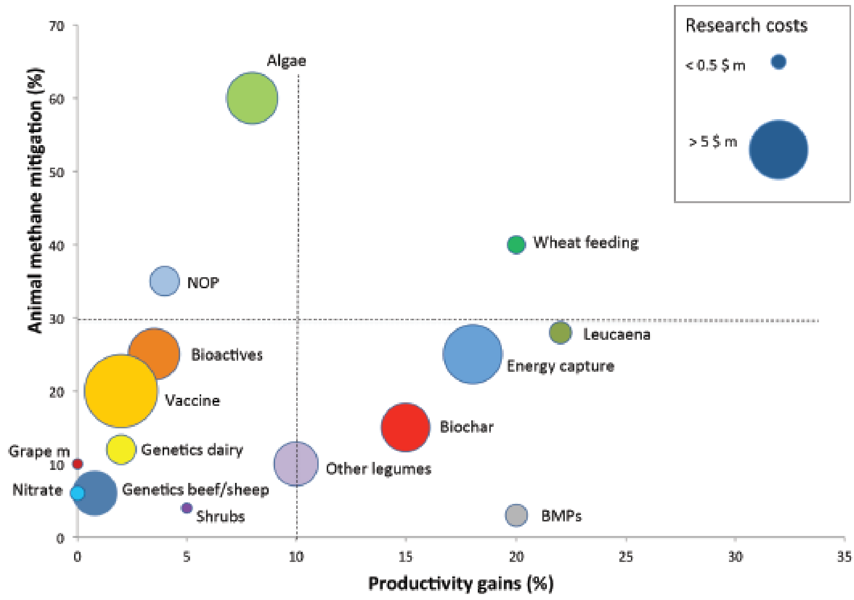


Figure 24 Relationship between methane mitigation potential in individual animals and estimated productivity gain for a range of methane mitigation strategies examined. Size of the bubble-dot represents a relative estimate of the likely R&D cost

7.3.3.1 Reducing emissions associated with fossil fuel energy use

An industry environmental sustainability review indicated 18% increase in energy consumption across processing sites since 2003. Although in part attributed to changes in the methodology, this increase indicates that despite existence of opportunities, uptake of GHG abatement associated with energy consumption may continue to be challenging. In addition to targeting efficiency measures, MLA and AMPC are encouraging adoption of renewable energy, such as solar, wind or fuel cells and supporting identification of options for energy recovery from waste materials, e.g. using paunch as boiler fuel or recovering biogas from anaerobic lagoons. Examples of energy savings with GHG emissions reductions include:

- **Flash steam recovery project on a boiler**, delivering savings of 16,866 GJ/yr (5.3% of energy consumption);
- **Reduction in hot water temperature**, saving 3,335 GJ/yr - 1.1% of the plant's energy usage.

Processors also have opportunities to participate in carbon credit markets (AMPC 2015). The highest potential GHG abatement for meat processors will likely come from waste-water treatment projects involving methane capture and reuse/destruction. There is also good potential for fuel switching e.g. biogas for process heat or cogeneration, and energy efficiency for heat and electricity. The two ERF methodologies most relevant to meat processors are:

1. *Carbon Credits (Carbon Farming Initiative – Domestic, Commercial and Industrial Wastewater) Methodology Determination 2015* which aims to recognize reduction in emissions from wastewater treatment arising from the replacement of deep open

anaerobic lagoons with new anaerobic digesters in the form an engineered bio-digester or a covered lagoon; and

2. *Carbon Credits (Carbon Farming Initiative – Industrial Electricity and Fuel Efficiency) Methodology Determination 2015* which aims to account for industrial emissions reductions arising from reduced energy consumption or increased energy efficiency that are real and additional to business-as-usual. Included in the scope of activities is changing the energy sources or mix of energy sources used by existing energy-consuming equipment, such as using biogas to replace the use of natural gas or coal in a boiler.

Investment in wastewater management to contribute to reducing processors' GHG emissions liability under NGERS (Jensen 2013) has the potential to reduce the value to below the NGERS default of 0.29 kg CO_2-e/kg HSCW (approximately 0.17kg CO_2-e /kg LW), and deliver savings equivalent to $20/t HSCW ($12/t LW).

7.3.4 Critical aspects for future GHG mitigation strategy development

A successful strategy to mitigate GHG emissions from red meat production will need to:

- minimize adverse and capture positive social, environmental and economic impacts;
- consider effective measures to address the social and economic impacts of actions across scales from profitability of individual producer and corporate enterprises to viability and prosperity of rural, regional communities and national/international industry competitiveness and market share.

Clear potential exists for red meat supply chains to reduce GHG emissions, in many cases using strategies that also improve productivity and/or reduce input costs. The significant gains that can be made from strategies to reduce GHG emissions through associated benefits for efficiency, animal welfare and consumer relationships also provide benefits through assuring ongoing market access and economic growth of the red meat industry.

Recognition of the threat of climate change has raised awareness of the importance of all economic sectors contributing to global mitigation of GHG emissions. At the same time discriminating consumers are seeking to purchase high quality nutrition that is safe and produced sustainably. The Australian red meat industry is well placed to benefit from these market trends. Priorities for **mitigation of GHG emissions**, which are compatible with productivity growth exist now (e.g. **feeding Leucaena**); and provide exciting future prospects e.g. **rumen microbial changes to capture additional energy**. Focussing on collaborative research in global initiatives will assist in accelerating progress in these and other innovative strategies. Recent research has identified opportunities for near-term gains including:

- **developing a dose response relationship for Leucaena** in Northern beef cattle diets to support ERF methods;
- understanding response and practical implementation of **red algae as a dietary supplement** (Cole 2015);
- evaluating whether **3-nitrooxypropanol (3NOP)** can give **consistent inhibition of enteric methane** (Hristov A. N. 2015);
- **improved efficiency of fossil fuel energy across the supply chain** to minimise emissions and costs; and

- decreasing direct and indirect emissions from waste while utilising carbon and nutrients.

7.4 Focus area: Solid wastes

7.4.1 Introduction to wastes in the red meat industry

Waste in the red meat industry arises at each stage in the supply chain and encompasses a wide variety of forms. The challenge is to develop potential applications to transition from ‘waste’ to ‘co-products’ and then to value added products to generate new revenue streams for the industry. Waste, for the purposes of this section will focus on solid wastes as liquid waste will be covered under the ‘water’ focus area. Also, direct anaerobic digestion of solid waste will be excluded from this discussion as this is largely covered under water waste processing focus area. Anaerobic digestion is recognised, however, as a strong potential processing technology for many solid wastes from meat processing.

7.4.1.1 Current position

The areas of focus in this report are production and processing with some consideration given to at market and transportation areas. The major waste from livestock production is **manure**, which is **composed of** a variety of materials and compounds of potential value including **fibres, polysaccharides (e.g. starch, cellulose), lignin and nutrients (e.g. phosphate, nitrogen, metal ions)**. **Meat processing co-products** include edible offal, rendered products, pet food, hides and skins and alternatives such as pharmaceutical or biotechnology products.

At market wastes include packaging (which is covered in a separate project and therefore excluded from the scope of this document but will be included in the wider solid waste analysis) and the meat, bone and offal products not purchased or consumed. Examples of at **market wastes** would **include ‘out of date’ meat not sold in supermarkets or carcase waste from larger butcheries** (e.g. in supermarkets). **Transport** is also a **major component** of the supply chain and wastes arising here include used **engine oil and tyres**.

Recent data from the Australian Bureau of Statistics (Figure 25) suggest that around 7,900 on-farm agricultural businesses performed at least one type of animal waste management practice in 2013-14 with dry manure being the most managed waste (compared to wet manure or other practices). The region with the highest percentage of businesses employing on-farm animal waste management was Temperate Coast East with 16.3% followed by Temperate Coast South (11.4%) indicating that the overall rate of on-farm waste management is very low with the majority (over 90%) of Australian business not undertaking waste management practices. The actual number of businesses managing dry manure was broadly in proportion to the number of feedlots in each state. Queensland however seems under represented given the state has the highest number of head on feed (see Figure 26).

7.4.1.2 Common language and key benchmark indicators

On farm waste will be quoted in terms of mass (kg) or value (AU$) of waste per head of livestock - 465 kg for cattle and 24 kg for lambs (NSW Lamb Marketing Document). Processing waste will be considered in terms of mass (kg) or value (AU$) of waste per tonne of Hot Standard Carcase Weight (HSCW), which equates to around 240 - 270 kg HSCW per head for cattle (QLD ecomeat manual, 2001; MLA co-products compendium) but can vary between 40 and 60 % of the live weight depending on the specific species and the individual animal. HSCW is the national standard for 'over the hooks' selling and is defined as the carcase mass up to two hours post slaughter following a standard trim. Value of the waste will be quoted in Australian dollars.

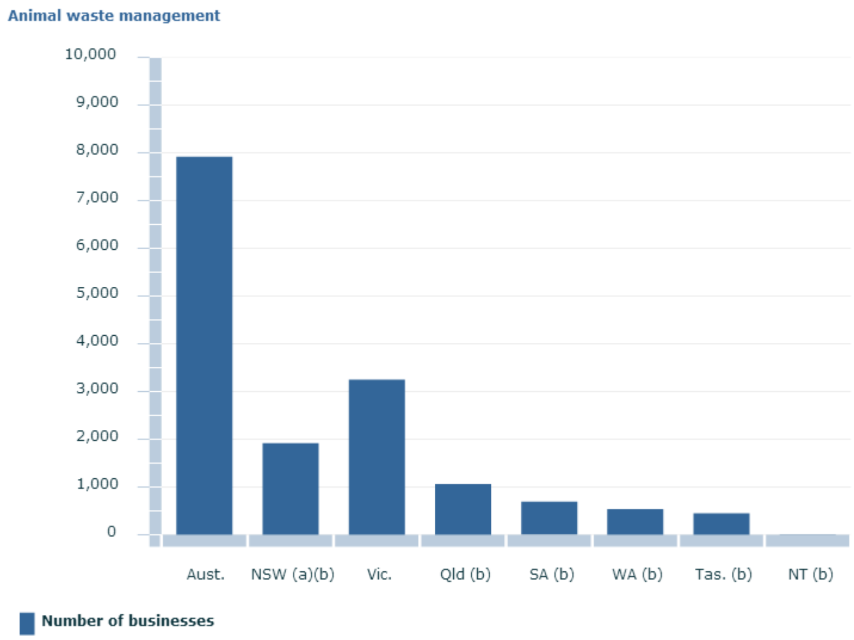


Figure 25 Numbers of businesses employing on-farm waste management practices. (a) Includes ACT (b) Zero values may be due to unavailable data due to confidentiality restrictions. Source: (ABS 2015c)

7.4.2 Current status of waste in the red meat industry

7.4.2.1 On-farm

A previous MLA report (MLA 2011b) performed a mass balance on feedlots using literature-derived data. They reported that a **600 kg live weight animal** would produce in the order of **1,300 to 1,900 kg of manure (total solids) per year** depending on the breed and ration. Excreted and harvested manure were assessed from literature as well as a study of Nebraska feedlots suggesting that between **4.3 and 7.5 kg of total manure solids (1.5 to 2.3 kg of volatile solids) per head per day based on a 445 kg animal could be harvested** (Kissinger, 2007). Total solids refer to the dry manure and volatile solids refers to the mass loss obtained when dry manure is combusted. As **manure is composed of both faeces and urine**, harvested manure includes a **moisture content** of anywhere **between 20 and 78%** with **excreted manure** around **90% moisture** (Kissinger, 2007).

The Queensland Government has published similar figures (no reference regarding the source of the data) for animals of various sizes (Table 7).

Table 7 Manure production data Source: (DAF 2011); *BOD = Biological Oxygen Demand.

Animal size (kg)	Manure production (kg/day)	Total solids (kg/day)	Volatile solids (kg/day)	BOD* (kg/day)	Nutrient content (kg/day)		
					N	P	K
220	13.2	1.54	1.32	0.35	0.075	0.024	0.052
300	18.0	2.08	1.06	0.48	0.104	0.034	0.076
450	27.0	3.10	2.70	0.72	0.153	0.050	0.108
600	36.0	4.18	3.56	0.96	0.206	0.068	0.149

The technology employed to generate value from manure and its commercial viability will depend on the volumes of material that are available. These volumes and viability are dependent not just on the amount of manure per head but also the total number of head and their geographical distribution. Often, **a major limiting cost in processes to convert waste to products is the transportation of the waste feed stock or transportation of the product**. Often, agricultural waste is distributed over a large area and the cost of aggregation of that waste to a central processing facility imposes limitations on how much waste can be collected and processed. As such, transport logistics play a critical role in the viability of a processes and this is a well-established consideration in cellulosic ethanol manufacture (Lin 2015).

Data from 2013 are available on total livestock numbers (Table 8) but this doesn't necessarily directly correlate to what numbers are kept in conditions where manure could be collected. For example, only cattle in feedlots or dairies are available for manure collection as collection from pasture is impractical. The Australian Lot Feeders' Association report that in the final quarter of 2015 there were 997,765 head on feed (Figure 26) with the majority being on farms with over 10,000 head (ALFA 2016).

Table 8 Numbers of head of livestock on holding at 30 June 2013. (a) Includes bulls, steers, calves and heifers, (b) Includes bulls, steers and calves, (c) Including maiden ewes intended for breeding, (d) Includes rams, marked lambs, wethers, hoggets and non-breeding ewes. Table reproduced from (ABS 2014).

	Number on holding ('000)	Change in number on holding since 2011-12 (%)
CATTLE AND CALVES		
Dairy cattle		
Cows in milk and dry	1 688	-1
All other dairy cattle (a)	1 146	11
Total dairy cattle	*2 834*	*4*
Meat cattle		
Cows and heifers one year and over	13 430	-1
All other meat cattle (b)	13 027	8
Total meat cattle	*26 457*	*3*
Total cattle and calves	**29 291**	**3**
Proportion of total herd		
Dairy cattle (%)	10	
Meat cattle (%)	90	
SHEEP AND LAMBS		
Breeding ewes one year and over (c)	40 250	-10
All other sheep (d)	35 298	18
Total sheep and lambs	**75 548**	**1**

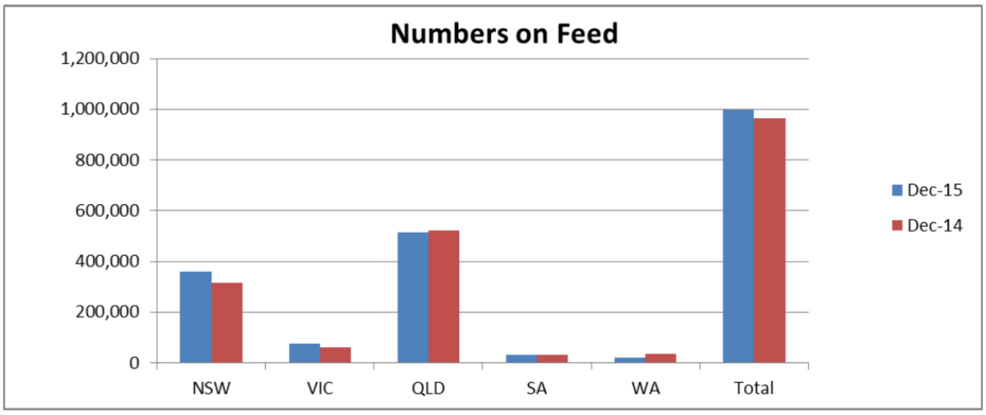


Figure 26 Numbers of head of cattle on feed by state. Source: Australian Lot Feeders' Association

Using the numbers of **997,765 head on feed and manure production from a 450 kg animal of 27.0 and 3.1 kg/day for total manure and total solids respectively gives a national production of 27,000 tonnes of total manure per day** (3,100 tonnes of total solids). The geographical distribution of this biomass feedstock will be crucial, however, in determining process viabilities. As the **majority of cattle are on feedlots holding over 10,000 head** (over 31 tonnes of manure per day) then waste conversion processes should be evaluated along with the potential for waste aggregation if large feedlots are clustered in particular areas.

A model has been generated and updated termed BEEF-BAL that predicts the quantity and composition of feedlot manure based on the class of stock and diet (Davis 2012). This model could be used for a more accurate assessment of manure volumes that could be coupled with a more detailed understanding of the geographical distribution and numbers of head per feedlot (over a minimum number to exclude farms too small to be viable for aggregation of manure).

7.4.2.2 Meat processing

Recent data are available on the numbers of head of livestock slaughtered per month with the latest figures shown in Table 9.

Table 9 Data on livestock slaughtered in Australia. (a) Excludes calves

Livestock (no.)	December 2015	January 2016	Change Jan 2015 to Jan 2016
Cattle (a)	678 615	668 113	-15.8%
Calves	37 114	32 706	-46.3%
Sheep	706 957	698 567	-8.4%
Lambs	1 925 828	1 939 751	2.1%

MLA has developed a spread-sheet tool to analyse co-product yields and values and an example is summarised in the MLA co-products compendium. This evaluation showed that from a **465 kg steer, 190 kg of edible meat can be derived along with 167 kg of rendered products (including 48 kg of meat meal and 52 kg tallow), 36 kg gut fill/paunch, 3 kg pet food, 17 kg edible offal, 18 kg blood and a 28 kg hide**.

MLA publishes monthly reports on prices and volumes of offal, the latest being February 2016 data. In January 2016, 7,656 tonnes and in February 2016, 11,494 tonnes of offal were exported (seemingly the major destination for offal as opposed to the domestic market). From the above data, the 680,819 head of cattle slaughtered in January 2016 should equate to 11,574 tonnes of edible offal, which is close to the February 2016 export total, again suggesting that export is the major destination for this co-product and that a significant opportunity exists for domestic consumption. As human consumption is likely to be the highest value and most beneficial use of offal, effort should be directed at increasing **human offal consumption with waste processing technologies focused on non-edible fractions** (provided human consumption acceptance can be achieved).

These **non-edible fractions include gut fill (paunch), blood, hide and rendered products**. Current market prices (February 2016) for those with current sales values are shown below in Table 10.

Table 10 Current (February 2016) market prices for selected co-products. FFA = free fatty acid. TFA = tick free hides. QLD = Queensland. Hide values vary from state to state and depending on quality

Product	Average Price	Range
Foetal Blood	$215.00/kg	n/a
Gall (concentrated)	$21.00/kg	n/a
Rendered Products		
Blood meal 85	$891.83/tonne	$90.00
Tallow Ined.<1FFA	$812.60/tonne	$70.00
Hides		
Hides QLD TFA 281 - 350	$45.50/head	$7.00

Paunch/gut fill is the major co-product that is not included on the list (or in the Co-products compendium) as a product with value with most other products being covered under rendered products. Paunch is also one of the **largest volume waste streams from livestock processing**. At **36 kg per head, 25,000 tonnes** would have been **produced in Australia in January 2016**. The paunch **consists of the rumen contents** that includes **undigested feed (grass and grain)** as well as **nutrients (e.g. phosphate) and microorganisms (including possible pathogens)**. The paunch can be dewatered mechanically to yield a solid waste that could be processed to alternative products. The proportion of liquid removed depends on the dewatering method with paunch being composed of 40-50% total solids (Mehta). Additional information can be found in the MLA waste solids environmental best practice manual (AMPC).

Further products from livestock processing include solid wastes (including fats) from primary processing of liquid waste by rotating drum or air flotation. The variable quality of this waste stream means not all can be directed into the rendering process. A final waste stream for consideration that has not been mentioned in previous reports is hair derived from the salting of hides prior to transportation. Opportunities exist for the processing of hair (and other types of keratin such as horns and hooves) to the constituent amino acids in a manner similar to the treatment and use of feather meal from poultry.

7.4.2.3 Transportation

Transportation is a major part of the red meat supply chain that includes on farm operations (feed delivery), cattle transportation and transportation of products to market. Transportation of livestock to processing facilities can either be performed by the producers or by transport contractors (see http://alrta.org.au/ for the Australian Livestock and Rural Transporters Association). Given the scale of the red meat industry in Australia, the transport of livestock will be a significant proportion of total truck activity and as such will generate **significant wastes in the forms of lubricant oils and tyres**. No specific data have been identified on volumes or aggregation of these waste streams. In general terms, in the **year ending 31**

October 2014 there were 3.4 million freight vehicles registered in Australia with **30.544 billion tonne kilometres** travelled for food and animal feed, the second largest category with **live animals accounting for 6 billion tonne kilometers** (see (ABS 2015d) and the associated spread-sheet).

7.4.3 Current and emerging trends in waste innovation

The MLA Co-products compendium, published in 2009, provides details on opportunities for products from various forms of waste as well as a review of past MLA funded projects relevant to the topic. It is recommended that a similar compendium be generated that updates MLA funded projects from 2009 to the present day. The above analysis indicates that a significant opportunity exists for gut fill/paunch processing and this is largely excluded from the 2009 compendium as the authors felt there was little opportunity for alternative uses.

Along **with manure, the solids recovered from paunch** could be viable **substrates for solid or liquid state fermentations** when **coupled to biomass pretreatment processes that would help yield fermentable sugars**. These fermentations could be used to generate biofuels and other fermented chemical products as well as a protein enriched animal feed from the accumulated microbial cells (e.g. yeast). Liquid phase fermentations of biomass derived fibre to generate fuels and feed are now practiced at large scale in Italy (Beta Renewables) and in the USA and Brazil. Solid state fermentation of sweet sorghum coupled with lignocellulosic degradation has also been demonstrated at commercial scale (100 tonnes per day) by researchers at Tsinghua University in China (Li 2013).

Alternative products for meat processing waste are detailed in the Co-products compendium (see Appendix 3) and range from pharmaceutical products and microbiological growth media to glue and fertiliser.

A recent review detailed opportunities arising for increased value from rendering (Mekonnen 2016). The review focuses on beneficial uses for the three main components of rendering waste; namely protein, lipids and ashes. A major focus of the review is the production of plastics from protein biomass (e.g. from blood meal, meat and bone meal). These fractions may be combined with plasticisers to obtain functional plastics. The conversion of protein to industrial flocculants, surfactants/firefighting foams and wood adhesives was also considered. Beneficial uses of lipids was mostly centred around biodiesel production although use in animal feed, soap and cosmetics was also considered. Finally, ash, rich in calcium and phosphate, could be used as fertiliser, an animal feed additive or to generate advanced materials such as hydroxyapatite for use as an absorbent, catalyst or in medical implants.

Waste engine oil and used tyres have the potential to be recycled into hydrocarbon fuels and oils. In a recent development, Southern Oil Refining announced plans to construct a $16 million pilot plant in Gladstone, QLD to produce fuel from biomass (that could potentially include meat industry solid waste) as well as tyres. The current Southern Oil business (including the Northern Oil refinery near Gladstone) refines waste oils from industries such as mining to recycle and re-use the oils. Rockhampton is well suited for access to the Queensland feed lot industry and could open up processing possibilities.

7.4.4 Critical aspects for future waste innovation development

There are a range of opportunities to access increased value from solid waste processing across the red meat supply chain. Whilst opportunities will exist for high value low volume products (such as pharmaceuticals) the major opportunities are around co-products of significant volume (manure and paunch) or where beneficial processing could also solve a current industry issue (e.g. hair accumulation).

Further details are required around waste volumes and their geographic distribution and any proposed waste processing solution should also account for transportation issues and costs.

7.5 Focus Area: Water

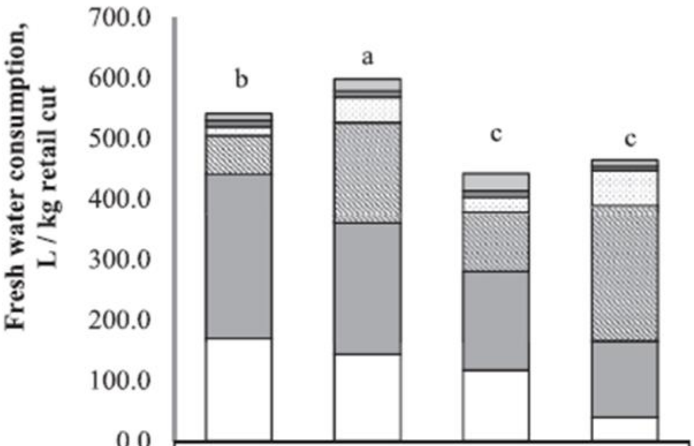
7.5.1 Introduction to water in the red meat industry

Comprising approximately 2/3 of the animal live weight, water is the largest feed component consumed during animal production and an essential requirement for maintaining animal health. Therefore, water is a critical resource in the red meat supply chain. After land, water is generally considered the most valuable resource in Australia, due to the scarcity of good quality water. This creates strong economic, environmental and social pressures to manage water consumption in a responsible and sustainable manner.

7.5.2 Current water usage in the red meat industry

7.5.2.1 Overview of water use across the supply chain

Red meat production is considered a large consumer of water resources. The total water consumption for the red meat life cycle is presented in Figure 27, with the overall water demand calculated in terms of Litres (L) of water per kg retail cut. Figure 27 considers only water consumption defined as evaporative uses or uses that incorporate water into a product that is not subsequently released back into the same catchment (ISO, 2014). A very high fraction of water use in the red meat supply chain occurs during production, with only a small fraction of water use occurring during processing. However, the distribution of water use across the supply chain does not directly represent the relative distribution of water costs to these sectors. **Primary sources of fresh water consumption during beef production are related to drinking requirements of the livestock and irrigation water used to grow animal feed –** water for these applications can be lower quality and is therefore lower cost. **Primary water requirements** in **meat processing** relate to **cleaning, sterilisation and materials transport operations**. Water quality **requirements** for meat processing are **higher** due to **food hygiene requirements** and this substantially increases the cost on a volume basis.



	Beef grass	Beef MF	Beef LF	Lamb
Other minor use	11.2	19.5	28.9	10.0
Meat processing	10.1	10.1	10.1	7.1
Irrigation losses	15.1	42.2	25.4	58.2
Irrigation	63.4	165.8	97.8	223.7
Drinking losses	272.1	217.1	163.7	126.5
Drinking	168.6	142.9	115.9	38.2

Figure 27 Contribution of supply chain elements to water consumption, per kg of retail ready Australian beef and lamb exported to USA. Grass refers to grass-fed, MF refers to medium fed grain (115 days), LF refers to long-fed grain (330 days). Different letters on bars indicate significant differences (P < 0.05) between cases assessed using comparative Monte Carlo analysis i.e. there is a statistically significant difference in the fossil energy consumption between the different finishing options for beef (Wiedemann 2015a).

Drinking water: Typically drinking water is predicted from livestock inventories and consumption models that take into account live weight, feed intake, moisture content of feed and ambient temperature. Australian Water Quality Guidelines (ANZECC 1992) suggest that a maximum total dissolved solids (TDS) concentration for healthy growth of beef cattle is 4000 mg/L (6.25 dS/m), however, higher TDS concentration are possible for short periods. An example of drinking water requirements and the resulting water balance for cattle is shown in Figure 28.

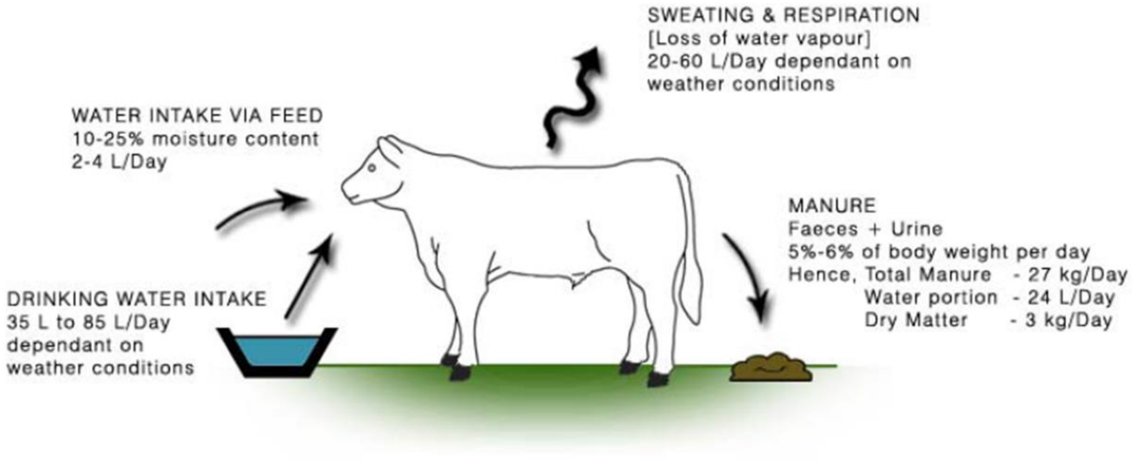


Figure 28 Water balance during beef production (Davis 2008)

Drinking water supply losses: Evaporation and other losses from the drinking water supply are highly dependent on the design of the water supply system. Currently, there are no detailed statistics reporting the breakdown of drinking water supply sources (bore, creek/river, dams) in Australia, therefore data is based (in part) on information supplied while surveying industry experts. Generally, the highest losses arise from uncapped bores flowing freely to open, unlined drains. Evaporation losses from farm dams are a major contribution to losses in drinking water supply, partly due to high evaporation rates and partly due to the widespread use of this supply method. The redesign of farm dams is a potential strategy to reduce losses from the drinking water supply.

Irrigation water and Irrigation water supply losses: Irrigation water presented in Figure 27 was determined from national land use statistics and data for irrigated pasture (used for beef cattle), and irrigation use associated with the production of purchased hay, grain and supplements. National water use statistics report the sources of irrigation water supply as distributed sources (46%), bores (27%) and other surface water supplies (24%), with the remaining 3% being reuse water from other industries. Irrigation losses correspond to evaporation losses from state owned supply dams and seepage losses from irrigation channels. Losses from surface water sources (i.e. direct extraction from unregulated creeks and rivers) and bores are assumed to be negligible. The average loss rate is estimated at 27.1% of total water extracted from the environment.

Literature reports a **decrease in water consumption from the Australian Beef heard of more than 60% in the period from 1981 to 2010** (Figure 29). During this period, drinking water supply losses decreased by more than 65%, with the savings **mainly related to lower supply losses from artesian bores in the pastoral regions**. **Irrigation water decreased more than 80%**, although key strategies that contributed to this decrease, are not readily available. There was little or no change in the drinking water requirements during the period 1981 – 2010.

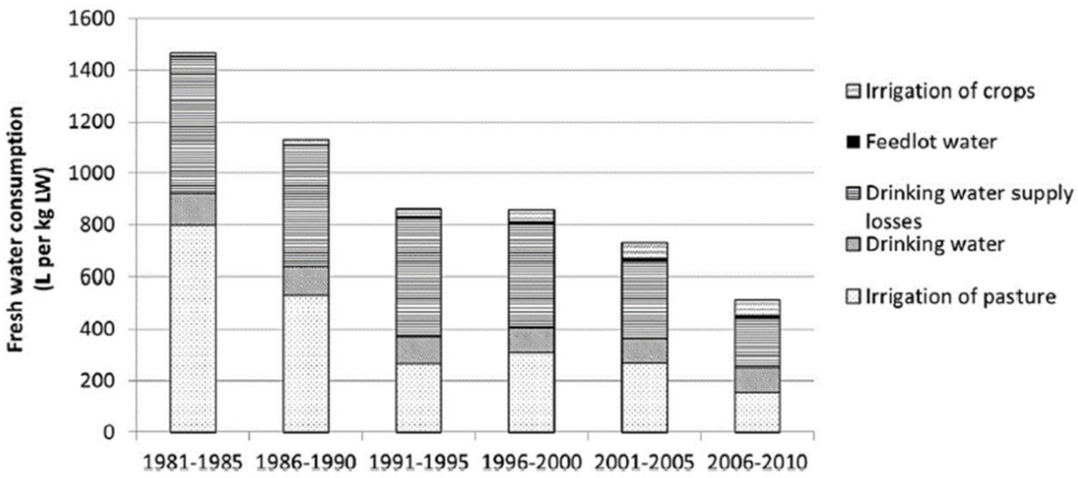


Figure 29 Change in fresh water consumption per kilogram of LW from the Australian beef herd from 1981 to 2010 (Wiedemann 2015d).

7.5.2.2 Production

Figure 30 presents a breakdown of total water use and contribution of different activities at 8 Australian feedlots surveyed in 2007/8. Consumption of drinking water represents 70-90% of water usage, depending on the time of year and cattle washing operations.

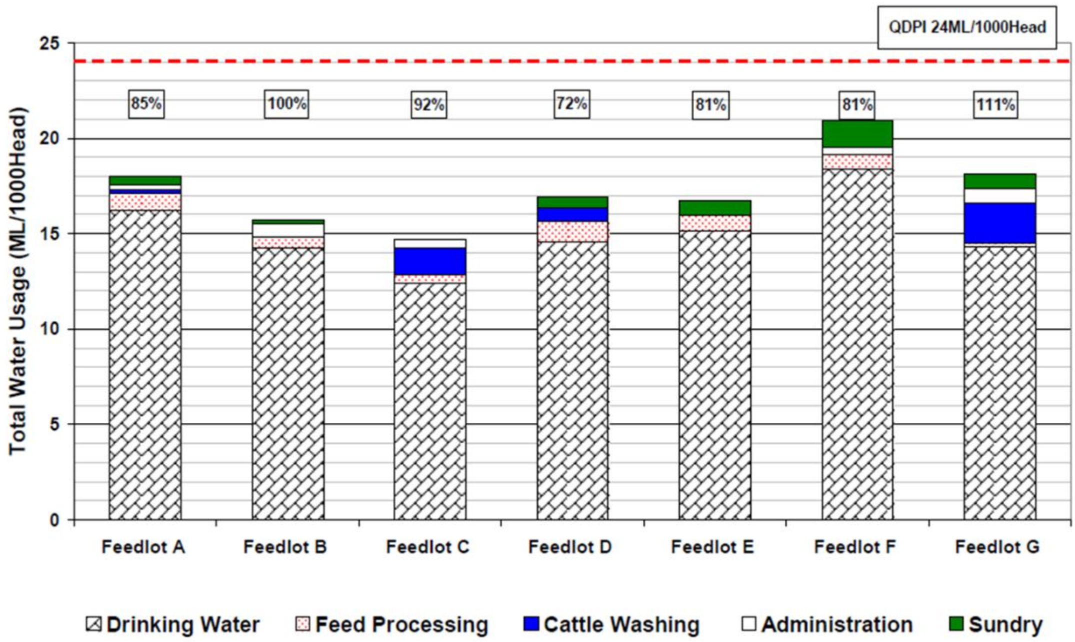


Figure 30 Summary of total water use and contribution of different activities at 8 Australian feedlots surveyed in 2007/8 (Davis 2008)

Initiatives developed to reduce water consumption in feedlots include:

- Reusing water in cattle wash-down facilities;
- Covering dams to reduce evaporation;
- Only using necessary water requirements for feed milling;

- Using neighbouring coal seam gas development water;
- Reusing effluent water for dust suppression.

The industry is also researching other initiatives such as treating effluent water for cattle drinking purposes and more efficient ways to use water collected from rainfall. Table 11 summarises opportunities for the use of reclaimed water during cattle production as advised by the Victorian EPA. If the recycled water includes inputs from saleyards or abattoir waste, additional measures are required to ensure that young cattle (under 12 months of age) are not exposed to the reclaimed water to minimise the risk of infection (i.e. with Johne's disease).

Table 11 Opportunities for use of reclaimed water in cattle production (Victorian EPA, note AG1089)

Type of water usage	Class A	Class B	Class C
Livestock drinking water	✓	✓	✗
Dairy shed wash-down	✓	✓ 1	✗
Pasture or fodder crop application – lactating dairy cattle	✓	✓ 2	✓ 3
Pasture or fodder crop application – non-lactating cattle	✓	✓	✓ 2
Hay production for use on farm by cattle	✓	✓	✓
Pasture ensilage- Use on farm by cattle	✓	✓	✓ 4
Sale of fodder or crops	✓ 5	✓ 5	✓ 5

✓ use is recommended (subject to comments, if any, below)

✗ not to be used for this purpose

1 but not for milking machinery

2 restrict access for 4 hours or until pasture/fodder crop is dry

3 restrict access to lactating cattle for 5 days after application

4 wait for 4 hours or until dry before ensiling

5 product to be labelled or sold with instruction 'fodder not for consumption by pigs'

7.5.2.3 Processing facilities

Australian red meat processors consume around 8 kL of water per tonne of hot standard carcase weight produced (A.PIA.0086, A.ENV.0151). Water use in the processing sector is not consumptive and therefore **results in large wastewater streams** in the order of **2 ML/d of wastewater for a plant processing 800 head per day**. Considering the purchase price (up to \$3.5/kL, \$28/tHSCW) and the costs for treatment and disposal (\$1-2/kL volume, plus possible penalties for organic and nutrient contaminants, >\$10/tHSCW), **water usage** represents a **large financial cost** for the industry. Currently, most Australian abattoirs use municipal potable water supply, this water may be used in production areas including contact with meat and meat surfaces (e.g. final rinse of carcasses). A breakdown of water use in Australian slaughterhouses is shown in Table 12.

Table 12 Breakdown of water consumption in Australian Slaughterhouses

Major Areas of Water Consumption	Contamination Level	Fraction of Total Fresh Water Consumption
Stockyard (mostly wash-down)		7-24%
Slaughter, evisceration	Low	44-60%
Boning		5-10%
Inedible & edible offal processing		7-38%
Casings processing		9-20%
Rendering		2-8%
Chillers	Low	2%
Boiler losses	Low	1-4%
Amenities		2-5%

There have been a **range of initiatives by the Australian red meat industry to improve water efficiency including** (MLA, 2014):

- Reducing consumption through initiatives such as waterless cleaning
- Increasing reuse / recycling of water through initiatives such as process improvement and tertiary treatment of water
- Increasing usage of alternative sources such as rainwater and geothermal systems

Examples of successful water saving initiatives implemented in the industry include (MLA, 2014):

- implementation of sealing and cryovac machines throughout the plant to capture water for reuse
- reused water used for yards, wash-down, cattle pre-wash, truck washing and other non-potable applications
- installation of sensors on hand wash stations and sterilisers
- hose nozzle size reduction

7.5.3 Current water treatment practices and emerging technologies

A high fraction of water usage in the production stages of the red meat industry is consumptive with limited opportunity for recovery during wastewater treatment, therefore opportunities related to wastewater and wastewater treatment will focus on processing.

Waste and wastewater originates from several major process operations at a slaughterhouse including cattle preparation, cattle slaughter and recovery/reprocessing of by-products. Cattle preparation occurs in the cattle yard and refers to holding yards where cattle are un-loaded from vehicles and stored prior to slaughter; waste from this area includes urine, faeces and water used to wash the cattle and the yards. The next stage in the slaughterhouse process is cattle slaughter. Cattle slaughter can be divided into 4 areas: (i) Slaughter Floor, where cattle are slaughtered while the hides, intestinal tracts and viscera (internal organs) are removed, the product from the slaughter floor is a stripped carcass; (ii)

Boning Room, where chilled carcasses are divided into primary cuts; (iii) Paunch Processing, where the intestinal tracts are opened to remove the stomach contents and cleaned; and (iv) Offal Processing, where the remaining viscera are cleaned and processed prior to rendering. The final area is the Rendering plant where the waste from slaughterhouses, such as heads, hooves, bones, blood and viscera are typically sent for recovery and/or reprocessing of by-products. Wastewater from the rendering plant will typically have a high temperature and may have a high concentration of fat, oil and grease. The composition and strength of wastewater from these 6 different process areas is expected to be very different.

Generally, waste streams from different processing areas are transported separately within the site then combined for bulk treatment (e.g. in an anaerobic lagoon). The structure of waste and wastewater handling processes varies between sites but the general processes in Australia are demonstrated in Figure 29 Figure 31. In particular, the extent of treatment, varies from site to site. Some sites will apply little to no treatment, other apply primary treatment only, however there is an emerging trend for application of more advanced secondary treatment processes.

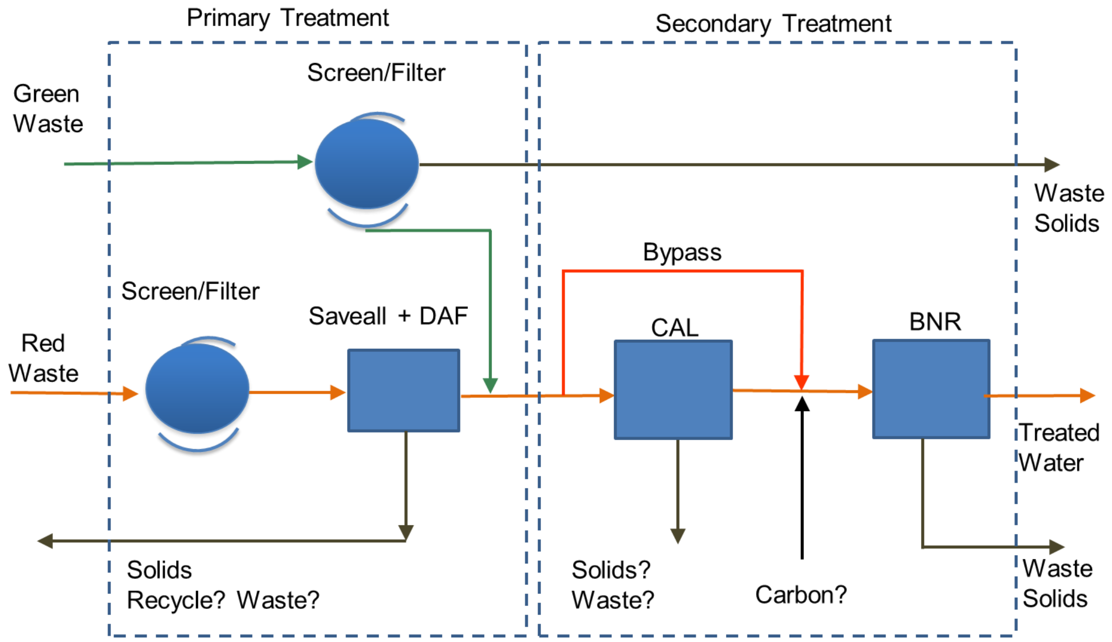


Figure 31 Structure of wastewater handling processes commonly utilised at Australian Slaughterhouses

The general treatment train in Australia includes:

<u>Primary treatment:</u> Typically screening to reduce total suspended solids, dissolved air flotation (DAF) as a pretreatment to remove fat, oil and grease (FOG) and further reduce total suspended solids (TSS).

<u>Anaerobic treatment:</u> Typically applied to remove organic material (COD) and generate biogas as a source of renewable energy; this step will also mobilise nitrogen and phosphorus that were bound in the organic material. Anaerobic lagoons and covered

anaerobic lagoons are effective and are widely applied. However, lagoons require large footprints and can generate odour. There are emerging options based on in-vessel processes (such as AnMBR and AFR) with much smaller footprints (up to 100x smaller), improved gas capture, elimination of odours and the ability to optimise for energy or nutrient capture.

Aerobic treatment: Typically applied as a clean-up step to remove residual biological oxygen demand (BOD) from anaerobic treatment and to remove nitrogen. Reliable BOD and nitrogen removal systems based on activated sludge systems have been development and applied in the industry. However, there are also emerging options such as anaerobic ammonium removal with reductions in cost, energy consumption, footprint and elimination of chemical addition.

There are multiple technologies commercially available or emerging for each treatment step with technology selection likely to be based on the specific requirements and constraints of each processing facility. A summary of current and emerging technologies is included in Table 13. Technologies highlighted in green are typically used to recover value from the wastewater, while the remaining technologies are generally targeted towards achieving discharge/licensing requirements.

Table 13 Summary of waste treatment and value-recovery technologies and technology readiness level

Technology Readiness Level	Primary	Secondary	Tertiary
Commercially Applied	• Screens • Hydrocyclones • Settling Tanks/Saveall • Dissolved Air Flotation	• Anaerobic Lagoon • Covered Anaerobic Lagoon • Aerobic Lagoon • Activated Sludge • Biological Nutrient Removal	• Ultrafiltration • Ozone • UV
Emerging	• Membrane based FOG recovery	• Covered High Rate AL • Anaerobic Membrane Bioreactor[1] • Anammox[1] • Struvite Precipitation[1] • Single Cell Protein	• Microfiltration[1] • Nanofiltration[1] • Reverse osmosis[1] • Forward osmosis

[1] Commercially applied in industries outside of red meat processing

Table 14 is a summary of wastewater production and the resulting energy and nutrient loads from 6 Australian Slaughterhouses surveyed in 2011/12. This table represents combined raw wastewater at each processing site, after primary treatment for recovery of FOG and before discharge to an anaerobic lagoon, compared with concentration ranges expected from literature. This study showed that while nutrient loads (N and P) were within the upper range of values previously report, organic loads (COD, TS, FOG) were 2– 4 times greater than loads previously reported (Cowan 1992) (Tritt 1992) (Johns 1995) (Cowan, MacTavish et al. 1992, Tritt and Schuchardt 1992, Johns 1995, Mittal 2004). The increase in organics was at least partly attributed to an increase in the temperatures of combined slaughterhouse wastewater and resulting challenges with existing primary treatment technologies.

Table 14 Energy and nutrient loads fin wastewater from 6 Australian slaughterhouses compared with literature values (per t HSCW) (Jensen 2014)

	Water m^3	COD kg	TS kg	FOG kg	N kg	P kg
Literature [a,b]	5.6 – 22.2	16.7 – 44.4	8.3 – 22.2	2.8 – 13.9	1.4 – 4.2	0.1 - 0.4
Site A[b]	8.1	64-109	70	19.6	2.0-4.8	0.4-0.5
Site B	7.4	71	31.7	5.8	1.7	0.37
Site C[b]	14.7	78-160	110	49	2.4-3.8	0.35-0.43
Site D	~11	55-101	32-59	6-10	2.8-3.6	0.38-0.45
Site E	7.1	78	44	11	1.9	0.3
Site F	7.1	86	49	14	4.7	0.3

a. Based on (Cowan 1992, Tritt 1992, Johns 1995, Mittal 2004). Based on beast weight of 600 kg, and HSCW yield of 60%.

Advanced water treatment trains designed for the production of high quality water from treated wastewater are an emerging option for Australian red meat processors. These advanced treatment trains generally consist of **ultrafiltration, reverse osmosis membrane and a disinfection system** (such as UV or advanced oxidation process). Conventional advanced water treatment trains have been implemented in a number of breweries, snack foods manufacturing and poultry slaughterhouse in Australia. These sites were able to greatly reduce use of external water supplies, thereby reducing costs and improving sustainability of the operation.

In a red meat processing context, water can be reused or recycled from various sources and can be produced at different quality levels depending on its end-use, typically as potable or non-potable water. However, **the use of recycled water has to follow strict requirements** such as (AQIS):

- Exclude human effluent from the water stream to be reused;
- Use a multiple-barrier approach;
- Access to the potable local authority water system or other acceptable alternative supply in case of system failure;
- Must meet the Australian Drinking Water Guidelines for potable water; and
- Must not use the water as a direct ingredient in meat products or use it for drinking water at the establishment.

Water recycling is now being applied in at least 1 red meat processing plant in Australia (Radford Meats, Warragul Victoria) and has reportedly been able to reduce water consumption to 2.5 kL/tHSCW. A guide for red meat processors considering application of water recycling and re-use was prepared by AQIS Meat Notice 2008 / 06 – Efficient Use of Water in Export Meat Establishments. This guide covers the procedures required to gain approval for water recycling, not the specific technologies available or specific application areas.

Water recycling options could be applied to combined effluent streams (however this may be energy intensive) or selectively applied to lower contaminated streams such as water from chillers, boiler systems or boning rooms using simpler treatments to reach an equivalent qu8ality of recycled water, thereby reducing the cost and energy required. However, there is a limit to the water available from these sources and this may limit the overall economic impact and benefit of water recycling. These lower contaminated streams can represent 40-60% of wastewater at a red processing plant.

However, there are several important differences in regulatory requirements between Australia and key export markets. This is a critical consideration when developing water use and re-use opportunities.

7.5.4 Water and Wastewater Value-Propositions

There are many existing and emerging options for value-adding to slaughterhouse wastewater, ranging from direct recovery of crude fats and proteins (and subsequent processing using the existing by-product facilities on-site, i.e. Rendering) to indirect energy recovery using established processes such as anaerobic digestion or the generation of new products, such as renewable fertilisers, bioplastics or commodity chemicals The value proposition of slaughterhouse wastewater is dependent on the technologies applied and the products targeted for recovery, with examples shown in Figure 32.

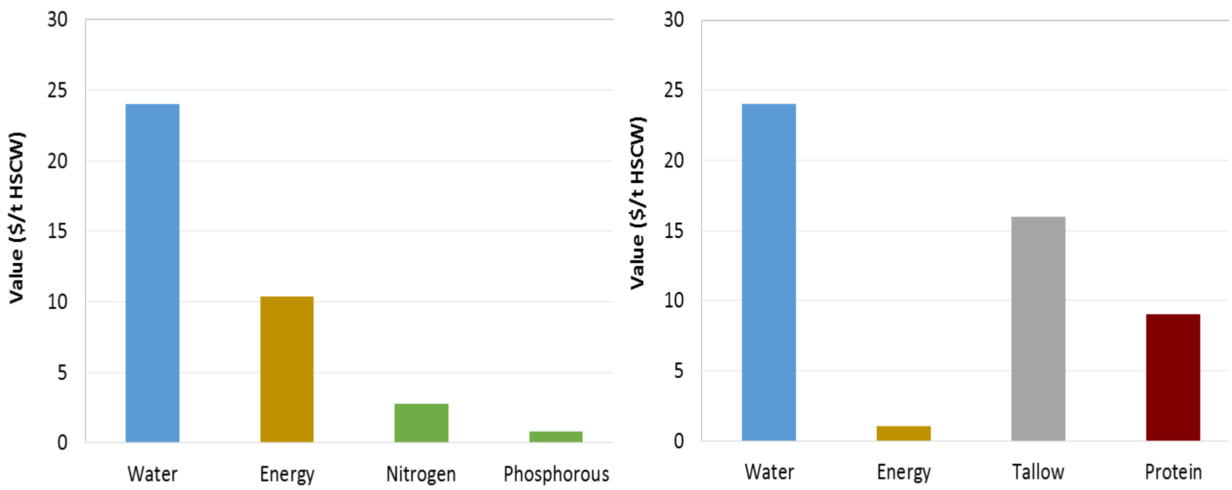


Figure 32 The potential value of slaughterhouse wastewater generate from 1 t HSCW, based on energy and nutrients (left) or direct recovery of fats and proteins (right). Water value at $3/kl for town supply, Energy valued at $10/GJ, Nitrogen valued at $1.20/kg, P valued at $1.50/kg. Tallow valued at $800/tonne and Crude protein valued at $600/kg.

8. CONCLUSION

This report has compiled a large amount of topical information relevant to the two workshops that are planned for this project. The goal of the workshops is to identify key opportunities to improve environmental performance and generate new products and revenue opportunities across the whole red meat industry value chain.

The four focus areas have examined the current position and quantitative assessment of the industry with regards to energy, water, waste and greenhouse gases. They have also discussed emerging trends and critical aspects that can act as a guideline during the workshops.

In summary the key hotspots for each focus area are summarised in Table 15.

Table 15 Key hotspots for energy, greenhouse gas emissions, waste and water focus areas

ENERGY	GREENHOUSE GASES	WASTE	WATER
Grain preparation for feedlots	Enteric fermentation (on-farm)	Manure (feed lots)	Design of drinking water systems (production)
Diesel consumption (on-farm)	Manure & urine (feed lots)	Paunch (RMP)	Cattle washing (feedlots, RMP)
Refrigeration (RMP)	Wastewater handling (RMP)		Slaughter evisceration (RMP)
Thermal loads to rendering (RMP)			Wastewater treatment & re-use (RMP)
Hot water for sterilisation (RMP)			
Replace aerated water with waste to energy (anaerobic, RMP)			

9. REFERENCES

ABS. (2013). "7106.0 Australian Farming in Brief." Retrieved 21.08.3013, from http://www.abs.gov.au/ausstats/abs@.nsf/mf/7106.0.

ABS. (2014). "7121.0 - Agricultural Commodities, Australia, 2012-2013." Retrieved 30.05.2014, from http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/7121.0main+features82012-2013.

ABS. (2015). "4610.0 - Water Account, Australia, 2013-14." Retrieved 21 Dec 2015, from http://www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0.

ABS. (2015a). "7121.0 Agricultural Commodities, Australia 2013 - 2014." Retrieved 29.09.2015, from http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/7121.02013-14?OpenDocument.

ABS. (2015b). "7111.0 Principal Agricultural Commodities, Australia, Preliminary, 2014 – 2015." Retrieved 18.12.2015, from abs.gov.au/ausstats/abs@.nsf/.../7111.0Media%20Release12014-15

ABS. (2015c). "4627.0 Land Management and Farming in Australia, 2013-14." Retrieved 31.07.2015, from http://www.abs.gov.au/ausstats/abs@.nsf/mf/4627.0.

ABS. (2015d). "9223.0 - Road Freight Movements, Australia, 12 months ended 31 October 2014." Retrieved 29.10.2015, from http://www.abs.gov.au/ausstats/abs@.nsf/0/7480A96EA1DF4527CA257EEC000EEB5D?Opendocument.

ABS. (2016a). "Livestock and Meat, Australia." Retrieved 29 May, 2016, from http://www.abs.gov.au/ausstats/abs@.nsf/mf/7218.0.55.001.

ABS. (2016b). "Meat Produced." Retrieved 27 May 2016, from http://abs.gov.au.

ADIC. (2015). "Australian Dairy Industry Sustainability Framework, Progress Report 2015." from http://www.dairyaustralia.com.au/~/media/Documents/Industry%20overview/Sustainability/2015%20-%20Australian%20Dairy%20Industry%20-%20Sustainability%20Framework%20-%20Progress%20Report%202015.pdf.

Alexandratos, N., Bruinsma, J., (2012). World agriculture towards 2030/2050: the 2012 revision, Global Perspective Studies Team FAO Agricultural Development Economics Division.

ALFA. (2016). "Cattle on feed close 2015 at record level." Retrieved 25.02.2016, from http://feedlots.com.au/wp-content/uploads/2016/02/December-2015-Qtr-Survey-Media-Release.pdf.

AMIC (2015). Senate Standing Committee on Rural and Regional Affairs and Transport Inquiry, “The effect of market consolidation on the red meat processing sector.

AMPC Fact Sheet: Recycled water opportunities in sustainable food production and manufacture.

AMPC "Waste solids."

AMPC (2015). "Final Report: Meat processor opportunities for Emissions Reduction Fund participation."

Australian Government (2015). Investment Opportunities in Australian Infrastructure.

Baylis, K., et al., (2008). "Agri-Environmental Policies in the EU and United States: A Comparison." Ecological Economics **65**(4): 753 - 764.

BDA Group and CSIRO (2007). Use of market based instruments by Catchment Management Authorities in NSW to achieve landscape scale change, Background paper.

Beckman, J., et al. (2013). Agriculture's Supply and Demand for Energy and Energy Products, EIB-112, USDA.

Beef Australia. (2015). "Beef Australia Handshakes Participants – meat processing and exporters." from http://beefaustralia.com.au/wp-content/uploads/Handshakes-Participants-Meat-Processing-and-Exporters-18.pdf.

Black, J., et al. (2015). National livestock methane program: National needs and gaps analysis.

Cole, A. J., et al. (2015). "Biorecovery of nutrient waste as protein in freshwater macroalgae." Algal Research **7**: 58 - 65.

Cowan, J. A. C., et al. (1992). "Membrane treatment strategies for red meat abattoir effluents." Water Science and Technology **25**(10): 137 - 148.

Cowan, J. A. C., F. MacTavish, C. J. Brouckaert and E. P. Jacobs (1992). "Membrane treatment strategies for red meat abattoir effluents." Water Science and Technology **25**(10): 137-148.

DAF. (2011). "Manure production data." Retrieved 01.07.2011, from https://www.daf.qld.gov.au/environment/intensive-livestock/cattle-feedlots/managing-environmental-impacts/manure-production-data.

Davis, R., et al. (2008). Part A Report: Water Usage at Australian Feedlots.

Davis, R. J., et al. (2012). B.FLT.0354 Final report: Quantification of Feedlot Manure Output for Beef-Bal Model Upgrade, MLA.

DAWR. (2016). "Red Meat Livestock Industry Structure." Retrieved 12.01.2016, from http://www.agriculture.gov.au/ag-farm-food/meat-wool-dairy/red-meat-livestock/facts.

DE. (2016). "Legislation, Environment Protection and Biodiversity Conservation Act 1999." from http://www.environment.gov.au/about-us/legislation.

Doran-Browne, N. A., et al. (2016). "Carbon neutral wool farming in south eastern Australia." Animal Production Science **56**(3): 417 - 422.

Environment Canada (2014). Canada's Emissions Trend

EU (2014). Agriculture: A partnership between Europe and farmers.

European Commission Joint Research Centre (2010). Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions, Institute for Environment and Sustainability.

Eurostat. (2012a). "Agri-environment indicator – energy use." from http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_energy_use.

Eurostat. (2012b). "Agri-environmental indicator – water abstraction." from http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_water_abstraction.

Eurostat. (2015a). "Agriculture – greenhouse gas emission statistics." from http://ec.europa.eu/eurostat/statistics-explained/index.php/Agriculture_-_greenhouse_gas_emission_statistics.

Eurostat (2015b). "Key energy indicators, 2002 and 2012 (million toe) EU world15.png."

Galvez, J. (2016). "Made in IBM Labs: Collaboration Aims to Harness the Energy of 2,000 Suns." Retrieved 24 April 2016, from https://www-03.ibm.com/press/uk/en/pressrelease/40908.wss.

Garcia-Escribano, M., et al. (2015). IMF Working Paper, Filling the Gap: Infrastructure Investment in Brazil.

Gerber, P. J., et al. (2013). Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities, Food and Agriculture Organisation of the United Nations (FAO), Rome.

GHD (2011). Industry Environmental Sustainability Review 2010, AMPC & MLA.

Government Canada. (2013). "Environment and Climate Change Canada: Greenhouse Gas Emissions by Economic Sector." from https://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=F60DB708-1.

Herrero, M., et al. (2016). "Greenhouse gas mitigation potentials in the livestock sector." Nature Climate Change

Hristov A. N., e. a. (2015). "An inhibitor persistently decreased enteric methane emission from dairy cows with no negative effect on milk production." PNAS **112**: 10663 - 10668.

Jensen, P., Batstone, D., (2013). Project A.ENV.0151 Final Report: NGERS and Wastewater Management – mapping waste streams and quantifying the impacts, MLA.

Jensen, P. D., et al., (2014). "Analysis of the potential to recover energy and nutrient resources from cattle slaughterhouses in Australia by employing anaerobic digestion." Applied Energy **136**: 23 - 31.

Johns, M. R. (1995). "Developments in wastewater treatment in the meat processing industry: A review." Bioresource Technology **54**(3): 203 - 216.

Jones, A. (2012). Rangeland goat production in western NSW: case studies of 7 successful enterprises, NSW DPI, Orange.

Kauffman, N. (2016). "Federal Reserve Bank of Kansas City: Farm Economy Tightens Further." Retrieved 13.07.2016, from https://www.kansascityfed.org/en/research/indicatorsdata/agcreditsurvey/articles/2016/2-11-2016/farm-economy-tightens-further.

Li, S., et al. (2013). "A demonstration study of ethanol production from sweet sorghum stems with advanced solid state fermentation technology." Applied Energy **102**: 260 - 265.

Lieffering, M., et al. (2012). A Greenhouse Gas Footprint Study for Exported New Zealand Beef, Meat Industry Association, Ballance Agri-Nutrients, Landcorp and MAF.

Lin, T., et al. (2015). "Biomass feedstock pre-processing and long-distance transportation logistics." GCB Bioenergy

LiveCorp. (2015). "Strategic Plan 2016 - 2020." from www.livecorp.com.au/about-us/livecorp.../strategic-plan-2016-2020.

Mehta, C. M., et al. "UQ Report 349671: Pilot Scale Resource Recovery From Cattle Paunch Waste."

Mekonnen, T., et al. (2016). "Valorization of rendering industry wastes and co-products for industrial chemicals, materials and energy: review." Critical Reviews in Biotechnology **36**(1): 120 - 131.

Mittal, G. S. (2004). "Characterization of the effluent wastewater from abattoirs for land application." Food Reviews International **20**(3): 229 - 256.

MLA (2011a). "FLOT.328 B Environmental Sustainability Assessment of the Australian Feedlot Industry, Part B report – Energy Usage and Greenhouse Gas Emission Estimation at Australian Feedlots."

MLA (2011b). "B.FLT.0361."

MLA. (2012). "National Beef Cattle Feedlot Environmental Code of Practice, 2nd Edition." from http://www.mla.com.au/CustomControls/PaymentGateway/ViewFile.aspx?W36biAMZ3le2QHPGlv7Vs+r1vNXZeMNhx7YmrS/BtbngRFGgAlTyQ4yY1Zy1IPGB3EYMKKAfsht7d1Tnt3BqiA==.

MLA (2014). "Fast facts: Australia's goatmeat industry."

MLA. (2015a). "Fast Facts 2015 Australia's Beef Industry." from www.mla.com.au/files/.../MLA_Beef-Fast-Facts-2014_EMAIL.pdf.

MLA (2015c). "Fast Facts 2015: Australia's goatmeat industry."

MLA (2015d). More meat, milk and wool: Less methane.

MLA (2016a). "2015 Australian beef eating quality audit."

MLA. (2016b). "The next big things for red meat production." Retrieved 23 May 2016, from http://www.mla.com.au/News-and-events/Industry-news/The-next-big-things-for-red-meat-production.

NDSU (2015). Regulation of the U.S. Food Processing Sector.

NIR (2015). National Inventory Report 2013.

OECD. (2013). "Innovation, Agricultural Productivity and Sustainability in Australia." Retrieved 04.08.2015, from http://dx.doi.org/10.1787/9789264238367-en.

OECD (2015a). Innovation, Agricultural Productivity and Sustainability in Brazil.

OECD (2015b). Innovation, Agricultural Productivity and Sustainability in Canada.

Pesonen, H.-L. (2001). "Environmental Management of Value Chains." Greener Management International **2001**(33): 45 - 58.

REN21 (2015). Renewables 2015 Global Status Report.

RMAC (2015). MISP 2020.

S. Kidman & Co Ltd. "Anna Creek." from http://www.kidman.com.au/properties/3/anna-creek.

Sandell, G. R., Szabo, P.M., Baillie, C.P., Woodhouse, N.P. and Schmidt, E., (2013). North-east farming futures R&D support: Increasing the knowledge and adoption of energy saving initiatives amongst farming enterprises in Western Australia National Centre for Engineering in Agriculture

Schmidt, C., et al. (2012). The Greening of Canadian Agriculture: Policies to assist farmers as stewards of the environment MLI.

Statistics Canada. (2012). "Table 153-0101 - Water Use in Canada, by sector, every 2 years (cubic metres), CANSIM." from http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=1530101&tabMode=dataTable&srchLan=-1&p1=-1&p2=9.

Taylor, A. a. J., S.,. (2012). "Innovative APC boosts LNG train produciton." Retrieved 1 Jan 2012, from http://www.hydrocarbonprocessing.com/Article/2959324/Innovative-APC-boosts-LNG-train-production.html.

Tritt, W. P. and F. Schuchardt (1992). "Materials flow and possibilities of treating liquid and solid wastes from slaughterhouses in Germany. A review." Bioresource Technology **41**(3): 235-245.

Tritt, W. P., Schuchardt, F., (1992). "Materials flow and possibilities of treating liquid and solid wastes from slaughterhouses in Germany. A review." Bioresource Technology **41**(3): 235 - 245.

US EPA (2013). Sources of Greenhouse Gas Emissions, Emissions and Trends.

USDA. "Farm Bill Forum Comment Summary & Background: Farm and Rural tax policy." from http://www.usda.gov/documents/FARM_AND_RURAL_TAX_POLICY.pdf.

WDI. (2013). "World Development Indicators Database." from http://data.worldbank.org/data-catalog/world-development-indicators.

Wiedemann, S., et al. (2015a). "Environmental impacts and resource use of Australian beef and lamb exported to the USA determined using life cycle assessment." Journal of Cleaner Production **94**: 67 - 75.

Wiedemann, S., et al. (2015b). "Resource use and environmental impacts from beef production in eastern Australia investigated using life cycle assessment." Animal Production Science.

Wiedemann, S. e. a. (2015). "Environmental impacts and resource use of Australian beef and lamb exported to the USA determined using life cycle assessment." Journal of Cleaner Production **94**: 67 - 75.

Wiedemann, S. G., et al. (2015c). "Resource use and environmental impacts from Australian export lamb production: a life cycle assessment." Animal Production Science

Wiedemann, S. G., et al. (2015d). "Resource use and greenhouse gas intensity of Australian beef production: 1981–2010." Agricultural Systems **133**: 109 - 118.

Wiedemann, S. G., et al. (2015e). "Resource use and environmental impacts from Australian export lamb production: a life cycle assessment." Animal Production Science.

Wiedemann, S. G. e. a. (2010). Scoping Life Cycle Assessment of the Australian lot feeding sector MLA.

Wiki. (2016). "Economy of Australia." Retrieved 22.03.2016, from https://en.wikipedia.org/wiki/Economy_of_Australia.

World Bank. (2013). "World Development Indicators Database." from http://data.worldbank.org/data-catalog/world-development-indicators.

World Economic Forum (January 2016). World Economic Forum Annual Meeting Report.

Zeigler, M., Steensland, A., (2015). 2015 GAP Report: Global Agricultural Productivity Report.

Abbreviations

3NOP	3-Nitrooxypropanol
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ACT	Australian Capital Territory
ADIC	Australian Dairy Industry Council
AEM	Agri-environmental measures
AFGC	Australian Food and Grocery Council
AFR	Anaerobic Flotation Reactor
AHA	Animal Health Australia
ALEC	Australian Livestock Exporters Council
ALFA	Australian Lot Feeder's Association
ALTA	Australian Livestock and Rural Transporters Association
AMIC	Australian Meat Industry Council
AMPC	Australian Meat Processing Association
AnMBR	Anaerobic membrane bioreactor
AQIS	Australian Quarantine and Inspection Service
ARC	Australian Research Corporation
ARENA	Australian Renewable Energy Agency
AS	Australian Standards
BOD	Biological oxygen demand
BSE	Bovine spongiform encephalopathy
CCA	Cattle Council of Australia
CEFC	Clean Energy Finance Corporation
COD	Chemical oxygen demand
CO_2-e	Carbon dioxide equivalent
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAWR	Department of Agriculture and Water Resources

DAF	Department of Agriculture and Fisheries
EG&S	Ecological Goods & Services
EMS	Energy Management Systems
EPA	Environmental Protection Agency
ERF	Emission Reduction Fund
EU	European Union
excl.	excluding
FOG	Fats, Oils and Greases
FAO	Food and Agricultural Organisation
FSIS	Food Safety and Inspection Services
GDP	Gross Domestic Product
GFC	Global Financial Crisis
Gg	Gigagram
GHG	Greenhouse Gas
GICA	Goat Industry Council of Australia
GJ	Gigajoule
Gt	Gross tonnage
HCPVT	High Concentration Photo Voltaic Thermal
HHV	Higher Heating Value
HSCW	Hot Standard Carcase Weight
incl.	including
Kg	Kilogram
kL	Kilolitre
KPIs	Key Performance Indicators
kWh	Kilowatt hour
L	litre
LF	Long-fed grain
LGC	Large-Scale Generation Certificates

LHV	Lower Heating Value
LULUCF	Land use, Land-use change and forestry
LW	Live Weight
LWG	Live Weight Gain
MISP	Meat Industry Strategic Plan
MF	Medium-fed grain
MJ	Megajoules
MLA	Meat & Livestock Australia
MSA	Meat Standard Australia
M2M	Machine-to-Machine
MWh	Megawatt
NDSU	North Dakota State University
NFF	National Farmers Federation
NGER	National Greenhouse and Energy Reporting
NIR	National Inventory Report
NLMP	National Livestock Methane Program
NSW	New South Wales
NT	Northern Territory
NTCA	Northern territory Cattlemen's Association
OECD	Organisation for Economic Co-operation and Development
OIE	World Organisation for Animal Health
p.a.	per annum
PV	Photovoltaic
QLD	Queensland
RELRP	Reducing Emissions from Livestock Research Program
RD&A	Research, Development & Adoption
RMAC	Red Meat Advisory Council
RMP	Red Meat Processing

SA	South Australia
SCA	Sheep Council of Australia
SMAC	Sheepmeat Council of Australia
RSA	Republic of South Africa
Tas	Tasmania
TSS	Total suspended solids
UNEP	United nations Environment Programme
UNFCCC	United Nations Framework Convention in Climate Change
US	United States
USA	United States of America
USDA	United Stated Department of Agriculture
VIC	Victoria
WA	Western Australia
WTO	World Trade Organisation

Energy Conversion

1.0 L diesel = 38.6 MJ of energy HHV = 36.9 MJ of energy LHV[4] = 10.3 kWh of energy LHV. Therefore, 1.0 kg of retail cut meat from grass fed beef requires approximately 0.9 L of diesel equivalent in energy (LHV).

The Lower Heating Value (LHV) is where the products of combustion contains the water vapour and that the heat in the water vapour (or latent heat) is not recovered. This is more routinely used as a “realistic” or “practical” value for the energy contained within fuels.

The Higher Heating Value (HHV) is the gross heating value or where the water of combustion is entirely condensed and that the heat contained in the water vapour is recovered. HHVs are only used in industry where a condensing heat exchanger is used to recover the latent heat contained in water where it condenses.

However, note that a diesel generator at 30% efficiency would produce approximately 3.1 kWh of electrical energy from 1.0 L of diesel.

[4] National Institute of Standards and Technology (NIST), U.S. Department of Commerce, 2016. (Assumes diesel density of 0.85 kg/L).

By-Products RMP Plant

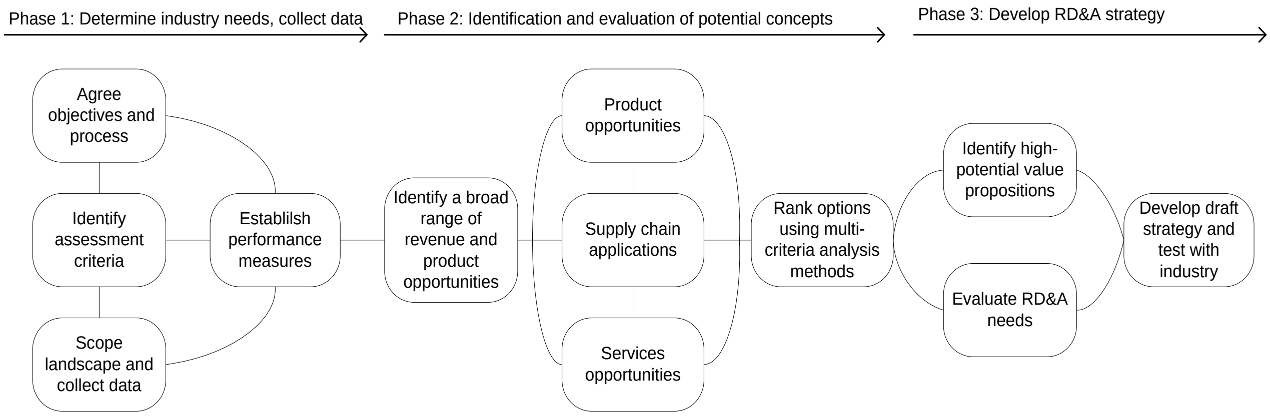
Tallow	Biodiesel production	Biodiesel is a potential alternative to established uses of tallow. About 30,000-50,000 tonnes of tallow are expected to be used in Australia to make biodiesel in 2009.
Hides	Collagen for sausages casing wound dressing, tissue sealants orthopaedic implant coatings injectable collagen and isinglass	Collagen casing produced from hides is well established in Australia and overseas. Other uses are small scale or potential uses of bovine collagen.
Hide pieces and bone	Gelatin for food use, capsules and pill coatings; photographic use	
Glue		
Pet food treats	Gelatin for food and pharmaceutical use is produced in Australia. Small quantities of hide pieces are used to make pet food treats.	
Lungs	Heparin blood thinner and anti-coagulant for pharmaceutical use.	Lungs are exported for pharmaceutical use
Trachea	Chondroitin sulphate and trachea extract for arthritis treatment.	Trachea is used in Australia to make extract for arthritis treatments. Trachea could be exported to China for chondroitin production but prices are low.
Gall	Cleaning agent for leather, paint and dyes, steroid pre-cursors.	Concentrated gall is exported for production of mixed crude bile salts and products derived from bile salts.
Intestines	Surgical sutures, tennis racquet strings musical instrument strings, heparin from the mucosa	Production of sutures and tennis strings is no longer carried out in Australia. There may be a small export market for intestinal serosa.
Pancreas	Insulin and pancreas extracts	Pancreas-derived insulin and other pancreas preparations are no longer produced in Australia. There may be some production overseas.
Nasal septum	Chondroitin sulphate	No production in Australia
Bones	Edible bone extract, bone char, ceramics, gelatin for photographic use. Ossein, Dicalcium phosphate, glue	Bone extract is produced in Australia. Use of bone to make photographic gelatin has almost disappeared due the prominence of digital photography. Other uses of bone may occur overseas
Horns	Organic fertiliser	Horns are reputed to be an excellent fertiliser and there may be some cottage industry use.
Hooves	Glue, neatsfoot oil	Hoof glue and neatsfoot oil has been mostly replaced by synthetics.
Thyroid	Thyroid extracts for pharmaceutical use	Thyroid extracts are produced overseas
Calf stomach	Rennet for cheese making	Rennet from calf vells is still used in cheese making

APPENDIX B

EXPLANATION OF PROJECT METHODOLOGY

EXPLANATION OF PROJECT METHODOLOGY

The methodology used in this project was adapted from a feasibility study framework[5] that involves determining and validating client's needs and collecting data followed by generation, analysis and evaluation of potential concepts. This framework was adapted to incorporate the elements shown in the following figure:



Phase 1. Determination of industry needs and data collection

The first phase of this project involved the development and collation of baseline information on current environmental performance of the red meat industry, which was summarised in Milestone Report 1.

The report covered the following areas:

- Industry analysis;
- Stakeholder Analysis;
- Commercial value chain participants;
- Industry peak councils;
- Research and development corporations;
- Government bodies;
- Customer and consumer groups;
- Other relevant stakeholders;
- Environmental policy, regulation, markets, emerging issues and trends;
- Profiling of customer's/consumers knowledge, understanding and value attribution to sustainable red meat supply chains;
- Previous work in environmental value chain innovation;
- Value chain thinking; and
- Baseline information on the current environmental performance of the red meat industry in relation to energy, water, greenhouse gas emissions and wastes.

[5] Australian Cost Management Manual Volume 5

The information contained in the report was obtained from detailed literature searches including MLA reports.

Phase 2. Identification and evaluation of potential concepts

Two workshops on "Waste & Water" and "Energy & Greenhouse Gases" were planned with selected industry experts to:

- Discuss outcomes of the scoping and engagement process;
- Develop a broad suite of product opportunities, service applications and service opportunities;
- Compile a list of potential product opportunities, supply chain applications and service opportunities for adding value to red meat and livestock waste.

The invited participants represented industry stakeholders specialised in areas of agriculture, environmental sustainability, energy, greenhouse gases, water and waste management and engineering, process automation and water distribution. Representatives from the Department of Environment, academic institutions (business, process chemistry and waste management) and Meat and Livestock Australia were also invited.

The brainstorming sessions resulted in close to 200 ideas. These ideas were compiled, clustered and condensed into 22 potential opportunities shown below.

These opportunities were then ranked by an expert panel which included the steering committee and staff from MLA using multi-criteria analysis. The ranking was based on the following criteria:

- Economic benefit
  - 1 - High cost
  - 2 - Medium cost
  - 3 - No impact
  - 4 - Medium benefit
  - 5 - High benefit
- Environmental / sustainability benefit
  - 1 - High cost
  - 2 - Medium cost
  - 3 - No impact
  - 4 - Medium benefit
  - 5 - High benefit
- Technical achievability
  - 1 - Highly complex
  - 2 - Significant uncertainty
  - 3 - Possibly achievable
  - 4 - Likely achievable
  - 5 - Readily achievable
- Risks (safety, quality, unintended consequences, availability, animal welfare, health)
  - 1 - High level of risk
  - 2 - Significant level of risk

    - 3 - Medium level of risk
    - 4 - Little risk
    - 5 - No risk
- Impediments to adoption (regulatory, community)
    - 1- High level of impediments
    - 2 - Significant level of impediments
    - 3 - Medium level of impediments
    - 4 - Few impediments
    - 5 - No impediments
- Customer / consumer acceptability
    - 1 - High level of impediments
    - 2 - Significant level of impediments
    - 3 - Medium level of impediments
    - 4 - Few impediments
    - 5 - No impediments
- Capability - research / industry / training
    - 1 - No capability exists
    - 2 - Limited capability exists
    - 3 - Some level of existing capability
    - 4 - Significant level of existing capability
    - 5 -High level of existing capability

The results of the ranking process are shown in the following table. The opportunities are listed in order of ranking with the most highly ranked opportunities at the top of the table.

Potential opportunities
■ **Improve adoption of water reduction strategies** on farms, feedlots and in RMP to increase productivity and reduce water utilisation and treatment costs, e.g.: - deeper and narrower dams, underground water storage, pump water periodically to dams and troughs, increase number to decrease distance between water sources, cap bores, cover dams with foil containing solar panels or balls, redesign water distribution and collection, upgrade waste water and re-use water for non-critical operations.
■ **Develop enhanced anaerobic digestion technologies** that include advanced monitoring and control and methane collection for the treatment of waste from feedlots and RMP to, e.g.: - reduce operational costs, optimally run the plant, generate electricity (or upgrade to transport grade bio-methane) and reduce GHG emissions.
■ **Develop new approaches to benefit from cross-industry opportunities** (agricultural and other) through coordinated approaches to, e.g.: - regional issues, optimised asset utilisation, outsourcing, and new business models.

Potential opportunities

These approaches aim to:

- decrease future capital requirements, increase viability of new project through improved economies of scale, co-develop infrastructure for transportation, waste utilisation and water and energy efficiency.

■ **Develop technologies and create business models to improve adoption of solar technologies** on farms, feedlots and RMP, e.g.:

- generate electricity for running machinery and equipment;
- reduce operational costs and reduce GHG emissions.

■ **Minimise the impact of drought** by combining feed crop technologies (new grasses, legumes, drought resistance, increase protein content) and animal breeding programmes (drought resistance) with improved weather forecasting and drought management strategies, e.g.:

- to mitigate against decreases in productivity during droughts and hence increase industry revenues, minimise environmental damage, reduce impacts from destocking, and decrease price and supply variability to feedlots and RMP.

■ **Remove nutrients and add-value to RMP waste water** by producing protein, feed and biochar using, e.g.:

- purple phototrophic bacteria, duckweed, anaerobic ammonium oxidation to increase industry revenues, decrease wastes and decrease GHG emissions.

■ **Develop methods to give an accurate assessment of meat quality and meat yield on-farm and feedlot**, e.g., animal scan to:

- reduce resource consumption, reduce energy requirements and reduce GHG emissions.

■ **Develop technologies** (including using industry wastes) **that have the potential to inhibit methanogenensis** to, e.g.:

- improve productivity, improve industry revenues, decrease water usage and GHG emissions. Examples include Leucaena, probiotics, marine red macro-algae, other bioactive feed additives.

■ **Develop new generation feedlot designs** for more energy and water efficient operations, energy generation and improved animal welfare, e.g.:

- solar shading;
- manure capture for biogas and electricity production;
- energy and water efficiency design.

■ **Develop and demonstrate technologies for remote monitoring, sensing and automation** on farm to, e.g.:

- increase energy efficiency, reduce diesel usage, decrease GHG emission, reduce

Potential opportunities
labour requirements, increase productivity, decrease water usage, and reduce operational costs. Examples of technologies include: - driverless vehicles, UAVs for bore and fence monitoring, robot use in farming, virtual fences, machinery and equipment sensors, monitoring sheep movement to safeguard against dog attacks, 2sensor-controlled water systems.
■ **Develop opportunities to leverage international agritechnology venture capital investment in "new-foods"**, e.g.: - nutraceuticals, protein powders, sports nutrition products, fibre and health products, new foods from wastes.
■ **Extraction of high value biological products**, e.g., protein and glycans from RMP wastes to improve industry revenues and reduce wastes, e.g.: - microbiological growth media, enzymes, probiotics, nutritional/dietary supplement products.
■ **Develop hydrothermal technologies**, e.g.: - smouldering, - liquefaction, - pyrolysis, using aggregated solid wastes from feedlots, RMP and retail sources to produce energy and chemical products, decrease industry wastes and reduce operational costs
■ **Develop large-scale fermentation technologies**, e.g.: - methylotrophs, anaerobic bacteria or algae, capable of utilising methane or syngas for the production of single cell protein or other value-added bio-products to improve industry revenues, reduce wastes and reduce GHG emissions
■ **Develop new technologies to improve carcass quality**, e.g.: - increase interstitial fat, muscle mass, growth rate, male production herds etc. by cross breeding, genomic DNA fingerprinting of bulls or CRISPR technology to increase productivity and efficiency on farms, feedlots and RMP, to increase industry revenues and decrease GHG emissions.
■ **Develop mixed farming opportunities** to benefit from additional income streams, reduce operational costs and reduce GHG emissions e.g.: - displace diesel by producing bioenergy from harvested woody weeds or prickly acacia or dedicated energy crops.

Potential opportunities
■ **Upgrading of tallow** (enzymatic, chemical) to, e.g.: - high value oleochemicals, nutritional and nutraceutical products to increase industry revenues and reduce wastes.
■ **Improve water treatment operations in feedlots and RMP waste water treatment plants**, e.g.: - reverse osmosis, ozone, - UV, - forward osmosis, - biochar, - process redesign, to enable greater water re-use in non-critical operations to reduce water usage and decrease operational costs
■ **Adapt existing new energy technologies to Australian agricultural conditions** (climate, geography) and improve adoption in grain preparation, RMP and on-farm to, e.g.: - reduce operational costs, reduce wastes, reduce fossil fuels use, and reduce GHG emissions. Examples include: - dual-fuel vehicles, biodiesel, bio-methane, solar PV and solar thermal applications.
■ **Increase adoption of "Internet of Things" models** for: - monitoring costs, profitability, predictive maintenance, risk-based management of assets, optimising supply chain, improving process flow and improving monitoring to reduce operational costs, increase industry revenues, reduce energy and water usage and decrease labour requirements.
■ **Utilisation of solid wastes**, e.g.: - aggregated paunch, RMP wastes and tyres, for the production of bio-composites & bio-polymers materials to reduce wastes and improve operations. Examples of products include: - shade cloth for feedlots, covers for dams, feedlot pads, etc.
■ **Production of protein-based bio-products from RMP and retail wastes** to improve industry revenues and reduce wastes, e.g.: - plastics, surfactants, firefighting foam, dust suppressors, feed.

Three R&D programmes for the MLA RD&A strategy resulted from the ranking and down selection process. These programmes represented new product opportunities, service application and service opportunities across the supply chain that increase productivity, efficiency and profitability while at the same time promoted environmental sustainability across the industry by reducing waste production, energy and water consumption and greenhouse gas emissions.

Phase 3. Development of the RD&A strategy

The three R&D programmes that resulted from the above process were:

1. Increasing productive efficiency and environmental performance using enhanced supply chain information systems (1);
2. Using biological processing systems to convert wastes from feedlots and red meat processing into enhanced feed protein (2);
3. Driving adoption of technologies to improve water and energy management in the Australian red meat supply chain (3);

In the last stage of the project the business cases for these three value propositions were developed and they addressed the following points where applicable:

- Business and market opportunities across the sector;
- Potential waste sources, composition, location and estimation of quantities;
- Process and technology requirements;
- Quality, compliance and safety aspects;
- Business models and supply chain aspects.

Information collected during the project was used to analyse and identify:

- Information gaps across the supply chain;
- Areas of innovation across research horizons and technology readiness levels;
- Capacity issues requiring further attention;
- Technical, business, supply chain and other issues requiring further research.

The draft of the strategy was presented to MLA for feedback and review prior to submission.

APPENDIX C

SUPPLEMENTARY INFORMATION FOR THE DEVELOPMENT OF VALUE PROPOSITIONS AND BENEFITS

Supplementary material for “Increasing productive efficiency and environmental performance using enhanced supply chain information systems”

Supporting data and assumptions for Project 1

Lamb

The initial benefit: cost assessment was performed on beef cattle ony due to two main sources of low confidence for lamb:

- Less data was available to undertake an analysis of potential value of Project 1 for sheep meat and there is yet no certified Emissions Reduction Fund method for sheep flock management.
- Projection of a baseline level of lambs graded to 2020 has a high uncertainty due to recent jumps in participation. However, with 56 per cent of MSA lambs or 3.2 million head formally identified to consumers as MSA product in 2015 (up from 35 per cent in 2013) there is likely significant additional benefits from also providing incentives for uptake for lamb.

Cattle

Value of Compliance

2014-15 data

Young cattle – grass-fed, 0-2 tooth (Grass-fed = 55% of total graded with 89.3% compliance)
Premium: $0.33/kg over the hooks (OTH)
Average carcase wt.: 277kg
Premium per head: $91.41

Grained (45% of total graded with 87.7% compliance)
Premium: $0.10/kg over the hooks (OTH)
Average carcase wt.: 294kg
Premium per head: $29.40

MSA data for scaling up

Data relevant to MSA (2014-15)	
Cattle graded (head)	3,224,198
Compliant carcases	3,005,544
% carcases graded	93%
MSA Index improvement 2010-11 to 2014-15 (likely most on-farm)	2%
% of all adult cattle slaughter (2.8M from feedlot; 52% graded)	34%
MSA registered producers	41,973
MSA Licensed processors	42
End users	3,676
Licensed beef brands	120

2016 Baseline:
Total benefit from compliance = $186 million

2020

- Growth in the number of cattle presented for MSA grading has been approximately 440,000 per year since 2010-11.
- Total benefit of compliance if (1) the baseline growth assumes a linear rate of growth; (2) constant rate of compliance at 93% and (3) Price premium is unchanged (2015 AUD with no adjustment for inflation) = $212 million
- Assumptions relative to the 2020 baseline:
    - 1% increase per year (on average) in the number of grass-fed cattle graded driven by awareness of improved environmental performance and potential for carbon credits; and
    - 1% higher compliance driven by improved practices for live weight gain.
- Therefore, the additional benefit from price premium is estimated at $1 million

Assumptions for value of carbon credits:

- Of the additional cattle graded above the 2020 baseline, 100% were driven by interest in carbon offset income but only 25% were actually in approved projects that earned carbon credits;
- By 2020 the carbon price = $20/tonne carbon dioxide equivalent greenhouse gas emissions (higher than the 2015/16 price of ~$12/t CO2-e but conservative relative to Climate Institute modelling)
- A reduction of 1 kg CO_2-e/kg LW is achievable with adoption of good practice for live weight gain (from preliminary modelling for the beef Herd Management).
- For a carcase weight of 277kg for grass-fed young cattle (~500kg live weight), income from sale of carbon credits = $10 per head.
- Costs of participation in the Emissions Reduction Fund = $100,000 (Ramp Carbon 2015) over 7 years. For the purposes of this estimate the credits are assumed as a single project and all costs are incurred within the 4 years.
- Number of young grass-fed cattle MSA graded above the 2020 baseline = 227,000 head
- Preliminary estimate of potential carbon credit income = $0.57M to 2020.

Total economic benefits of Project 1 = $1.6 million

Preliminary costs of Project 1

The costs for a researcher to deliver the outputs of Project 1 focussing on quantifying the benefits for greenhouse gas emissions intensity of beef of adopting practices that target live weight gain (weight for age) to achieve MSA compliance are estimated at $280,000. This assumes a 15 months' project with some data collection at a post-doc or early stage researcher.

Benefit cost ratio

The benefit cost ratio of Project 1 = 1570000/280000 = 5.6:1

Supporting data and assumptions for Project 2

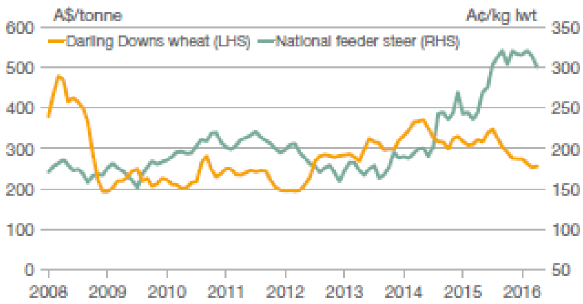
Table 1 MLA/ALFA Survey of feedlot activity

	Feedlot capacity			Numbers on feed			Utilisation %		
	Mar-15	Dec-15	Mar-16	Mar-15	Dec-15	Mar-16	Mar-15	Dec-15	Mar-16
NSW	365,483	409,571	352,273	308,274	358,067	291,312	84	87	83
Vic	71,272	85,344	115,791	58,582	75,387	62,889	82	88	54
Qld	614,785	658,510	662,243	519,248	513,969	495,578	84	78	75
SA	40,131	39,619	28,382	33,108	30,738	25,146	82	78	89
WA	55,324	45,694	60,824	39,929	19,604	39,976	72	43	66
Australia	**1,146,995**	**1,238,738**	**1,219,513**	**959,141**	**997,765**	**914,901**	**84**	**81**	**75**

Source: MLA/ALFA

The number of cattle on feed assumed to be relatively stable at 950,000.

Figure 4 Feed grain and feeder steer prices



Source: Profarmer, MLA

Base data for feedlot cattle:

- GHG emissions = 8 kg CO_2-e/kg LW gain from range of 7.5 (for short-fed) up to 11.3 (long-fed) kg CO_2-e/kg LW gain, with up to 60% from enteric fermentation and up to 25% from ration preparation and delivery.
- Blue water use = 511 L/kg LW gain with a range of 151 to 871 L/kg LW gain; larger values including irrigation.
- Primary energy use = 40 MJ/kg LW gain with a range of 34.5 – 49.1 MJ/kg LW gain; around 90% for feed preparation e.g. steam flaking (Wiedemann 2010).
- Number of grain-fed cattle = 2.8 million (2014-15 data)

TABLE 9 – CATTLE PERFORMANCE DETAILS FOR FEEDLOT 1 AND 2

Parameter	Feedlot 1	Feedlot 2
Avg. Entry Weight (kg)	360	440
Avg. Daily Gain (kg/hd/day)	1.7	0.95
Avg. Total Days on Feed	63	330

2016 Baseline:

Assumptions for domestic market:

- 60-70 days on feed
- 12 – 15 kg feed intake /day (assumed little difference between days on high energy and high roughage rations) @ $300/tonne
- Feed cost = $3/kg LW
- Cattle on feed = 950,000 head
- For short fed, average entry weight = 360kg
- For short fed, average daily gain = 1.7kg/hd/day

- For short fed, average total days on feed = 63
- For long fed, average entry weight = 440kg
- For long fed, average daily gain = 0.95kg/hd/day
- For long fed, average total days on feed = 330

The most recent national greenhouse as inventory data (2013) were assumed to apply to the 2016 baseline. This introduces a small error only as they have been relatively stable with a standard deviation of <3% over the previous 6 years.

Supplementary material for “Using biological processing systems to convert wastes from feedlots and red meat processing into value-added products”

Single cell protein market opportunity

Based on microbial protein value of $600/tonne and i) application at feedlots with capacity >10,000 head per day and 50% nitrogen conversion and ii) application to abattoirs with capacity >500 head per day (cattle) and 80% nitrogen conversion.
1 kg nitrogen translates to 6.25 kg protein

6.25 kg translates to 10 kg SCP biomass (dry weight).

Cost of solid and liquid waste disposal to feedlotters and red meat processors each year

Assuming 1,000,000 cattle on feed, producing approximately 20 kg fresh manure per animal per day and 7,300,000 tonnes per year at a disposal cost of $10-20 per tonne; and assuming 8,000,000 cattle slaughtered per year producing 20 kg paunch per animal and 160,000 tonnes per year at a disposal cost of $10-20 per tonne; and producing 20 GL of wastewater at treatment costs ranging from $0.1/kL to $2/kL

Numbers of cattle on feed

Numbers of cattle on feedlots

Feedlot size (head)	Feedlot capacity	Numbers on feed	Utilisation (%)
<500	32,851	11,851	36
500 - 1000	110,120	32,822	30
1000 - 10,000	431,894	341,356	79
>10,000	663,874	611,736	92
Total	**1,238,739**	**997,765**	**81**

Source: Lot Feeding Brief, results for the December quarter 2015, MLA Market Information Service, March 2016

Energy and protein calculation on feedlots and red meat processing plants

Energy from Feedlots

Energy from	Feedlots												
	Per animal				feedlot								
Size	1				10000			660000				1000000	
Maunre	27	kg Fresh per animal			27	kg Fresh per animal		27	kg Fresh per animal			27	kg Fresh per
	2.7	kg VS per animal			2.7	kg VS per animal		2.7	kg VS per animal			2.7	kg VS per ani
total manure	2.7	kg/day			27000	kg/day		1782000	kg/day			2700000	kg/day
Methane	160	L/kg VS			160	L/kg VS		160	L/kg VS			160	L/kg VS
	432	L CH4/ day			4320000	L CH4/ day		285120000	L CH4/ day			432000000	L CH4/ day
	157680	L CH4 / year			1576800000	L CH4 / year		1.04069E+11	L CH4 / year			1.5768E+11	L CH4 / year
Energy	5361120	kJ/yr			53611200000	kJ/yr		3.53834E+12	kJ/yr			5.36112E+12	kJ/yr
	5.36112	GJ/yr			53611.2	GJ/yr		3538339.2	GJ/yr			5361120	GJ/yr
value	10	$/GJ		value	10	$/GJ	value	10	$/GJ		value	10	$/GJ
	$ 53.61				$ 536,112.00			$ 35,383,392.00				$ 53,611,200.00	

Energy from abattoirs solid waste

Energy from abattoir solid waste											
Size	1				500			32000	8,000,000.00		
Paunch	20	kg Fresh per animal			20	kg Fresh per animal		20	kg Fresh per anin	160,000,000	
	5	kg VS per animal			5	kg VS per animal		5	kg VS per animal		
total manure	5	kg/day			2500	kg/day		160,000	kg/day	40,000,000	
Methane	250	L/kg VS			250	L/kg VS		250	L/kg VS		
	1250	L CH4/ day			625000	L CH4/ day		40000000	L CH4/ day		
	456250	L CH4 / year			228125000	L CH4 / year		10000000000	L CH4 / year		
Energy	15512500	kJ/yr			7756250000	kJ/yr		3.4E+11	kJ/yr		
	15.5125	GJ/yr			7756.25	GJ/yr		340000	GJ/yr		
value	10	$/GJ		value	10	$/GJ	value	10	$/GJ		
	$ 155.13				$ 77,562.50			$ 3,400,000.00			$ 38,783,392.00
											$ 63,116,512.00

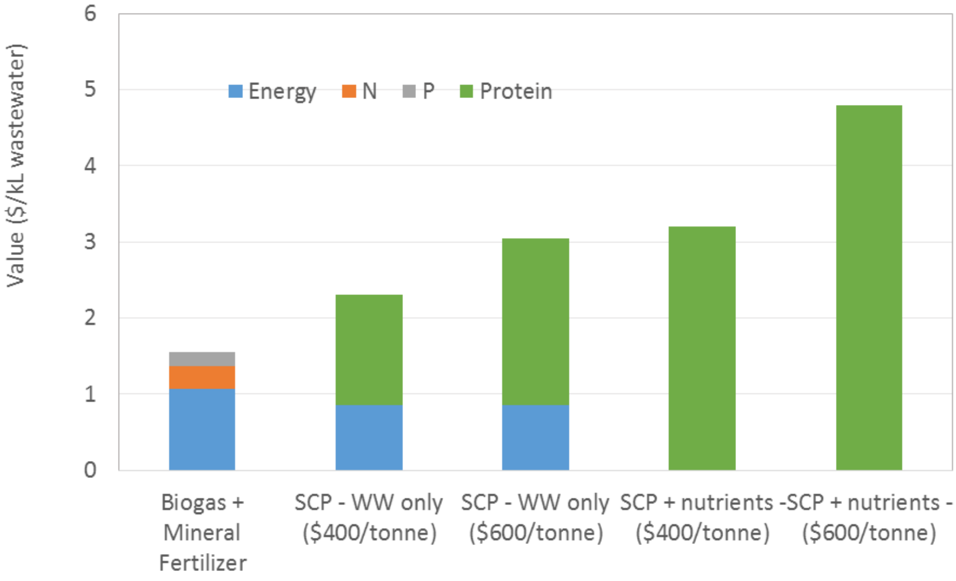
Energy from abattoirs wastewater

Energy from abattoir wastewater										
Size	1				500			32000		
wastewater	0.36	carcass yield		wastewater	0.36	carcass yield		0.36	carcass yield	
	7.1	WW in kL per tHSCW			7.1	WW in kL per tHSCW		7.1	WW in kL per tHSCW	
total waterw	2.556	WW in kL per day		total waterw	1278	WW in kL per day		81792	WW in kL per day	
Methane	3500	L/kL		Methane	3500	L/kL		3500	L/kL	
	8946	L CH4/ day			4473000	L CH4/ day		286272000	L CH4/ day	
	3265290	L CH4 / year			1118250000	L CH4 / year		71568000000	L CH4 / year	
Energy	111019860	kJ/yr		Energy	38020500000	kJ/yr		2.43331E+12	kJ/yr	
	111.01986	GJ/yr			38020.5	GJ/yr		2433312	GJ/yr	
value	10	$/GJ		value	10	$/GJ	value	10	$/GJ	
	$ 1,110.20				$ 380,205.00			$ 24,333,120		

Protein from abattoir wastewater

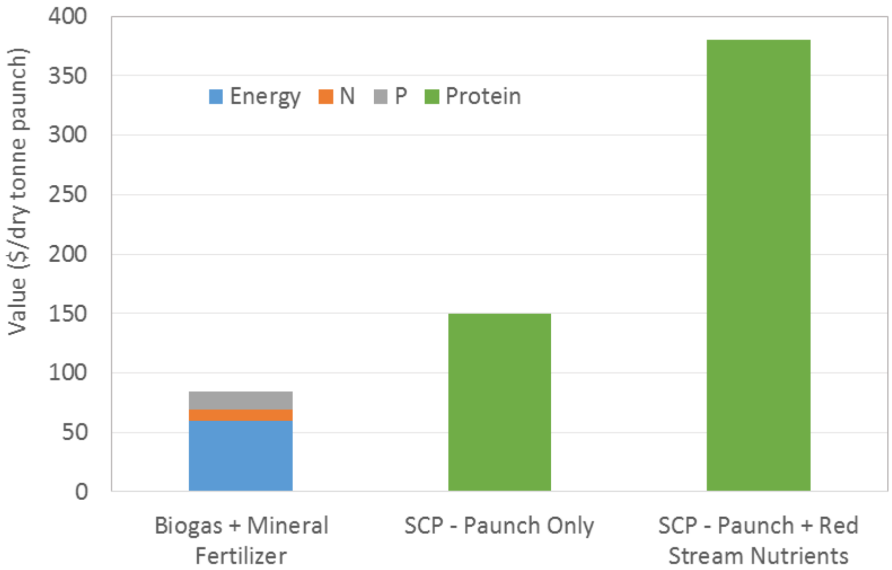
	Protein from abattoir wastewater										
	Size	1			500			32000			
	wastewater	0.36	carcass yield	wastewater	0.36	carcass yield		0.36	carcass yield		
		7.1	WW in kL per tHSCW		7.1	WW in kL per tHSCW		7.1	WW in kL per tHSCW		
	total waterwater	2.556	WW in kL per day	total waterwat	1278	WW in kL per day		81792	WW in kL per day		
	Nitrogen	0.25	kg/kL	Nitrogen	0.25	kg/kL		0.25	kg/kL		
	Protein	4.1535	kg/ day	Protein	1996.875	kg/ day		132912	kg/ day		
	SCP	6.9225	kg/day	SCP	3328.125	kg/day		221520	kg/day		
		1730.625	kg/yr		832031.25	kg/yr		55380000	kg/yr		
					832.03125	499.21875	299.53125				
	value	0.6	$/kg	value	0.6	$/kg	value	0.6	$/kg		
		$ 1,038.38	$/year		$ 499,218.75	$/year		$ 33,228,000.00	$/year		
Value energy (RMP solid waste & wastewater) + value protein (RMP wastewater)					$ 956,986.25	$/year					

Comparison of potential value recovery from 1 kL of red meat processing wastewater as protein, methane energy and mineral nutrients



Potential value of 1.0 m^3 of red meat processing wastewater when recovering all resources (WW). Based on energy value of $10/GJ, N value of $1/kg, P value of $3/kg or selling the biomass at $400/tonne and $600/tonne.

The potential value recovery from 1 tonne of paunch (dry weight) as protein, methane energy and mineral nutrients



Potential value of 1.0 dry tonne of paunch waste when recovering energy and mineral

nutrient resources or single cell protein (SCP). Based on energy value of $10/GJ, N value of $1/kg, P value of $3/kg and crude protein value of $1/kg.

A summary of common animal feeds, protein content and costs

Summary of animal feed compositions and pricing. DM - dry matter. MJ - mega joule. t – tonne. CP – crude protein.

Source	DM (%)	Metabolisable energy (MJ kg DM^{-1})	Crude Protein (% DM)	$ t^{-1}	$cent kg DM^{-1}	$cent MJ^{-1}	$ kg CP^{-1}
Barley	90	12	12	230	25.6	2.1	2.1
Pasture hay	88	8	12	135	15.3	1.9	1.3
Sub clover silage	45	9	16	83	18.4	2.0	1.2
Maize green chop	35	10	6	45	12.9	1.3	2.1
Wheat feed	90	13	-	200	22.2	1.7	-
Lucerne hay	90	8.5	-	300	33.3	3.9	-
Lupins	90	-	32	450	50.0	-	1.6
Urea lick blocks	100	-	40	850	85.0	-	2.1
Meat Bone Meal	100	12.9	53.2	600	60	4.7	1.1

Supplementary material for "Driving adoption of technologies to improve water and energy management in the Australian red meat supply chain"

Cost of water for red meat processors is relatively well defined, at approximately $37 million per year nationally

Approximately $37 million per year nationally. This value is estimated using an average water consumption of 7.1 kL/tHSCW at an average cost of $2.20/kL as reported in AMPC factsheet "Recycled Water Opportunities in Sustainable Food Production & Manufacture" (AMPC) and a processing capacity of 2.4M tHSCW per year at larger plants.

Water used by the red meat supply chain

Potentially valued at well over $80 Million/yr. for beef production alone is based on water consumption of 550 L/kg beef at a value of $0.08/kL and 2 million tonnes beef produced per year.

Estimation of the current energy costs throughout the red meat supply chain:

Sector	% Energy breakdown	Total energy cost
On-farm (grass fed), consuming 16.92 GJ / tonne retail cut averaged for cattle and sheep.	Diesel: 47% Embodied energy (assumed cost of diesel): 42% Petrol: 7% Grid power: 4%	$706 mil per annum
Beef feedlots, consuming 6.12 GJ / tonne HSCW gain per head[6].	Assume all energy at equivalent cost of diesel	$280 mil per annum.
Red meat processors, consuming 8.03 GJ / tonne retail cut averaged for cattle and sheep.	Natural gas: 37.0% Power: 31.0% Coal: 18.0% LPG: 2.0% Diesel: 1.0% Fuel oil: 5.0% Biofuels (costs excluded): 6%	$349 mil per annum.
TOTAL ESTIMATED FOSSIL FUEL ENERGY COSTS PER ANNUM FOR THE AUSTRALIAN RED MEAT INDUSTRY		**$1.335 billion per annum**

Assumptions:

- 2.19 mil tonnes per annum red meat retail cuts (75.6% cattle, 24.4% sheep).
- 10% of cattle are finished in feedlots for 115 days (average).
- Costs for each form of energy in $ / GJ: grid power at $39, LPG at $30, petrol at $19, diesel at $18, natural gas at $12, fuel oil at $9, coal at $5.