Renewable Energy Technologies and the Broiler Poultry Industry

Cost reduction and income diversification

A report for

By Ben Edser

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Executive Summary

The way things have been done in the past will not be the way things are done in the future. The energy industry is ripe for disruption with a monopolistic energy sector, inconsistent government energy policy, and titanic investment across numerous energy generating technologies and storage. Large energy consumers are in the box seat to capitalise on this momentum, with broiler farm owners possessing a few unique industry factors when it comes to energy use and production.

Approximately 70% of operating costs at a broiler poultry operation fall into four key operating cost areas – labour, electricity, gas and bedding. Significant operational advantages exist where solutions can be implemented which tackle one or more of these items.

The political environment surrounding energy generation and supply in Australia is inconsistent and lacks certainty. Australian farmers have experienced escalating electricity and gas costs over the past ten years.

A technology solution which utilises large quantities of poultry manure as a feedstock input to an anaerobic digestion (AD) renewable energy plant is now proven where sufficient quantities of poultry litter are available or accessible. When this solution is implemented on farm it has the potential to generate two to three times the energy required to run the farm, creating the opportunity to generate an alternative income stream for the business through selling the excess power.

Significant investment in renewable energy technologies internationally has seen substantial reductions in the cost of renewables, particularly in the solar photovoltaic (PV) space. Implementing a solar PV installation at some level at a broiler poultry operation today is a viable investment. Scaling up this technology creates a diversified business opportunity where a network connection is cost effective, and the exported power can be sold to an offtake third party for a reasonable price.

Project funding assistance currently exists for the implementation of renewable energy technologies in agriculture and more specifically, poultry.

Some very interesting alternative technology solutions exist to dispose of bird mortalities on farm through enclosed vessel composting methodologies.

The opportunity for waste to energy and renewable energy technologies on a poultry farm to offset energy costs (electricity and gas) has positive implications for the industry, farmers, policy makers and the community as a whole.

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Foreword

Nuffield really is a journey… of a lifetime.

I became aware of Nuffield through an industry colleague and former Nuffield Queensland poultry Scholar Jodie Redcliffe, when we were discussing progress in the poultry industry and new ideas we were exploring in poultry farming in Queensland. We were working hard on exploring alternative bedding materials and had started value-adding spent poultry manure by composting it to create a high value soil conditioner. The seed idea of renewable energy alternatives and waste-to-energy technology solutions had just been planted. I was strongly encouraged to throw my hand up, and so the Nuffield journey commenced.

It was not until I arrived at the National Conference in Albury the enormity of the opportunity and responsibility dawned on me.

We were advised that it is likely that the final report we would write may be slightly different from that which we pitched and put forward in order to receive the scholarship. This certainly held true for me.

Initially, a focus of my topic was to explore and further commercialise the potential associated with the poultry manure waste stream which is generated from broiler farming operations, with a focus on composting. However, it was the incredible notion associated with alternative and renewable energy generation associated with a poultry farming enterprise which quickly took over and became the focus.

The idea of an integrated renewable energy design utilising the by-product of an intensive farming operation as an input into a renewable power plant that could generate energy far in excess of its needs, whilst also harnessing the sun's energy, was an idea that I was keen to focus on and excited me.

With increasing electricity prices users are actively looking for an energy solution and with significant investment having been deployed in the renewable energy sectors in recent times, technology solutions are now more viable than before.

I had done significant research within Australia but continued to hear a similar response, that large quantities of poultry manure could not be used as an input to an anaerobic digester. I wanted to get in front of experienced industry professionals and meet some of the most forward thinking and progressive farmers and technology providers who were operating in the most innovative countries in the world, to get their view.

My travel took me to the United Kingdom (UK), Northern Ireland, Singapore, India, Qatar, Turkey, France, United States of America (USA), Denmark and China.

I never expected to have the exposure, access, acceptance and holistic view that Nuffield provided me. I saw more and learnt more than I ever expected possible.

I am proud to be able to report that I not only researched and analysed potential solutions but am now looking at implementing these findings in Australia, through an opportunity to start working for an agricultural and fund management company entering the poultry industry.

Acknowledgements

The opportunity to undertake a scholarship, could not, and would not have been possible without the devoted support of my wife Steph and both our families. At the time of being awarded the scholarship, it was just the two of us that made up our beautiful family. During the Nuffield journey, Steph and I were lucky enough to welcome our daughter Ivy. We also renovated and sold a house, where most of the time I was either flying out or flying back in right on time to line up with major life events. Steph kept everything going at home while I travelled the world, so thank you.

To our India Global Focus Program (GFP) group – what a blast. We were fortunate to have such an incredible group of people thrown together, who got along so well. It was like we had known each other for decades. Australia, New Zealand, Ireland, Northern Ireland, and Canada - quite the eclectic mix! We were energised and motivated, full of laughs and challenged each other intellectually. Memories which are going to stay with me a lifetime.

I would like to extend a huge thank you to Rural Industries Research and Development Corporation (RIRDC) Meat Poultry, now known as AgriFutures Australia, for standing behind me and backing me to deliver on what I set out to achieve. I am grateful for the ongoing and continued support I received during the scholarship tenure.

Abbreviations

ABARES: Australian Bureau of Agricultural and Resource Economics and Sciences

AD: Anaerobic digestion

ARENA: Australian Renewable Energy Agency

AUD: Australian Dollar

CEFC: Clean Energy Finance Corporation

CHP: Combined Heat and Power

GBP: Great British Pound

GFP: Global Focus Program

GW: Gigawatt

kW: Kilowatt

kWh: Kilowatt-hour

LGC: Large-scale generation certificate

MW: Megawatt

MWe: Megawatt electric

m3: Cubic metres

PV: Photovoltaic

RET: Renewable Energy Target

RIRDC: Rural Industries Research and Development Corporation

USA: United States of America

USD: United States Dollar

UK: United Kingdom

W: Watt

Glossary

Behind the meter	Energy which is generated by and within an operation and which is consumed by the operation. Energy consumed does not come from external sources (i.e. from the network).
Grow-out period	The time required to raise a broiler chicken from a day old chick to a full-grown broiler bird, ready for processing for meat purposes.
kWh	The kilowatt hour (symbolized kW·h as per SI) is a composite unit of energy equivalent to one kilowatt (1 kW) of power sustained for one hour.
MW	A unit of power equal to one million watts, especially as a measure of the output of a power station.
Solar PV	Solar cells, also called photovoltaic (PV) cells, convert sunlight directly into electricity. PV gets its name from the process of converting light (photons) to electricity (voltage).
Solar module	PV modules consist of PV cell circuits sealed in an environmentally protective laminate and are the fundamental building block of PV systems.

Objectives

- What can be done to reduce key operational expenditure on a poultry farm to increase farm profitability.
- Understand what energy mitigation options exist, including renewable energy technology solutions, and apply those most suitable to broiler poultry farming.
- Investigate and understand the strengths, weaknesses, opportunities and threats associated with implementing an anaerobic digestion (AD) waste-to-energy solution at a broiler poultry farm, looking at size and scale of operation.
- Understand whether it is technically possible to utilise large quantities of poultry manure as a feedstock input in to an AD biogas plant.
- Investigate and understand the strengths, weaknesses, opportunities and threats associated with implementing a solar solution at a broiler poultry farm, looking at size and scale of operation.
- Analyse the investment and business case associated with applying any cost mitigation or alternative income revenue opportunity that come with these two renewable energy technologies; so that the outcomes are in a manner suitable for the industry and Australian farmers.
- Understand the macro economic and political environmental factors associated with these technology solutions in Australia.
- Ensure international solutions are suitable for Australia when applied.
- Enjoy the journey!

Chapter 1: Introduction

When first applying for a Nuffield Scholarship, I was committed to gaining enough information and knowledge to allow me, with a degree of confidence, on the suitability, relevance, and ability to implement renewable technology options in an Australian poultry setting.

The broiler poultry industry has a relatively unique set of factors which are reserved to only a few intensive farming industries. Broiler poultry operations are very large consumers of energy and water. Further, livestock is held in very large poultry houses and operations produce significant waste.

Energy use and cost is front of mind with price escalations continuing; and investment in renewable energy technologies are at never-before-seen levels.

Perhaps the cost of energy has finally aligned to allow investment of alternative energy solutions at poultry operations.

The Broiler Industry in Australia

Chicken is the fastest growing and most consumed source of animal protein in Australia, with the Australian chicken industry producing more than 630 million birds per annum (The Australian Chicken Meat Federation ((ACMF), 2011). The total volume of chicken consumed in Australia grew at a compounding annual rate of approximately 4% per annum over the past 25 years to 2015, with chicken consumption almost doubling in this period. On a per capita basis, Australian people consume just over 41 kilograms of chicken each per annum, and chicken now represents over 35% of total animal protein consumed (ACMF, 2011).

The gross value of poultry meat at time of slaughter was forecast by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) to total AUD2.179 billion in 2010–11, and the industry estimates that consumers currently spend approximately AUD5.6 billion per annum on chicken meat in retail outlets and restaurants. This is expected to grow at a rate of 2.7% per annum to reach AUD7.6 billion by 2022 (ACMF, 2011). Chicken in Australia is now the most affordable animal protein, having a 2.1 times price-per-kilogram advantage over the next cheapest (being pork), and a 3.2 times price-per-kilogram advantage over the most expensive protein (beef) in 2015 (ACMF, 2011)

This growing affordability can be largely attributed to a phenomenal improvement in feed conversion ratio, improved genetics, feed and nutrition, technology and the growing environment. In 1975 it took 4.66 kilograms (kg) of feed and 64 days to grow-out a bird; compared to 2011 where it required 3.4 kg of feed and 35 days to reach the same outcome (ACMF, 2011).

With more than 95% of chicken meat grown and processed in Australia being consumed domestically, the industry is well set-up to capitalise on further domestic and international growth and opportunities.

To stay nationally competitive and drive international export opportunities, industry must focus on mechanisms and innovative solutions which keep cost down, or at least, reduce the rate of increase in relation key cost areas.

Key operating costs

The broiler poultry industry is typically structured such that poultry farmers hold responsibility for the infrastructure that is required to house and grow broiler birds, including sufficient quantity and quality of water. The farmer will enter into an agreement with a processor, where the processor will supply day-old chickens, the feed required to raise and grow birds and some veterinary and support services. The processor will pay an agreed base rate to the poultry farmer (usually on a square metre or per bird basis), and often an incentive or bonus component as well.

The farmer is responsible for all operational costs associated with the farming operation, including labour, electricity, gas, bedding, litter removal and shed cleanout, water supply, any rates and taxes, and any other costs and services required to operate the farm.

This structure incentivises the farm owner to innovate, analyse and potentially implement technology or solutions that assist with farming and operational cost reductions.

In consultation with industry, analysis of the operational expenses associated with a broiler poultry farm commonly shows that a few key items make up a large percentage of overall operating costs. This is shown in Table 1 below.

Cost item	Average % of overall operating cost
Labour	33% (30-35%)
Electricity	17% (15-20%)
Gas	12% (10-14%)
Bedding	13% (10-15%)
TOTAL	**75%**

Table 1: Cost items as percentage of overall operating cost based on actual costs from broiler farms in South Australia and Queensland

Outside labour, which is controlled largely by external policies and factors, any cost mitigation strategy in relation to electricity, gas and bedding (which are responsible for approximately 40% of total operating expenses) will flow directly to the farms viability and profitability.

Waste generation

A broiler farmer is responsible for removing and disposing of spent litter at the end of a grow-out period (up to 55 days).

Spent litter, or poultry manure, is made up of fresh bedding that was put in the sheds prior to chicken placement and the broiler birds' excreted waste accumulated throughout the grow-out period. The spent product can be made up of anywhere between 20 to 50% of bedding, and 50 to 80% of animal excrement. This balance is largely driven by whether the processor has a single batch or multi-batch litter policy. A single batch policy requires the farmer to completely remove all litter from the shed at the end of the grow-out period; whereas a multi-batch policy allows a farmer to windrow a portion of the litter from the shed and reuse this litter, with the addition of some fresh bedding, for subsequent grow-out periods. Different processors in different states within Australia enforce different policies. For example, Ingham's growers in Queensland have traditionally been allowed to multi-batch their litter, whilst Baiada has strictly enforced a single batch policy. There is inconclusive research as to whether one policy is more favourable however those who run single batch policies indicated that bio-security is the primary reason for this decision.

Table 2 outlines baseline estimates of the quantity of waste that can be generated from a broiler poultry farm. N.B: this is based on a 165 metre x 16 metre broiler shed where the processor requires the broiler farm to run a single batch policy. This assumes six grow-out periods per annum.

Number of sheds	Spent litter per batch	Spent litter per annum
6	1,080m3 (430t)	6,480m3 (2,600t)
13	2,340m3 (935t)	14,000m3 (5,600t)
40	6,000m3 (2,400t)	36,000m3 (14,500t)

Table 2: Quantity of poultry manure with reference to poultry house based on personal experience in dealing with product

Traditionally, spent litter has been perceived as a problematic and onerous by-product of the core business of broiler poultry farming. Poultry farmers have traditionally relied on contractors to clean out and remove the poultry litter from sheds. This business model has some different iterations, but most commonly little money will change hands, and the contractor will provide the service for the value of the spent litter. Frequently the contractor will take the product from shed to farm where it is used as manure fertiliser and soil conditioner.

This background information is critical to analysis made later in this report, where it will be outlined how this once problematic by-product has significant opportunity.

Chapter 2: The Australian Energy Climate

Australians have experienced significant electricity price increases in recent times. Household electricity prices doubled over the ten years between 2004 and 2014 (Clean Energy Australia, 2016).

Figure 1 below tracks the increase in household electricity prices in Australia against the consumer price index.

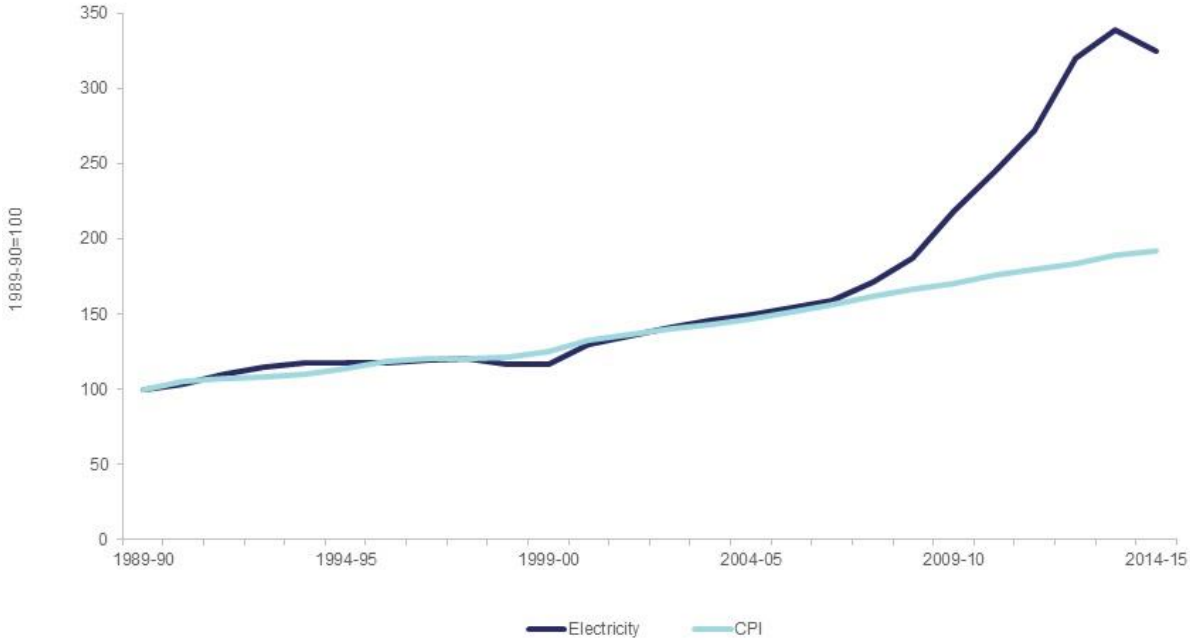

Figure 1: Australia's household energy prices and the consumer price index (Australian Bureau of Statistics, 2015)

A recent report outlined that between 2006 and 2016, electricity prices rose 136% in Queensland, 118% in Victoria, 109% in New South Wales, and 87% in South Australia (Clean Energy Council Australia, 2016).

The Australian Electricity Commission expects wholesale costs (the actual cost of generating power) to rise over the next few years with the closure of the South Australian Northern Power Station and the Hazelwood Power Station in Victoria (Clean Energy Australia, 2016).

A large percentage of Australia’s base load power plants are fuelled by gas, and with some of our large energy companies committed to contracts to supply gas offshore to countries such as Korea, Japan and China, the economics of supply and demand have been skewed unfavourably for the Australian energy consumer (Clean Energy Australia, 2016).

With intensive agricultural industries consuming significant quantities of both electricity and gas, and with forecasts pointing to further increases, the luxury of simply 'doing nothing' and relying on historical certainty and stability in the national energy sector, may no longer be an option for farmers.

Farmers and large energy consumers must take it upon themselves to innovate and think differently to underpin the future viability of their operations and their industries.

The Australian renewable energy policy and agenda

Investment in renewable energy has been challenging over the last number of years due to the inability of policy makers to commit to any long-term plan for the electricity generation sector (renewable and traditional energy). Renewable energy has been used as a political tool in recent years which has created instability and hindered long-term planning by businesses across all sectors. A bipartisan deal on Australia's Renewable Energy Target (RET) was struck in 2015, which provided some short-term relief in this space. The RET seeks to achieve a 33,000 gigawatt (GW)/hour target of large-scale renewable energy by 2020 (Clean Energy Australia, 2016).

At the time of writing this report the Australian Government were considering the implementation of the National Energy Guarantee which is focused on delivering lower energy pricing for consumers in to the future and there has been ongoing discussion in relation to a royal commission investigation in to the energy industry. However, just prior to publishing this report the Prime Minister changed from Malcolm Turnbull to Scott Morrison and it would seem the National Energy Guarantee is now off the table. This goes directly to the heart of the issue, a political environment which lacks certainty and consistent long-term policy. A change of government at the next federal election would again likely result in another change in energy policy.

The business case for renewables continues to improve, and the Bloomberg New Energy Finance analysis confirmed renewable energy is now the cheapest type of power generation that can be built in Australia (Clean Energy Australia, 2017). The cost of large-scale solar generation has dropped 40% in recent years, due to significant investment in the industry which has resulted in innovative steps forward in the cost of production. This has seen the emergence of three significant multinational companies - Trina Solar, Canadian Solar and Jinko. These three companies alone have a combined market capitalised value of circa USD3 billion (Clean Energy Australia, 2016).

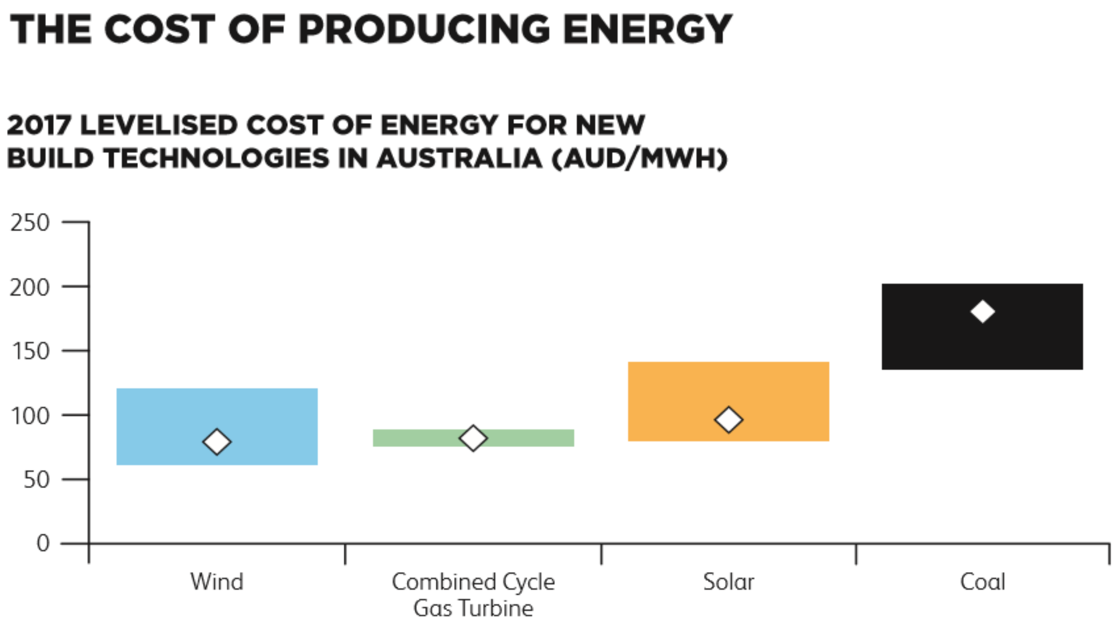

Figure 2: Levelised cost of energy (Clean Energy Australia, 2016)

In addition to federal policies, Australia's States and Territories have also been proactive in their agendas. For example, Queensland has set a policy of generating 50% of its power use being renewable energy by 2030, and South Australia has set of target of 50% renewable energy by 2025 (Clean Energy Australia, 2016).

Solar technology trends

Globally, the solar power generation capacity is 305 GW. More than 76GW of this capacity was built in 2016, which was an increase from 50GW the previous year (Clean Energy Australia Report, 2016). The rapid increase in investment, particularly solar photovoltaic (PV) technology, is driving competition and huge reductions in production costs (Clean Energy Australia, 2016).

Deutsche Bank has noted that total module costs of leading Chinese solar companies have decreased from around USD1.31/watt (W) in 2011 to around USD0.50/W in 2014, and approximately USD0.40/W in 2017. This was confirmed with a pricing request from one of the top three panel manufacturers at USD0.38/W. These cost reductions, to a large extent, are a result of reductions in manufacturing costs, the fall in polysilicon costs and improvement in conversion efficiencies. That represents a fall of around 60% in just three years. (Clean Energy Australia, 2016).

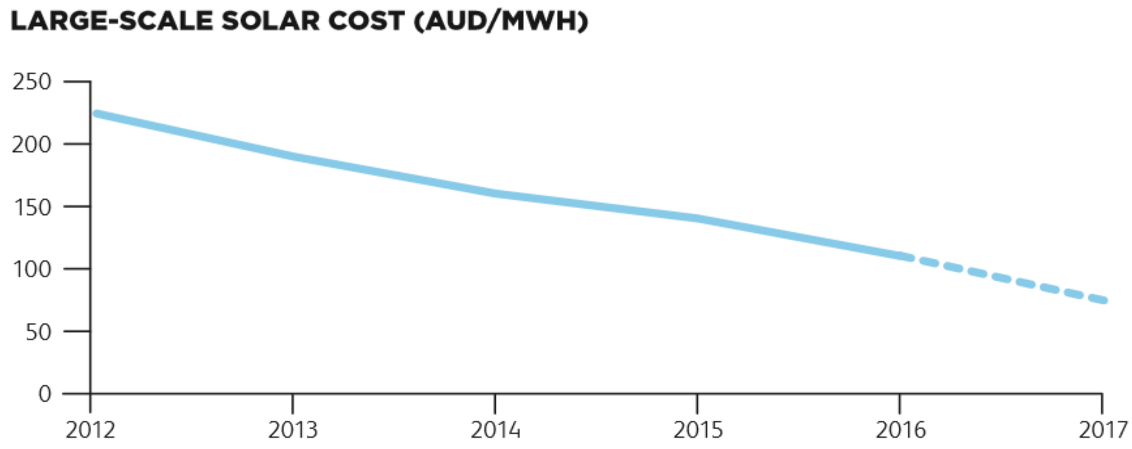

Figure 3: Large-scale solar cost (Clean Energy Council, 2016)

Chapter 3: Relevant Renewable Energy Technologies

When considering a typical broiler poultry operation, and with an understanding of the strengths of some of the renewable energy technologies available, some technologies present themselves more favourably for further consideration. The enclosed housing structure of a broiler shed means poultry farms have a large amount of roof surface area available for use. Further, as outlined previously, there is a significant quantity of waste produced as a by-product of broiler poultry operations. Given this, the renewable energy technologies that should be considered are:

- Litter to heat.
- Anaerobic digestion.
- Solar PV energy generation.

Litter to Heat

There are a number of technology options which exist which use poultry litter as a feedstock to generate heat. Some include incineration, pyrolysis and gasification. All are premised on the requirement to utilise poultry manure as a feedstock to generate thermal energy in the form of steam, hot water and electricity usually in the form of a boiler and steam turbine. Utilising poultry litter as a feedstock in a renewable energy plant in this form generates a by-product low carbon ash, or high carbon biochar.

Based on initial business case and feasibility investigations, these technologies were not pursued in a detailed analysis due to inability to gain levels of comfort and confidence around the by-product which was generated by the process, being biochar, and to which the business case required as income stream to apply in order to make feasible.

There is industry discussion of the high value nature of biochar in the marketplace. However, whenever these discussions were pursed in order to understand the detailed commercial practicalities of achieving the discussed high prices (for example + $1,000 / tonne), there did not appear to be an established fluent market trading in the quantities and at the rates required to enable a business case to be built. The value of composted poultry manure is understood and there is awell understood market operating and trading in these product lines. As a result, detailed further analysis and investigation was not undertaken in relation to this technology area.

Anaerobic digestion

Anaerobic Digestion (AD) is the principal biological technology which forms the foundation of this report. AD can be used to recover energy from organic waste and involves the conversion of biodegradable organic matter to energy by microbiological organisms in the absence of oxygen. The biogas produced in the process is a mixture of methane and carbon dioxide and can be used as a fuel for heating and electricity production. The residue left behind, known as digestate, is semi-solid and has further opportunities as a liquid and solid fertiliser (Warren et al, 2013).

This technology solution, not only delivers an outcome for energy and gas, but as was outlined at the UK AD and Biogas and World Biogas Expo 2017 (attended as part of the travel program), AD and biogas can also help reach the United Nations' Sustainable Development Goals due to its ability to provide a sustainable energy source, which outlines 17 specific targets that were to be adopted by countries in 2015 to end poverty, protect the plant and ensure prosperity for all as part of a new sustainable development agenda (Warren et al, 2013).

Figure 4: Anaerobic digestion and the United Nations' Sustainability Goals (ADBA and WBA, 2017)

Solar photovoltaic technology

Solar panels use energy from the sun to generate electricity. The conversion of sunlight into electricity takes place in cells of specially fabricated semiconductor crystals (Clean Energy Council, 2016). When sunlight is absorbed by these materials, the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. This process of converting light (photons) to electricity (voltage) is called the photovoltaic effect.

Chapter 4: Global Perspective

General

The overall strategy applied to personal travel was to focus on countries which are experiencing significant investment and uptake in renewable energy technologies, to see and experience the latest in the renewable energy space and state-of-the-art generators.

In addition to visiting and interacting with as many farmers as possible, the author met with technology and industry experts to allow the ability to investigate the fundamental issues, solutions and finer details of what was being investigated. It was also important to gain a holistic and comprehensive understanding of these technologies to ensure they were fully understood improving confidence around recommending the adoption of these solutions in an Australian setting.

Travel was therefore broken down in to three key trips. The structure of this report provides for a general overview, with a detailed trip visit breakdown included in Appendix A. There were a few key visits which were topic-defining moments which are included in the body of the report. These include Foresight Group in London, DVO in the United States, Xergi in Denmark, and the three solar manufacturing plants in Shanghai, China.

The first trip involved the Contemporary Scholars' Conference in Ireland, followed by personal travel and topic investigation in the UK. This involved meetings with AD scientific experts, incineration technology experts, a large number of different farms with on-farm anaerobic digesting units, and a meeting with an asset and renewable fund manager who is investing in renewables in Australia.

By the end of this first stage of travel, industry experts, technology and engineering providers and technology operators had helped further an understanding of the ancillary and add-on opportunities that some waste-to-energy technology solutions could provide. Meetings with financing companies also enabled a good understanding of what is required to fund a project.

This stage of travel identified a major challenge in the initial thinking. All the experts, technology providers and operators saw a major issue with a high chicken manure input AD proposal. It was also clear that all stakeholders involved in this renewable energy space required certainty from Australia's policy makers to ensure the offtake agreement required to underpin a feasible project would not be clouded with ambiguity.

It was evident that countries where a lot of investment in this technology was occurring, generally had some form of secure long-term renewable energy subsidy in place.

The second trip was the Global Focus Program (GFP). This included visiting Singapore, India, Qatar, Turkey, France and the USA.

The third and final trip occurred after the GFP. This provided the ability to apply what was learned from the first two trips and focus on a well-planned program. It also allowed time to better understand the challenges raised so further travel could be targeted at investigating how to overcome these identified issues. This trip included the USA, Denmark, UK and China.

Topic and report defining scholarship moments

Case Study 1: Foresight Group

London

The author was aware of the creation of the Australian Bioenergy Fund, which was being managed by the Foresight Group and where the Clean Energy Finance Corporation (CEFC) had committed AUD100 million as a cornerstone investment in a new equity fund for bioenergy and energy from waste. The Foresight Group has approximately GBP1.8 billion (AUD3 billion) of funds under management (CEFC, 2015). The author met Nigel Aitchison who leads and manages the origination, execution and monitoring of Foresight's investments in the bioenergy and waste infrastructure sectors. This allowed the opportunity to dig down into the structuring and return expectations for an investment manager and fund, like Foresight. They engaged and worked through the feasibility and financial modelling requirements for a 'bankable' project. Shortly after, the Foresight Group had employed an Australian-based company representative who the author has met with a number of times.

Case Study 2: DVO Renewables

Steve Dvorak, Wisconsin, USA

Much of the technology seen in Europe was based on a continuous stir tank system (Appendix A), it was clear that DVO Renewables (DVO) offered a very different 'plug-flow' technology solution.

DVO is North America's largest biogas company and the company has a two stage Linear Vortex patented technology solution.

As had been clearly outlined earlier in the UK, unless other waste streams can be sourced and added, or a large amount of water is utilised to dilute the manure, AD plants cannot run on poultry manure alone. This was a scholarship defining moment.

Steve Dvorak from DVO did not hold the same reservations for a high content chicken manure AD system, advising that his system can run on 100% chicken manure as a feed input. As broiler poultry manure is around 60% solids and 40% moisture, without some form of technology solution these solids would have to be diluted to 7 to 10% for the digester to handle feed input.

However, even where this recirculation problem is overcome there is another issue with 100% poultry manure as an input. With continuous liquid recycling comes an accumulative build-up of ammonium/ammonia (nitrogen). At levels above 3,500 parts per million this build-up becomes toxic to the methogenic bacteria and the digester will fail. The high protein poultry manure biodegrades first into amino acids, and then from amino acids into ammonium (Dvorak, 2017).

DVO has a multi-solution system which deals with this issue and allows the digester to run only on poultry manure. Part of this solution is in the 'plug-flow' tank system, see Figure 5.

DVO has developed a digester system that uses digestate after it has been through a solids separation system. The solids separation system reduces the total solids content of the digestate so that this effluent water is suitable for dilution of the high solids content poultry manure. DVO also have a solution which removes the ammonium/ammonia from the liquid digestate to bring this below the toxic level which effect the methogenic bacteria. This process also creates a valuable high-nitrogen fertiliser product for use in agriculture (Dvorak, 2017).

A large number of DVO digesters are used in the dairy industry in the USA, where DVO also provides another technology solution that screw separates the solid from the liquid in the digestate, allowing the solid form digestate to be reused in the dairy barn as bedding.

There was also a visit to a local DVO plant at a dairy farm. Unfortunately, due to a disease outbreak, access to the poultry farm digester was not possible.

DVO’s set-up and the system was impressive. It provided a solution to a major challenge – a high quantity of chicken manure feedstock. Steve and his family gave many generous hours of their time during the visit.

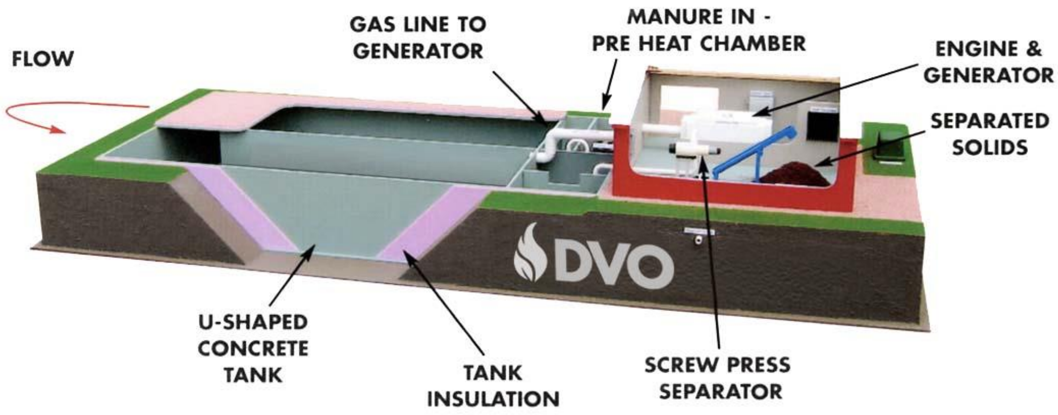

Figure 5: Plug-flow digestate solid separation system (DVO Renewables, 2017)

Case Study 3: Xergi

Denmark

The author’s interest in the Willen Biogas operation (see Appendix A), led to ongoing communication with Xergi, in Denmark. Xergi highlighted how they had been running a pilot scale 100% chicken manure AD plant for a number of years, and were currently building a plant in Northern Ireland which would run on 100% poultry manure.

The author met Xergi’s Country Manager Jorgen Fink at their head office in Stovring, followed by Foulum, where they were operating their test facility which included the chicken manure pilot plant. Following this, there was a visit to Holsted plant which was the latest AD plant that Xergi had constructed. The Foulum plant is situated at the Aarhus University Faculty of Engineering. The plant consists of a full-scale biogas production plant and a test plant.

In addition to the actual production plant on site, which runs a 625 kilowatt (kW) engine, the author was particularly interested in the research and testing centre.

The test plant consists of four digesters of 2 x 30m2 and 2 x 10m2 respectively. The plant is one of the world’s largest facilities for biogas research and enables development of biogas and manure separation technologies (Fink, 2017).

The site has a well-equipped lab together with conference facilities which make the plant a central point for Danish biogas research. Xergi's own research and development department is based at the research centre with a number of lab and pilot scale test plants, including the chicken manure pilot scale plant which has been successfully running for two years.

There was a visit to NGF Nature Energy Holsted, Denmark, and a biogas plant based on animal slurry, deep litter and industrial food waste. The plant is owned by the Danish energy company NGF Nature Energy, and the local farmers supply the plant and Xergi.

NGF Nature Energy wants to replace natural gas with bio-methane. The produced biogas is cleaned and upgraded to bio methane. The annual bio methane production is approx. 13 million m3. This corresponds to the annual energy needs of approximately 8,000 households which is enough biogas to run continuously a generator set of approximately seven megawatt electric (MWe). The bio methane is of the same quality as natural gas and is compressed and fed in to the national natural gas grid (Fink, 2017).

It was an extremely impressive and cutting-edge energy solution and provided an understanding to the scale of the engineering that is required to deliver a successful AD and biogas solution project.

Xergi also highlighted some of the detail around their Ballymena project. The Northern Ireland plant, which is currently under construction, is to run on a high quantity of chicken manure feedstock. The plant will will generate three megawatt (mW) of renewable electricity from up to 40,000 tonnes of chicken litter each year. The electricity will be sold through the electricity network and is enough energy to power 4,000 homes. The capital cost of the plant will be approximately GBP20 million. The project is being developed by Irish-based renewable energy development firm, Stream BioEnergy, and will be co-financed by funds managed by Foresight Group and Invest Northern Ireland (Fink, 2017).

Xergi will use the pre-treatment technology NiX (Nitrogen Extraction) in the Ballymena plant to pre-treat the chicken manure feedstock which is high in nitrogen. The nitrogen is isolated as ammonium sulphate, which can be disposed of or used as commercial fertiliser.

Figure 6: Photo of NGF Nature Energy in Holsted, Denmark (Source: Author)

Case Study 4: JinkoSolar, Canadian Solar, Trina Solar

Shanghai, China

The author had a keen interest in visiting Shanghai as the largest solar PV companies in the world had a base in and around this area. Factory tours were arranged with the top three largest solar PV module suppliers (by shipment) in 2016.

In any solar project, solar modules and panels accounted for approximately 50% of total project cost, and any major steps forward in technology solutions and cost savings are going to be driven by the power producing cells.

The author was keen to see first-hand the manufacturing and production processes these companies undertake that allows the supply of such a significant quantity of solar PV modules to the market, which continues to grow.

These companies have become corporate powerhouses, each with a market capitalisation of circa USD1 billion, meaning these three companies have a combined market presence of circa USD3 billion (AUD3.8 billion) in the global market (Bloomberg, 2017). Jinko Solar for example, had shipments in 2016 of approximately 3.7 GW of solar PV modules.

Firstly, a visit to Canadian Solar at Suzhou New District, Jiangsu, China. The company has state-of-the-art facilities in Canada, China, South East Asia and Brazil; and employs around 9,000 people worldwide.

The factory tour was insightful as it became obvious how automated, mechanised and robotic the production floors were. The majority of the process is completely automated, and every module and solar cell is checked for production and performance before being packed. Every module is trackable and traceable.

Next, a visit to Jinko Solar, just under two hours outside of Shanghai, near Yuanhuazhen. JinkoSolar distributes its solar products and sells its solutions and services to a diversified international utility, commercial and residential customer base in China, USA, Japan, Germany, the UK, Chile, South Africa, India, Mexico, Brazil, the United Arab Emirates, Italy, Spain, France, Belgium, and other countries and regions. JinkoSolar has an integrated annual capacity of 5.0GW for silicon ingots and wafers, 4.0GW for solar cells, and 6.5 GW for solar modules, as of March 31, 2017.

JinkoSolar's manufacturing is also completely automated, mechanised and robotic. The author spent time in the research and development department with the engineers working on cutting-edge technologies and advances in solar PV.

The final visit was to Trina Solar, a Changzhou factory outside of Shanghai. This visit to Trina confirmed that all three market and production leaders have invested heavily and achieved a very productive, efficient and automated manufacturing process with the use of robots wherever possible, driving down costs of production. In addition to solar module, it was also possible to see the Solar Best, which focuses on storage and the use of battery technology, which provided the opportunity to discuss and explore the use of storage integration in a solar installation, something seen as crucial in the analysis of the overall solar renewable business case.

Canadian Solar, JinkoSolar and Trina Solar all have an Australian presence and Australian headquarters. They provide comparable guarantees and warranties offering ten-year manufacturing warranties and a 25-30-year guarantee on power output. A strong recognisable Australian-suitable warranty is critical when considering solar modules, particularly when considering a poultry shed can have a life expectancy of over 25 years.

Chapter 5: Knowledge Application and Opportunities Identification

Solar and Poultry

When considering and analysing the suitability of solar PV systems for broiler poultry farms four factors must be considered:

- the potential for energy generation.
- on-farm energy use requirements.
- network connection.
- potential power export ability.

Potential energy generation - opportunity

"Every few minutes enough energy hits the earth's surface to satisfy requirements for an entire year, if we could suitably harness, capture and utilise it" (Clean Energy Regulator, 2016)

Australia has a climate which is well suited to generating power from the sun. A poultry farm's location will therefore provide the first key criteria in establishing the suitability of a solar PV installation.

Solar generation also changes depending on the intensity of the irradiance and energy received at different times of the year. A system's typical variance between summer and winter is illustrated in Figure 7.

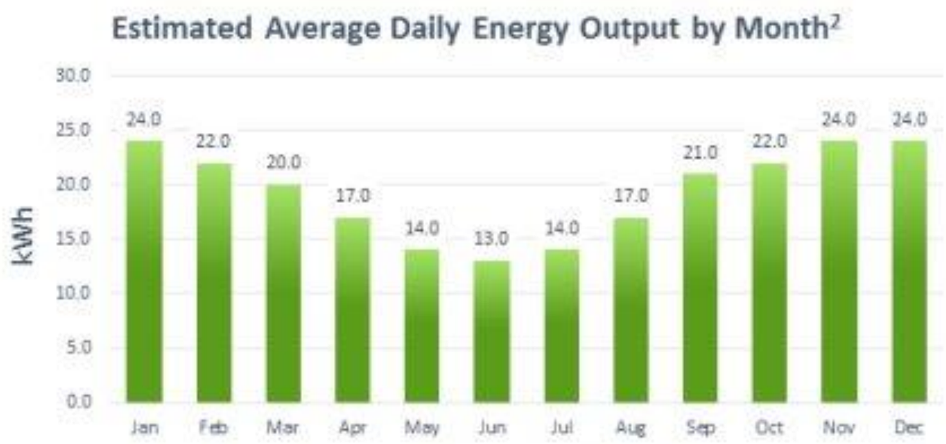

Figure 7: Estimated average daily energy output of a solar PV system (Solari, 2017)

A solar PV system will only generate energy when the sun is shining, and the quantity of energy that a system will produce will vary throughout the day.

On-farm energy requirement

A poultry farm's energy use is driven by a number of factors.

A poultry operation will usually grow-out approximately 5.5 to 6 cycles of broiler chickens per annum. Each of these grow-out periods can be up to 55 days in length. This means there can be up to ten days between batches, with no chickens on site. A farm will generally have a greater requirement for cooling when birds are larger and the density of chickens in sheds is highest.

Energy use is also seasonally dependent, with a greater requirement for cooling in the summer and a larger gas use requirement for heating in the winter.

Figure 8 provides an example of electricity used at a typical poultry farm in Australia during a 12-month period, as well as the typical energy generation of a solar PV system. Increases in electricity use at a broiler farm correlate with grow-out periods and vary at different times of the year.

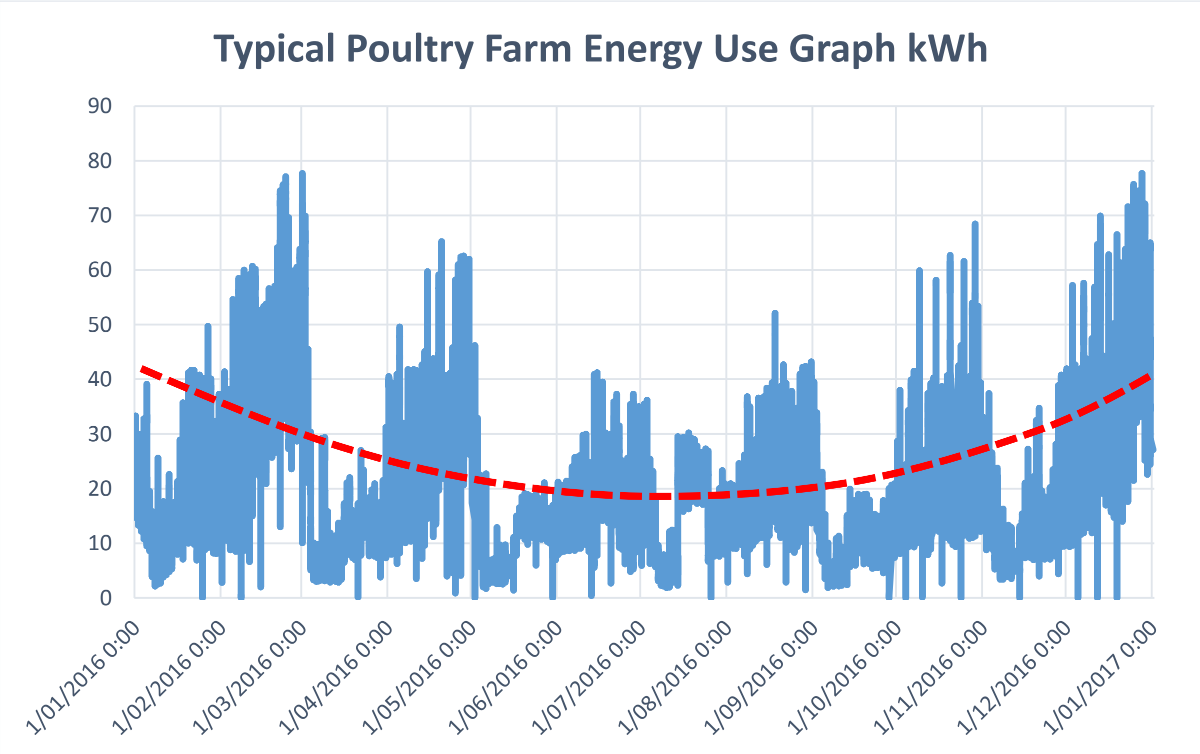

Figure 8: Typical energy use of Australian broiler poultry farm with solar system overlay based on actual interval data from poultry farm in South Australia

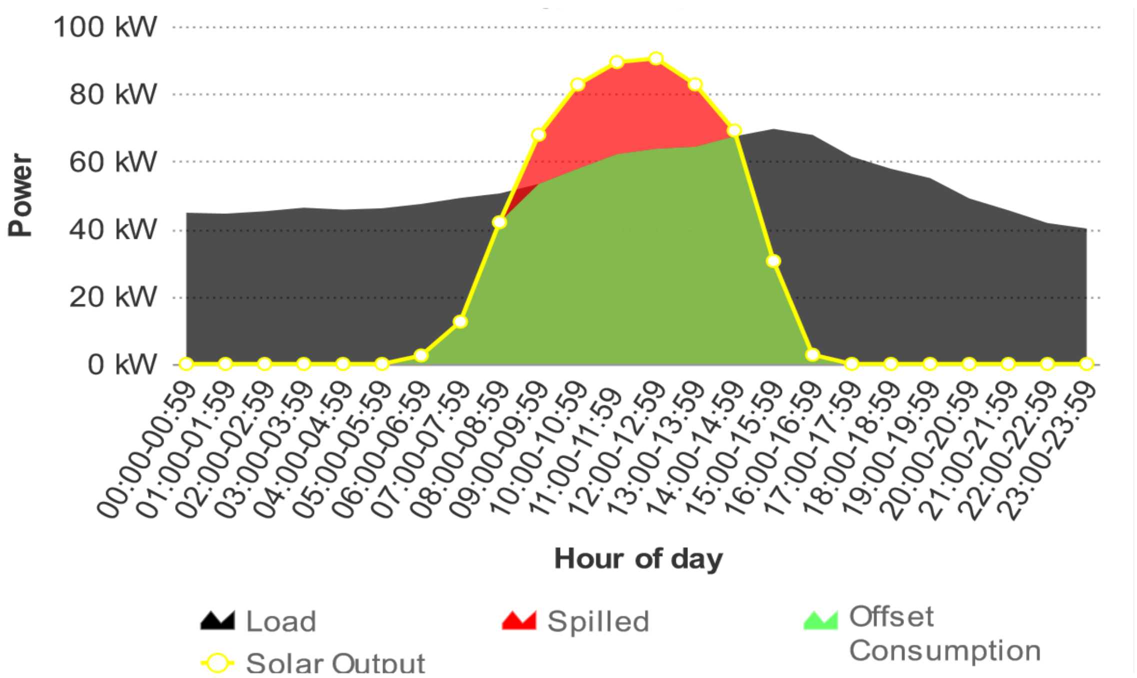

Figure 9: Typical daily energy use for a poultry farm with a solar system's energy generation overlayed (Solari, 2017)

Unlike the energy use requirements of a broiler poultry farm, a solar PV system's generation typically runs at stable levels throughout the year. As such, the technology has not traditionally been considered feasible. However, as has been outlined, the continuing fall in solar module pricing and the escalating energy costs in Australia have rendered the use of these technologies at poultry farms feasible.

Research has indicated that where farms are paying in the vicinity of AUD0.10-0.15/kilowatt-hour (kWh) during peak times, solar PV investments where installations offset on-farm energy usage are able to achieve good return on investment.

A solar PV system cannot however be thought of as a solution to 'take the farm off the grid' but rather a solution to help mitigate costs, and possibly provide a diversified income opportunity.

In considering solar PV, it is particularly important to understand how electricity retailers structure billing and how different tariffs work. Typically, electricity agreements are made up of a few key components, two of which account for the majority of the bill.

The usage component is directly linked to actual consumption of electricity and can have a number of rates charged at cents per kWh (i.e. peak and off-peak). The agreement will also have a network component to account for the infrastructure required to bring power to the site (poles and wires). The usage and network split on the agreement is important to understand, as solar will allow the reduction of usage but not generally network cost, as the farm still requires a network connection and infrastructure. A possible strategy to reduce network costs could be to consider a storage technology, like a battery, to try and lessen the draws on the system.

Two-way grid connection and export power

With a solar PV system installed, the opportunity to diversify income and help reduce energy costs is presented to a farming operation when two factors align:

- its location enables it to obtain a two-way grid connection at a reasonable cost.
- an offtake agreement can be struck with a third party to purchase the power generated on site which is export to the network.

The challenge here, is that commonly network infrastructure is not set up or able to accept exported power, as the transformers and substations are not designed to or capable of taking exported load back to the system.

When both these factors align however, the opportunity exists to install further solar PV at the farm and increase the energy sold to the network. If the limiting factors and hurdles of the network's capacity to handle electricity coming back to the network at that location and finding a third party to purchase the surplus electricity at a reasonable price can be overcome, investment in solar PV is scalable. Here the farm asset owner has the ability to mitigate electricity costs and diversity farm income with an onsite renewable energy power plant.

A solar PV installation in some form will generally make a good business decision right now for broiler poultry farmers. Further, because solar PV is acquired in circa 300W panels, in the future where an increase in generation becomes feasible for a farm, these systems can be easily added to and expanded. Scaling the technology provides the ability to negotiate a better price for the offtake agreement, and also disperse potential capital, if required, to obtain a two-way network and export connection.

Solar and Storage

The largest challenge with a solar PV installation is the inability to store power generated by the system for later use. Research and investigation was undertaken to the feasibility of storage and battery installations on farm. However, unfortunately the technologies that currently exist, like lithium ion battery packs, do not yet make commercial sense. It is however, anticipated that in a similar fashion to the solar PV industry, the storage industry will see increased financial investment that will improve the cost of production. A number of commentators believe, that we are approximately three to five years away from the cost of storage being at a commercially feasible level.

Anaerobic Digestion and Poultry

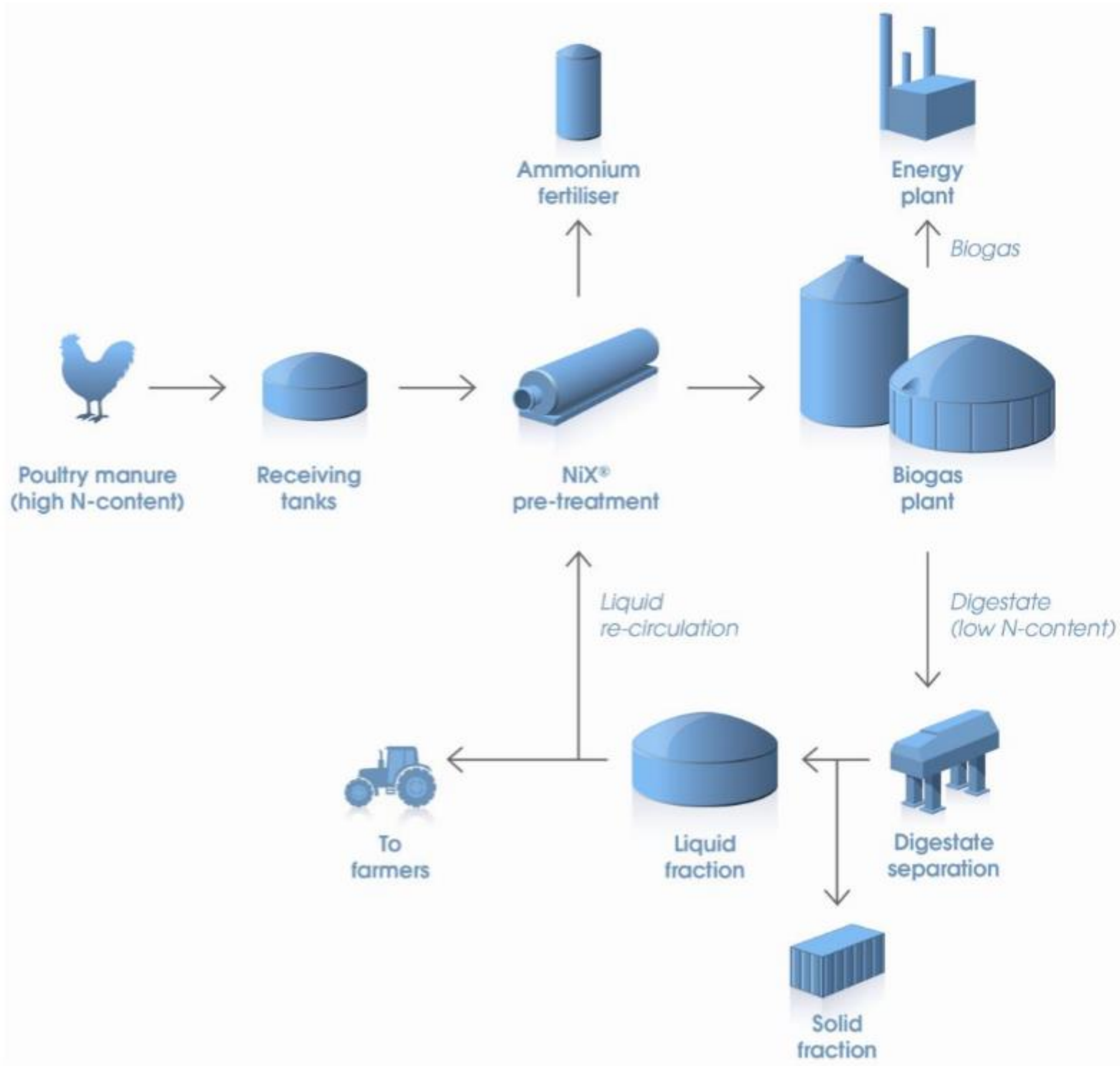

Figure 10: Poultry power opportunities (Xergi, 2017)

This international investigative journey has largely been focused on whether a high quantity poultry manure feedstock AD plant is both technically and operationally possible, and whether there is a feasible business case for this in Australia.

Consultation undertaken prior to international investigation concluded that an AD plant where the majority feedstock is chicken manure would fail. Chicken manure is extremely high in nitrogen which unsettles a digester's environment and causes the anaerobic bacteria to be inefficient in creating biogas which ultimately makes the digester inoperable. What was discovered is that this not the case and it is very satisfying to conclude that in fact, a high chicken manure content feedstock biogas plant is both technically possible and operationally achievable.

Two significant international biogas companies indicated that they have the technology solution to allow a plant to function on poultry manure which are covered in detail previously.

While the technology solution exists, the next challenge is whether this is viable for an Australian project.

Anaerobic digestion as a renewable energy technology holds a significant advantage over other intermittent renewable energy solutions, as it isn't reliant upon environmental factors outside the control of the operator to generate energy such as wind and solar.

Further work is currently being undertaken to determine at what scale and size a poultry farming operation must be, in order for this technology to be feasibly delivered on farm.

As with any capital-intensive project, an AD plant will include a number of fixed costs, which if implemented at scale can increase internal rate of returns and project returns. Some of these fixed costs include legal, planning, engineering, possible network connection requirement and upgrade.

Following investigations into anaerobic digestion renewable energy plants, a hypothetical plant was developed to give the ability to consider and understand key assumptions.

These assumptions are:

- Each tonne of chicken manure will generate approximately 200m3 of biogas.
- At 60% methane concentration and a 35% Combined Heat and Power (CHP) engine efficiency, a 500kWh engine will require approximately 5,500m3 of biogas per day.

- A 500kWh CHP engine project would require approximately 10,000t of poultry manure per annum.
- To achieve this scale on farm, this would require approximately 16 poultry sheds in a consolidated location.

The Australian broiler poultry environment has stemmed and grown from a family cottage industry where farm owners have been mum and dad operators and would traditionally be four to six sheds. Recently, however the industry has seen emerge commercial and large-scale operators with farms ranging in size from eight to 40 sheds, with many of these large-scale commercial farms having more than 12 sheds on a single site.

Due to the high capital nature of an AD plant, the most likely fit for the initial renewable energy AD plants are going to be associated with these large-scale operations, to the benefit of economies of scale in plant size and energy generation.

In order to deliver a solution for a smaller scale poultry farming operation it is likely that this will require the pooling or aggregation of resources and spent litter of a number of operations in a location where there is proximity of growers.

In any regard, an AD plant powered on the feedstock of a poultry farm is going to generate surplus biogas and energy over and above the farm requirements. Therefore, a network connection and secure off-take agreement for the surplus power would need to be obtained at reasonable rates.

A technology solution and business case which is less capital intensive and more suited to a single, traditional-sized poultry facility is continuing to be investigated.

A number of alternative iterations of the AD technology business model mentioned above could also exist. For example, an operation that generates surplus electricity and gas could source willing users or purchasers in close proximity, and use (at a cost) the established network to share this power and gas.

Also, a centralised digester could be used as a renewable biogas and baseload electricity generator in an area. The biogas could be used centrally in a large CHP unit or transferred/transported to each power-using/consuming location where a smaller CHP generator could be set up. This would also provide an excellent opportunity for on-site thermal energy usage, where the hot water could be circulated throughout the poultry sheds for shed warming, off-setting gas usage and costs.

Such ideas present the opportunity to have a single digester capital investment project. The construction of a single digesting unit will be far cheaper than numerous digesting units. A single large unit will also provide the opportunity for operational and gas yield optimisation. This also allows the ability to invest in a larger CHP generator unit.

Chapter 6: Project Funding

Central to bringing an AD project to life in Australia is funding and financing capabilities. Debt funding institutions in Australia have not traditionally had the technology expertise to finance these technology solutions. This potential issue was identified early, which led to consultation with the Foresight Group in London.

Some debt funding institutions are looking to target the renewable sector. For example, NAB has recently extended the Energy Efficient Bonus program, and provides customers with 0.7% discount on standard finance terms.

Opportunities with the Australian Renewable Energy Agency (ARENA) also exist. ARENA looks to use its funding, knowledge and network to bridge the gap between innovation and commercialisation.

Renewable energy projects are currently incentivised allowing the project proponent and site operator to trade and sell Large Scale Generation Certificates (LGC's) in the open market. The issue being faced presently is linked with market volatility and uncertainty around long term pricing. For example, the market for an LGC in 2015 was around AUD30 per certificate (Clean Energy Regulator, 2016). LGCs are currently trading on the market at approximately AUD80-85 per certificate (Green Market Energies, 2017). This price is expected to stay high in the short term, however market forecasters are predicting that in three years' time (post 2020), the price could drop back to as low at AUD40 per MWh (Green Market Energies, 2017). This would represent a reduction in current market prices of over 50%. Even a reduction much less than this still resembles an extremely volatile and an unpredictable market. Private and debt funding institutions do not look favourably at such volatility. Where an income stream on LGC sales provides a key input in to the feasibility of a business case, the uncertainty around renewable energy policies and agendas results in reduced sentiment.

Further industry stability could come in a range of ways. For example, an underwritten base rate that retailers must pay generators for renewable energy exported to the network and/or some stability or floor price around a market like the LGC market. Some certainty and stability around these offtake items would encourage further investment and provide some certainty for renewable project implementation and development.

Conclusion

Some bold goals and objectives were set at the commencement of this research. The aim was to be able to conclude, with some degree of certainty, the viability, both technical and financial, of energy mitigation measures, including renewable energy technology solutions, and their applicability to Australia's broiler poultry industry.

While solar PV is common place in the renewable energy space, an AD plant, with a poultry manure feedstock, had not been previously attempted at a broiler poultry farming enterprise in Australia. In the author's opinion however, this did not mean or warrant that the solution was not technically or financially possible.

The scholarship provided the opportunity to travel the world and meet technology and leaders across the renewable energy space. In today's world of technology, having the opportunity to meet people face-to-face in their home countries was invaluable. A key highlight was conversations with two AD companies, who both confirmed their ability to successfully digest a 100% poultry manure feedstock AD power plant. It also provided the opportunity to walk the factory floors of the top three solar PV module manufacturing companies in the world in 2017. In addition, the scholarship was full of memorable occasions conversing and 'chewing the fat' with farmers all over the world.

It is extremely satisfying to be able to conclude that renewable energy solutions are available and viable for Australian broiler poultry farms, where some interrelated factors can be established.

It is important to note, that while the technology may well be available and technically possible, this is only part of the solution. Because of the capital-intensive nature of these renewable energy solutions, the implementation and feasibility of investments are largely determined by external factors. This includes factors such as the political environmental, energy policy, renewable agenda, energy network and assessing body, available finance, grants funding, and poultry processor requirements.

When reviewing the current environment, it would not be unreasonable to conclude that the way energy has been used traditionally, may not necessarily be the way it is approached and consumed in the future.

This report has focused strongly on the commerciality of these technologies in order to reduce operating costs and provide the ability to generate an alternative income avenue for farmers. However, there must be consideration of social licence and the farmer's approach to sustainable farming practices and methodologies. This brings with it a range of additional factors to consider, which are no necessarily financially driven.

In concluding the Nuffield Scholarship, it is this authors' hope that work in this space continues, and it is the intention to continue to be involved in delivering and developing solutions that have positive implications for the industry, farmers, policy makers and the community.

Recommendations

- A very large percentage of a broiler farm's operating costs fall in to four key areas - labour, electricity, gas and bedding; and therefore, Australia's broiler poultry farm business model allows farmers to innovate and explore cost reducing mechanisms that may increase performance and farm profitability.
- Continual increases in energy prices means a renewable energy technology outcome should be considered by broiler poultry farmers if it has not recently been investigated, as it is likely that an investment will deliver a beneficial outcome.
- The case for implementing solar PV technologies at some level in the broiler poultry industry currently makes business sense.
- Scaling solar PV technology to create a diversified business opportunity is achievable where a network connection is cost effective, and the exported power can be sold to a third party for a reasonable price.
- Broiler poultry farms continue to generate significant quantities of spent litter (poultry manure on site) and the technology exists to utilise large quantities of poultry manure as a feedstock input to an AD plant which can be used to completely offset on-farm energy and gas requirements. It is likely that the energy generating potential on site will see the amount of energy generated far in excess of the farm's requirement, and therefore there is an opportunity to explore a diversified income opportunity where an export grid connection is feasible and an offtake counter party can be identified to purchase the surplus power.
- Further work is required to establish if smaller plants are better suited for more traditional poultry farming operations.
- Some on-farm enclosed vessel composting technologies currently exist for the disposal of deceased broiler birds.
- The political environment surrounding the energy and renewable energy industry in Australia still lacks long-term certainty for consumers.
- Project funding options currently exist for the implementation of renewable energy technologies in agriculture and more specifically, poultry.

Appendix A

Stage 1

Projen

Les Gornal, Projen House, Wellfield, Preston Brook WA7 3AZ, United Kingdom

Prior to the first stage of travel, the author had undertaken significant amounts of Australian-focused research and analysis, and a consistent theme of this was the complexities in trying to use high quantities of chicken manure as a feedstock to an anaerobic digester. It was understood Les Gornal from Projen was a long-term industry expert so sought out a meeting with Les to understand some of the fundamentals of the technology and chemistry issues around digesting poultry manure and what were the critical items that required consideration.

The foundation of AD is maintaining an optimal anaerobic environment for the methogenic bacteria to ensure the digestion system operates at a level which achieves maximum gas yield for feedstock input. Les advised that high chicken manure feedstock AD plants were not operationally functional and provided a few key reasons as to why this was the case:

- The anaerobic bacteria that digest and feed on the feedstock could not handle such a high quantity of nitrogen that goes with chicken manure. It was outlined that digesters can handle circa 14kg of nitrogen per tonne, any higher than this and the PH is permanently affected and the digester will malfunction. Digesters require a balanced diet and the ideal state is consistent with the ratios which apply to composting, being a carbon to nitrogen ration of approximately 25:1. Les provided that ideally an AD plant should not have too much more than 15% poultry manure as a feed source input.
- The complex carbon structure of pine shavings used as a bedding material base in sheds has negative effects on the bacteria in a digester. The product may also release a residue that can be problematic.

The significant potential value of the digestate was discussed. There is the ability to extract up to 85% of the phosphorous from the solids and up to 85% of potassium from the liquid, with the nitrogen fraction approximately 50% in the solid and 50% in the liquid.

In terms of budgeting and approximate costs associated with an AD plant in the UK, budgetary estimates were around GBP4 million per mW.

Applied Poultry

David Speller, Chesterfield, United Kingdom

David set up a business which uses the latest innovation, technology and management techniques to ensure optimal sustainable poultry meat production. David's company supplies this service to numerous poultry farmers.

The author very interested to discuss broiler poultry farming generally, and how some of the major items compared or differed from home in Australia. Unfortunately, David was not involved at the ground level with renewable energy projects in the UK, but his management system which provided staffing and resources services to broiler farmers between batches, was a very interesting concept which I had not seen implemented in Australia.

Energy Innovations

Tom Corbett

The author met Tom from Energy Innovations at a plant that he was installing at Tewksbury in the UK. Tom's company Energy Innovations, in addition to a number of other technology solutions, installs systems that burn and combust poultry manure, where this heat is then used for energy generation. It was interesting to understand how this technology solution compared with anaerobic digesters. Tom outlined that critical to the feasibility of this solution was realising an income stream for the thermal energy. Without maximising this it was likely it would be difficult to build a viable business case. The UK had on offer the Renewable Heat Incentive which provided the opportunity for long term offtake agreements offering payment for renewable heat generated. These subsidised systems were assisting the feasibility of projects in the UK. High-level numbers were discussed with Tom, but the key to the feasibility was to secure an offtake income and have a use for the thermal heat that generated an income stream for the proposal. This was because the poultry manure was used as a fuel for the furnace, which worked in conjunction with a boiler. Projects structured largely on the generation of electricity required significant quantities of feed source. When visiting and at the time of writing this report, a specifically structured heat incentive did not exist in Australia.

Wigley Farm

Rob Gough

Rob and his friend Phil gave a generous portion of their time. Rob ran a mixed farming operation and had recently built four poultry sheds on the family property, which was a new business venture he was leading. Rob had significantly increased the AD plant in size and capacity in the short space of time since its inception, where he was now running two engines – a 500kw and 600kw CHP. These engines supplied some power to the farming operation; however the majority of this power was sold to the grid. His AD plant ran on about 15% poultry manure with a mixture of silage, grasses and dairy whey. Rob has an AD system put together by Marches biogas and he had Edina CHP engines.

A lot of people in the UK were growing energy crops specifically as feed inputs to their AD energy plants where the feasibility of the projects worked due to the renewable energy subsidies which were on offer at the time. Rob took a really detailed interest in the chemistry, science and microbiology behind the renewable energy system. Working closely with the plant engineers to work through different feed mix blends in an effort to maximise the gas yield from his plant, maximising thermal and electrical energy generation and maximising the return on the investment. Rob’s tip was to source affordable dairy whey as it was a highly efficient product to work in to your AD feed stock diet.

Frogmary Green Farm

Nick and Clare Bragg, South Somerset UK

Clare Bragg is a Nuffield Scholar and she and her husband Nick ran a mixed farming operation with a number of broiler sheds. In addition to the farming operation, the couple run a diversified business and farming venture business model including a cooking school. They have built their farming and business enterprise from scratch over 20 years and were in the process of building an anaerobic digester during the visit. As opposed to utilising the biogas to run a CHP engine, the business model was structured on gas-upgrading technology which was cleaned and suitable for directly injecting to the national gas grid. This had some real benefits in a number of situations, particularly where the thermal energy could not be maximised. Where the biogas was able to be injected directly to the grid, this created a very efficient model, as there was no thermal energy waste.

Biogest was the company delivering and providing the technology and engineering for the project at Nick and Clare's place. This was particularly interesting as it was the first time the author had seen an AD plant that generated gas that was upgraded and suitable for direct use in the national gas grid system. Prior to this, the author was not aware that biogas and natural gas or LPG were effectively interchangeable.

Williams Industrial Services

John Bell, Northern Ireland

The author met with Williams Industrial Services (Williams). Williams has been to the partner on a number of project that were funded by the Foresight Group. Williams was heavily involved in an AD project in Northern Ireland and he outlined that they had undertaken quite a bit of work in relation to the gas upgrading and compressing or liquefying the biogas. Williams specialised in pre-treatment of the feedstock before going in to the AD plant to maximise the gas generation through thermal hydrolysis. John outlined that Williams had approximately 25,000 tonnes of poultry manure per annum in their AD system across Northern Ireland and were doing quite a bit of work on the pre-treatment to allow further poultry manure to be used as a feed stock.

Moy Park

Tom McKeown, Northern Ireland

At the Nuffield Contemporary Scholars Conference in Cavan the author was put in contact with Tom McKeown from Moy Park. Moy Park is one of the largest poultry processors in the UK, and have been involved in developing a solution to the huge quantities of poultry manure the sector produces in Northern Ireland. The meeting with Tom did allow a discussion more generally about the poultry industry and trends that exist in the UK. Tom outlined that there were some frustrations with the RSPCA branded product in supermarkets and that some supermarkets were pushing towards an antibiotic free meat.

The author also understood what processors like Moy Park enforced around single or double batch litter polices. Tom was stern on the fact that the only method that can exist is to run a single batch litter policy. Tom held the opinion with such importance around biosecurity and the risk around potential disease outbreak, that he believes litter reuse was a 'ticking time bomb'.

Here in Australia, it is something difficult to rationalise. It is possible to have two processors in the same state, some farms are only kilometres apart, and one processor will allow their growers to multi-batch litter and the other will not. However, both processors run with not dissimilar mortality numbers. The industry has done, and is continuing to do, work on this.

James Cromie

Banbridge, Northern Ireland

James had a mixed farming operation that included a dairy. James had an anaerobic digester which was engineered and designed by Williams and funded by Foresight Group. The AD plant ran a 500 kW CHP engine where the majority of the power generated was sold to the grid as electrical energy. The plant was owned by Foresight Group, and James was paid on feedstock, a management fee and a bonus for performance. It was good to discuss through some of the issues that can come with the stirring and mixing technologies, as James did encounter some issues early and had to empty the tanks to remedy the issue. The system was working on around 15 tonnes per day of feedstock which was a mixture of silage and manures (including chicken manure). James was receiving about 150m3 of biogas from his silage input and around 250m3 of biogas per tonne on his chicken manure feedstock. He ran a two tank system and had a number of agreements with local farmers who used his digestate as a fertiliser.

Gilfresh

Thomas and William Gilpin, Co Armagh, Northern Ireland.

Gilfresh Produce is a family run company based in Loughgall in Northern Ireland, established by the Gilpin family over 50 years ago. Gilfresh Produce now grows and manages the growing of over 2,500 acres of field vegetables and crops including traditional root vegetables, salad crops and brassica vegetables. Thomas utilises his lifetime of growing experience through management of the grower base while son William oversees the daily operations at the factory location.

Thomas has been the driver behind their recently installed AD plant, due to the opportunity to utilise the vegetable waste from their horticultural growers' network. The AD system at Gilfresh was engineered and designed by Weltec which is a German-based group and the biogas created generated a 500 kW Edina CHP. The system was well designed where Thomas informed he had quite a bit of input, as he was once a practicing architect.

The system was a three tank system, the first two tanks were for the biogas generation and the third was for digestate storage, which was used as a fertiliser for the surrounding farm land and contract growers.

Willen Biogas

Cattlegate Farm

The Foresight Group introduced Willen Biogas, a project it was currently funding. Cattlegate Farm is a 1,500 acre cropping operation around an hour outside of central London. It is a family business which had recently diversified into AD and composting. Willen Biogas appointed Xergi to build and operate its 27,000 tonne per annum waste-to-energy plant in Enfield, North London. The plant will generate renewable electricity for the grid and recycle nutrients from organic waste matter to make agricultural fertiliser. The plant capitalised on the large amounts of food waste produced each day in London's households, restaurants and food industry.

This plant had the most detailed engineering additions ever seen by the author, including a pre-treatment facility that separates plastics from the organic feed inputs, a pre-pasteurisation process to kill any pathogens, and digestate separation and liquid recycling which value-added to the spent digestate by further composting on–site. The plant powers a 1.5MW CHP GE Jenbacker engine, which generates enough power for around 1,750 households.

The Willen Biogas project really instilled the sustainable reuse and closed system opportunity that AD presented, and the ancillary and value-add opportunities that exist in an AD project. Electricity and power generation is really only one income producing mechanism in the business case. Discussions with the onsite operations manager Ron, allowed an understanding of the composting business and its opportunity to realise around 80 pounds per tonne, for finished product, which could be used locally in agriculture. It was insightful to see that food waste from London was being used to generate enough energy to power 1,750 homes, and the by-product waste was being used in agriculture to regrow crops which could then again be consumed locally, and where this waste would follow the same cycle.

Stage 2

Nuffield Global Focus Program

Stage 3

United States of America – Georgia, Tennessee, and Alabama

The first part of Stage 3 of the personal travel program was used visiting poultry farmers in the largest broiler chicken growing states in America. There was an opportunity to visit four different poultry farms across the southern states of Georgia, Tennessee and Alabama.

The team at Eco Drums, a company that had a solution to deal with broiler bird mortalities through an enclosed vessel composting system, took two days of their time to take the author to meet different poultry farmers and discuss the broiler poultry industry and the bird mortality composting system in the area.

Bird mortality disposal systems in the States are not dissimilar to what is being used in many parts of Australia – where refrigeration systems are required on-site to hold the dead birds until a contractor takes them away. These systems are expensive to run and maintain largely due to the price of electricity.

The Eco Drums system is an enclosed vessel technology solution where bird mortalities and a high carbon bulking material are combined and composted over a number of weeks, which generates a high-quality blood and bone fertiliser product which is very low in odour. The drums come in different sizes depending on the quantity of bird mortalities that require processing.

A number of systems were seen with a variety of bulking materials used, including fine sawdust, pine shavings, cotton trash and peanut hulls.

All farmers were happy with the solution and pay back periods were viable driven by savings in electricity costs. The farmers also gained the peace-of-mind with decreased biosecurity risk as contractors were not driving from one farm to another collecting bird mortalities.

Figure 11: Photos showing Eco Drum composting vessels (Source: Author)

UK AD & Biogas and World Biogas 2017

Birmingham, UK

Largely, the timing of Stage 3 of the travel was structured around the UK AD & Biogas and World Biogas Expo 2017, held in Birmingham in July 2017.

This show is arguably the landmark event for the biogas industry internationally, or at least for Europe. It was an excellent opportunity to maximise the use of time, as all the experts and engineering and technology providers are drawn to a single location. The show had over 180 exhibitors across all aspects of the industry, including a number of workshops and talks.

The author interacted and connected with each individual supplier with a view to understand the potential costings of each component, and provide some overall costing foundation and knowledge. Many companies had Australian distributors, from tank providers to engine and CHP suppliers.

It was also possible to connect with a group from the Netherlands called Byosis and had a number of interesting discussions with Bjorn, the Managing Director. Byosis specialises in pasteurisation and nitrogen stripping technology solutions. From discussions with Bjorn I understood that Byosis is involved, at some level, in the nitrogen removing technology in use at the Ballymena plant in Northern Ireland.

The event provided a comprehensive wrap-up opportunity to close the loop on any outstanding questions in the AD space.

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Plain English Compendium Summary

Project Title:	**Renewable energy technologies and the broiler poultry industry** ***Cost reduction and income diversification***
Nuffield Australia Project No.:	1617
Scholar:	Benjamin George Edser
Organisation:	23 Dovercourt Road, Toowong, QLD 4066
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Objectives	• What can be done to reduce key operational expenditure on a poultry farm to increase farm profitability focusing on energy. • Understand what energy mitigation and income diversification options exist, including renewable energy technology solutions, and apply those most suitable to broiler poultry farming. • Undertake in-depth analysis in to anaerobic digestion (AD) waste-to-energy solution, and solar PV, at a broiler poultry farm, looking at size and scale of operation. • Ensure international investigations are applied so as to be Australian-suitable.
Background	Approximately 70% of operating costs at a broiler poultry operation fall in to four key operating cost areas – labour, electricity, gas and bedding and significant operational advantages exist where solutions can be implemented which tackle one or more of these key cost areas as broiler farming operations are significant consumers of electricity and gas and are major generators of spent litter (poultry manure). Technology advancements are made daily, energy costs continue to escalate and the political environment surrounding energy is moves frequently. Understanding energy and providing the tools for farm owners to take control is key to operational risk.
Research	International investigations including seeing and meeting with professors, executives, technology solution providers, asset owners and farmers and financiers across 12 countries.
Outcomes	Renewable energy solutions in the form of solar PV and anaerobic digestion are available and technically and financially viable for Australian broiler poultry farms, where some interrelated factors can be established.
Implications	These solutions are viable and exist and knowledge and information sharing must increase to ensure accurate information in conveyed. Bilateral long term energy policies and stability is critically required for the Australian energy environment and Australian consumers.
Publications	Presented at Nuffield National Conference 2018