Rice Straw Utilisation

Value Adding and Alternative Uses for the Australian Rice Industry

A report for

By Antony Vagg

2013 Nuffield Scholar

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Executive Summary

The Australian Rice industry produces some of the highest crop yields in the world. As a result, the by-product of this is a significant stubble load, which is difficult to manage. Additionally, the silica content of Australian rice straw is significantly higher than most around the world. The current practices of burning stubble to allow a double cropping rotation are not likely to continue too much further into the foreseeable future due to environmental constraints and changes in policy. Few alternatives of stubble management are practised within the Australian Rice Growing industry, therefore, a ban on stubble burning could severely jeopardise the viability of the industry.

Throughout the world, rice growers are addressing the problem of stubble load with methods that eliminate the stubble load problem as well as value add and create additional revenue streams from a 'waste' product. These methods include:

- Biomass plants
- Biogas plants
- Strawlage as a stockfeed source
- Erosion control
- Composting
- Mulching for high value crops such as mushrooms
- Building products
- High value raw materials.

These findings aim at educating the Australian grower and industry to alternative uses for rice straw and encourage a shift in thinking from rice straw being considered a waste product to being a product of value. It may also allow the industry to further investigate potential energy solutions, as new technology and rising energy costs result in previous projects becoming viable again.

The report isolated two clear groupings: solutions that benefit the individual primary producer on an opportunistic scale, and solutions that benefit the industry as an industry wide solution.

As a result of these findings, clear recommendations can be made. Firstly, the Australian industry can capitalise on and benefit from international research, technology advancements and government policies. Given no feasibility studies have been done within the last fifteen years, opportunities that can benefit the whole industry exist. In terms of the individual farmer, lateral thinking and informed business skills may uncover solutions to the problem.

For a significant amount of these discoveries to become viable, there is a role for government to play in terms of project funding and consultation. The key difference noticed across the majority of places visited is that an active government aiding research and development to find solutions generally results in significant progress; results became apparent after several years of government interaction with industry.

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Foreword

I grew up on a rice farm near Bunnaloo, NSW. The farm is a family business, owned and managed by my parents, and the workload shared amongst my older brother Ryan, myself, and my youngest brother Lachlan.

After high school, I completed a Bachelor of Agricultural Science at the University of Melbourne, followed by a Bachelor Degree in Rural Science and Agricultural Consulting from the University of New England (via correspondence). I worked in Melbourne for two years as a consultant in the livestock industry before backpacking around Europe and returning to the family farm six months later.

Upon returning to the farm I became involved in outside interests within the community but particularly to do with rice. I participated in an emerging leader's course through the Ricegrowers' Association of Australia (RGA) and was voted onto their Central Executive Board. On the farm however, I was keen and just out of university, looking to make changes and advancements.

I am keen on the notion of value adding on products that we generally sell at wholesale prices and have continually pondered an alternative use for rice straw, as I would watch it burn, providing zero income and little agronomic advantage.

I had previously heard about Nuffield but knew relatively little about it. At a RGA branch meeting, fresh from the emerging leaders program, 2009 scholar Jennifer Hawkins talked about the Nuffield experience and I was convinced. I had the determination, the study topic and after hastily putting the application together, was lucky enough to receive a scholarship.

The Australian rice crop varies from year to year due to its high reliance on water allocation. However, the industry would like to see an average tonnage per year across the industry greater than 950,000 tonnes. Stubble load in rice is almost proportional to yield. One of the main issues faced by rice farmers is successfully removing the straw from the summer rice crop, to be able to utilise the soil moisture and plant a winter crop, usually wheat or canola.

Currently it is mostly burnt. It has little feed value, does not break down easily due to its high lignin content, therefore removal as an economic benefit is, to this point, limited.

With stubble burning already banned in most European Union (EU) countries, the United States of America (USA) and some Asian nations such as Japan banning the procedure, here is an added pressure the Australian industry is likely to face. If this occurs, there are very few alternatives for individual farmers and there is no industry solution currently available. This will leave a significant financial burden on farmers attempting to remove their straw load and will see rice land out of production for up to two years, to allow for the straw to break down naturally.

There are a limited number of farmers who have found a market for rice straw in Australia. One sells straw to horse studs and another has been attempting to market a chipboard like product made out of rice straw but so far is experiencing problems. Upon researching previous to my Nuffield studies, I knew there were straw burning plants in the UK, rice straw burning plants in India, as well as numerous other initiatives in countries such as Egypt, France, throughout Asia and the USA.

My studies took me to the following countries:

- USA: who have similar yields and growing conditions, however, a limit on burning no more than 25% of their stubble in California has led to innovation.
- United Kingdom (UK): where biomass powered electricity plants are now in production, including Ely power station, which burns 200,000 tonnes of straw a year.
- France: although they have limited rice production, their limitations on not only burning, but also crops and application of nutrients and chemicals have led to interesting innovation.
- Egypt: producing the second highest rice yields in the world, despite their political turmoil, the innovation and adaption of technology was quite impressive.
- Turkey: a significant increase in yields over the last decade has seen a quick transition in rice management practices to deal with the heavy straw load.
- India: an amazing contrast to what I imagined to be the norm. The culture, the people but more impressively, the innovation. Potentially the world leader in rice bi-product utilisation.

- Philippines: the central hub of world rice research and development, The International Rice Research Institute (IRRI) provides a worldly view on rice systems that puts everything in perspective.

My travels and discoveries could not have been possible without the Nuffield network but particularly my sponsors. I would like to thank RIRDC, especially John de Majnik, as well as Ian Mason from Rice R&D for making this all possible and I can only hope my experience and some of the discoveries I have come across can help the rice farmers and the Rice Industry of Australia into the future.

Figure 1: Author at International Rice Research Institute (A Vagg, 2013)

Acknowledgments

Completing and making the absolute most of my Nuffield scholarship would not have been possible without the assistance, patience and help of the following key people:

- Rural Industries Research and Development Corporation particularly John de Majnik, Ian Mason from Rice R&D and the Ricegrowers' Association of Australia (RGA) including Ruth Wade and Andrew Bomm for their support and determination to develop and bloom young people in a vibrant industry.
- Nuffield Australia, past chair Terry Hehir and particularly Jim Geltch, CEO, for his tireless efforts, email responses in the middle of night, attention to detail and organisation making CSC, GFP and personal travel streamlined and completely functional.
- The GFP group Peter Kaylock, David Cook, Kate Mason, Jason Size, Carly Bussenschutt, Matt Pooley and Steve Wilkins
- The Nuffield family, particularly Thibaud Brocard, Andrew Williamson and Ali Capper for providing accommodation and hospitality.
- Mum and Dad, Max and Andrea Vagg, for their understanding and support for my world adventure, usually during the busy times having to manage their business with me coming and going.
- My brother Ryan Vagg for taking up an exorbitant amount of work on the farm, contributing far more hours than should be expected to help everything run smoothly.
- My girlfriend Rachel Kelly. For relocating from Canberra to a foreign town to be closer, just in time for me to leave for the CSC, then again for the GFP. For her understanding, support and advice.

Abbreviations

GFP	Global Focus Program
CSC	Contemporary Scholars Conference
RIRDC	Rural Industries Research and Development Corporation
RGA	Ricegrowers’ Association of Australia
EU	European Union
USA	United States of America
TMR	Total Mixed Ration
DM	Dry Matter
HS	Haysaver – commercial hay application product
CP	Crude Protein
ME	Metabolisable energy
USDA	United States Department of Agriculture
OM	Organic Matter
MWh	Megawatt hour
MJ	Megajoules
OM	Organic Matter
USA	United States of America
IRRI	International Rice Research Institute
UK	United Kingdom
GWh	Gigawatt Hour

Objectives

There are many possibilities in turning a ‘waste’ product (that is straw) into something valuable. This could potentially be done through electricity production from biomass, a feed source for livestock, an erosion control aid or even valuable end products like health products, medicines and fertilisers.

The objectives of this report are to:

- Investigate alternative uses for rice straw around the world.
- Identify the best likely alternatives to be adopted in Australia.
- Determine if these alternatives will fit into the Australian rice production system.
- Formulate cost and benefit analysis for the industry.

Introduction

The Australian Rice industry produces an average of 850,000 tonnes of rice per year. This figure fluctuates highly due to the requirement of irrigation water, which varies from year to year. The Industry itself is looking to push that figure to 950,000 tonne average, as emerging markets continue to develop. Of all the rice grown around the world, Australia produces the world’s highest rice yields, averaging 10.8 tonnes per hectare in 2010 compared to the world average of 4.3 tonnes per hectare (Food and Agriculture Organization of the United Nations, 2011).

This high yield also produces a problem in terms of stubble management. The amount of rice straw is relevant to the crop’s grain yield. The majority of rice farmers in Australia like to remove or eliminate the straw load immediately after harvest, allowing for a winter crop, usually wheat or canola to be direct drilled, utilising the sub soil moisture left over from the rice crop. Currently, the majority of farmers burn the stubble creating plumes of smoke, returning few nutrients to the soil and receiving no financial benefit for the straw. When comparing burning straw to retaining straw in the paddock, burning causes almost complete nitrogen (N) loss, phosphorus (P) losses of about 25 per-cent, potassium (K) losses of 20 percent, and sulphur (S) losses of 5 to 60 percent (Dobermann & Fairhurst, 2002).

Nutrient removal, kg nutrient/tonne						
	N	P	K	Mg	Ca	Si
Rice Grain	10.5	4.6	3.0	1.5	0.5	2.1
Rice Straw	7.0	2.3	17.5	2.0	3.5	11.0
Burning	7.0	0.6	3.5	1.0	2.9	0.2

Figure 2: Nutrient removal comparisons between grain, straw and burning straw (Dobermann & Fairhurst, 2002)

If we consider these losses in a 10 tonne rice crop, where the amount of paddy and straw are approximately equal, by burning the farmer is losing 70 kg/ha nitrogen, 6 kg/ha of phosphorus and 35 kg/ha of potassium. The silica is left but the heat from burning makes it insoluble (Scheew, 2009). Additionally, each tonne of straw contains approximately 400 kg of carbon. If we consider that on average, 800,000 tonnes of rice straw is burnt each year in

Australia. That equates to 320,000 tonnes of carbon a year released into the atmosphere. While alternative uses for straw need to take into account the removal of nutrients from the paddock, the carbon released when burning is something that must be considered very carefully. In world terms, this can lead to significant pollution issues in dense production areas as shown in figure 3.

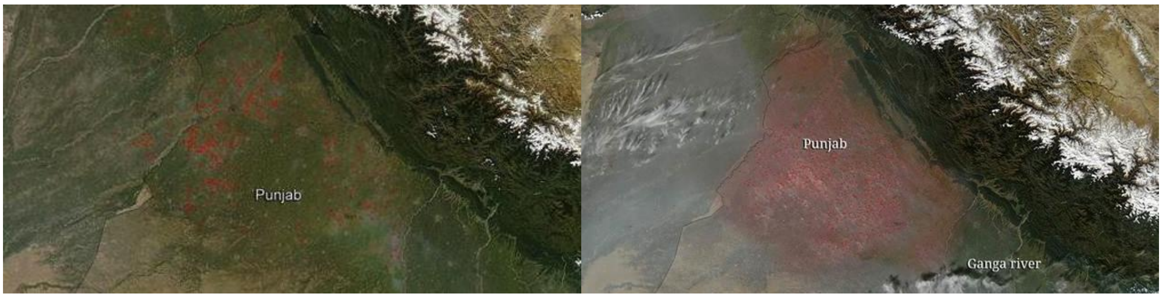

Figure 3: Aerial view of Punjab region before and during rice stubble burning. (NASA, 2013)

While the rice industry in Australia predominately runs from north of Griffith to south of Deniliquin, and as wide as Moulamein in the west and Berrigan in the east, the area is confined to a radius of approximately 250 km, of which the majority is rural. This geographic location creates potential for some solutions but hinders others as will be outlined later in the report. It also allows the burning of stubble without the attention it would otherwise receive in more urban areas of the country. This is despite some media attention within the rice growing area.

This is why it is important to provide an alternative to burning rice stubble. If the alternative can provide financial incentive, rather than a burden, of course the farmer is more likely to adopt the practice. The worry for the Australian rice grower is that if the issue receives exposure in the urban news, the Australian government may look at a similar direction to the EU, California and parts of Asia and ban burning of stubble. Researching and creating opportunities and putting into place viable alternatives, before a ban is enforced, is in the grower’s best interest.

Currently, there are few alternative practices occurring in the Australian rice industry. One farmer is selling the straw as horse bedding, another is trying to process the straw into building products. Some will incorporate the stubble but the sheer volume, combined with a dry, hot climate, results in a significant time-frame for the stubble to break down into organic matter. Traditionally, if the stubble was not burned, that piece of land would be out of production for over 12 months, a period the farmer can ill afford.

Rice straw as an animal feed source

Rice straw has been considered an inefficient source of animal feed due to the straw properties, such as low nutritional value and high energy requirements to break down. In times of drought, the straw has been used as roughage but this is purely on an opportunistic scale and is not a market that would provide constant turnover and stable prices.

Methods and techniques of adding synthetic nutrients to the straw have been investigated and researched. With the price of synthetics such as urea, the conclusion has been reached that this is not a viable alternative with current technology, especially when alternative straw such as wheat and barley is readily available.

Glenn Nadar from the University of California, Davis campus, has been researching rice straw as a valuable feed source for nearly 30 years. His research has come to a point where solutions are appearing, but the complete story has not yet been resolved. Glenn has concluded that it is the moisture content, time of baling and storage that greatly affects the nutritional value of the straw as a feed source (Nadar, et al., 2014).

The pressure to use rice straw in an alternative manner is becoming more relevant in California, as they are gripped by drought, reducing water availability. Currently in California, 25% of rice straw can be burnt in paddock and only as a disease control method. Of the remaining 75%, less than 3% is used off-site, despite a website setup to help trade rice straw (California Rice Commission, 2014). The remainder is incorporated into the soil by re-flooding the field, driving a steel wheel tractor over the stubble, mashing the straw into the ground and accelerating the breaking down process (Bird, et al., 2002).

Pressure for an alternative to this practice will increase as water increasingly becomes limited. This technique would use approximately 2 megalitres a hectare and with water prices fluctuating from $50 - $150 AUD per megalitre, it is unlikely to be a viable alternative for Australian growers, let alone Californian growers.

Current experiments have shown that adding urea and UN 32 at a combined rate of 8.8kg/t, costing $17.3/t AUD or applying a commercial product Haysaver, using a tank and nozzle setup on a baler, with a relevant nitrogen application costing $12.4/t AUD, showed an intake increase of approximately 30% and an increased energy level of about 20% (Nadar,et. al., 2014). This puts the rice 'strawlage' into a comparable category to low grade lucerne hay. It is referred to as strawlage as the process is similar to silage but in the form of straw. Reducing the oxygen exposure to the strawlage is crucial to achieving this result.

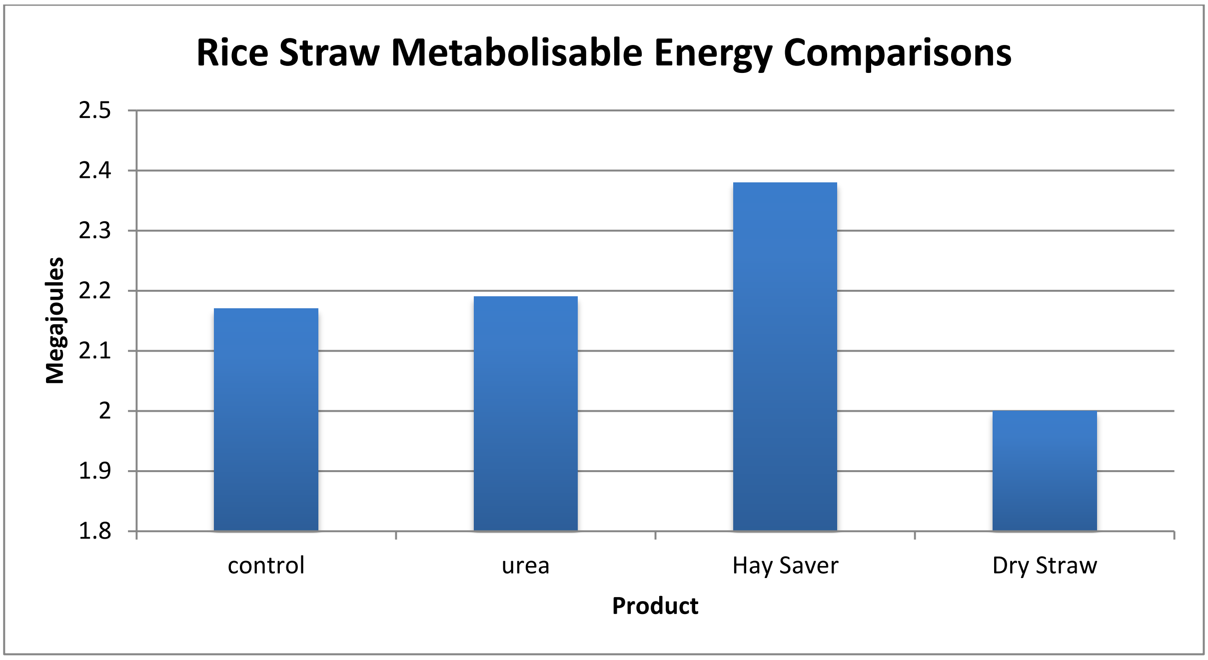

Figure 4: Comparison of estimated metabolisable energy (ME) of 4 different experiments (Nadar, et al., 2014)

The other crucial aspect of this process is the moisture content the straw is baled at. For the process to maintain digestibility, the straw needs to be baled between 45-65% moisture. This conclusion is based on evidence from investigations from Larry Roth, Technical Services Nutritionist with Provimi, North America, when investigating strawlage in Japan. He also discovered that not applying a nitrogen treatment results in a white mould appearing on the strawlage (Roth, July 2014).

While this feed source was originally targeted as a drought management strategy for beef and dairy farmers during times of high hay prices, his investigations suggest this could be a long-term solution for not only rice farmers, but also beef and dairy producers looking for a constant quality roughage source for their feed ration operation.

Rice straw for erosion control

Post bushfire erosion control

With the changing climate, urban sprawl and other pressures on natural vegetation, there has been an increase in demand for revegetation methods after natural disasters such as flood, bushfire and drought. This is evident in California where rice straw has been effectively used since 2001. The US Forest Service, along with the United States Department of Agriculture (USDA), contracts helicopter operators to perform the task over devastated areas, usually at a rate of 2.47 tonne per hectare creating a blanket of straw approximately 2.47 centimetres thick.

To complete the process, straw is transported to a location close and accessible to helicopters. From there, big square rice straw bales are placed in a net, the strings cut and then transported to the affected zone by helicopter. They are then released over the correct zone (Nadar, 2010). Despite the relative costs associated with this kind of project, it is more cost effective than manual application and so both government and private entities work together to achieve the result.

Despite the fact that there are multiple straw options available in California for this project, there are very relevant reasons as to why rice straw is chosen. Firstly, its high silica content means it takes significantly longer to break down compared to standard straw options such as wheat or barley. This results in longer rehabilitation phases, allowing natural grasses and vegetation to have the greatest opportunity to mature. The second reason is seed contamination. Rice straw, as it is a semi-aquatic product, has no weed seeds that are likely to germinate in revegetation zones. As the product is usually distributed within national parks, foreign flora is not spread, as they would be by wheat or barley straw. As part of the contract, the outside run of the harvester and mower is left in the paddock to avoid weed contamination from the banks and roads around the rice block.

As a result of this, K&R Farming in Willows, California, has sold up to 5,000 bales at a time to USDA for revegetation (Cal Recycle, 2014). This is an opportunistic market however, heavily reliant on wildfires throughout California. It would be the same scenario in Australia with bushfires infrequent and unpredictable. A Tripod Complex fire in Washington State in 2006 saw over 70,000 hectares burnt, of which, 20,000 to 30,000 tonnes of straw was required. In comparison, a 2003 Californian fire, which burnt over 200,000 hectares, only required treatment on less than 810 hectares, hence less than 2,000 tonnes (Erosion Control, 2013).

This comparison demonstrates the variation in requirements of straw from season to season. This initiative is not an industry solution, rather a marketing opportunity for individual farmers. Conversations would have to be undertaken with relevant authorities such as the state Department of Sustainability and Environments or relevant department that deals with fire mitigation control and clean up and recovery of natural vegetation. The author, on initial investigation, has no knowledge of this practice occurring in Australia and it therefore could present an opportunity for straw disposal.

Construction site and development runoff control

Rice straw may provide another opportunity for erosion control in a more common, regulated manner. Rice straw for construction sites and development areas could be used in a manner that is already seen across the country. Councils developing new roads and passes often use straw bales to control sediment runoff and stormwater management. The simple method to do this is to ‘stake’ a small square bale in the affected area with a steel or wooden peg, usually in the low lying area or areas on a steep embankment where fresh sediment runoff is likely.

However, companies in the USA have modernised this process with rice straw, creating a sausage like object, up to 7.5 metres long and in varying widths up to half a metre in diameter. Generally the netting holding the rice straw is made from a biodegradable product that is 85% high-density polyethylene, 14% ethyl vinyl acetate with 1% carbon black for UV inhibition (Rice Straw Fibre Roll, 2014). Rice straw again is chosen for its slow degradable properties and its certified weed free status, eliminating the spread of weeds.

This product can be seen commonly along roadways in the USA but a figure of how much straw is used annually with this innovation and the greater question of will it be something councils would adopt in Australia is something that needs to be investigated further.

Certainly the control of weeds and slow degradable properties of rice straw compared to its competitors makes it an inviting prospect. It is an opportunity that again is likely to be sought by knowledgeable businesses rather than a solution for the industry. Interaction with civil construction groups as well as local councils would need to be undertaken before a project would be known to be viable or not.

Mulching

Mushrooms

Straw mushrooms are called this name as they are produced on straw, year round. In Colusa, California, a mushroom farm called Premier Mushrooms uses rice straw as a bedding source to create straw mushrooms. The growing process takes 35 days and once the mushrooms are picked, the compost is recycled and the mushroom houses sterilised for the next batch of mushrooms (Ashbaugh, July 2014).

The difficulty with mushrooms as a user of rice straw is the processing plant has to be in very close proximity. Straw transport would destroy the prospect of supplying a mushroom farm unless it is within that close proximity to reduce transport costs. To build a mushroom farm just to service waste straw would not be a viable investment, as the setup of a mushroom farm is quite expensive. With climate controlled rooms and large cold storage facilities, as well as the daily running costs, the price of straw would be a low cost base. Again, this venture is something that would be a potential avenue if a mushroom farm was within a close proximity to a rice farm.

Rice straw as compost

High silica content makes breaking down a slow process, with extra energy required to complete this process, hence increased cost. Despite this, rice straw as a cheap source of organic matter has the potential to be mixed with other waste products, placed in anaerobic digestive situations and turned as required, to produce a compost product required both commercially by farmers and as a garden product.

Trials conducted in India at the Punjab Agricultural University, that included the addition of fungus cultures to accelerate breakdown, had successful results within three months. The addition of available cow dung provided the required environment for microbes and enzymes to perform. Rice hulls have also been extensively used successfully as a chicken litter in broiler houses and then converted to a compost solution to then be re-introduced to farm paddocks.

The unfortunate aspect of rice straw or hulls as a compost is they seem to be an additive to compost that is not so much required but more utilised due to the availability of the hulls and straw. The straw is in direct competition with cereal straw and other waste products that can be sourced for similar prices and the rice straw provides little benefit but rather a hindrance due to the high silica content.

Bioenergy

Last year, Sunrice, the grower owned company that mills, packages and markets Australian rice, spent $22.479 million on electricity costs (Sunrice Annual Report, 2014). Of this, the vast majority was through powering the rice mills. A joint venture feasibility study into power generation was undertaken in the late 1990's and a pilot biomass plant was run in the 80's and early 90's. This venture, unfortunately, was quashed by the decade long drought at the turn of the century. However with technology advances, on top of rising electricity costs, this research could be revisited.

Upon researching bioenergy, it became clear there are two separate methods for utilising rice hulls and rice straw. Rice hulls are widely burnt across the world as a source of energy. They provide a beneficial energy source due to their consistent size and shape, allowing a consistent throughput and efficiency gains of between 75 – 85% (Helal, August 2014). This is compared to rice straw biomass efficiencies of approximately 60 – 75%, depending upon technology and process.

In Australia, bioenergy is perceived to be relatively expensive to produce compared to other conventional sources such as coal. Black coal can be generated for approximately $36/MWh, brown coal for a dollar less. Solar is $190/MWh while wind is between $80-120/MWh. Biomass is estimated between $70-185/MWh, leaving it very competitive in terms of renewable, but very expensive compared to conventional sources such as coal (Alan Moran, 2014). This is the continuing trend we see within Australia where renewables, through their initial cost of production and efficiencies, are not as widely used as in other parts of the western world. However, this is changing with adoption of renewables occurring at a faster rate now than ever before in Australia.

Additionally, the price of electricity in Australia has continued to rise significantly over the past decade and is expected to into the future. In a five-year period, from June 2007 to June 2012, electricity prices rose by 72% (Australian Bureau of Statistics, 2014). To add to this, Australian businesses which account for 70% of electricity consumption, have seen an almost 80% increase in electricity prices since 2009 (Pearson, 2014). Looking into the future, electricity prices are likely to increase in the medium term by approximately 1% per year in real terms. In the short term, electricity prices are expected to increase by approximately 5% per year in real terms (Australian Energy Market Operator, 2014).

Cost of Electricity, by Capital City: 2007-2012

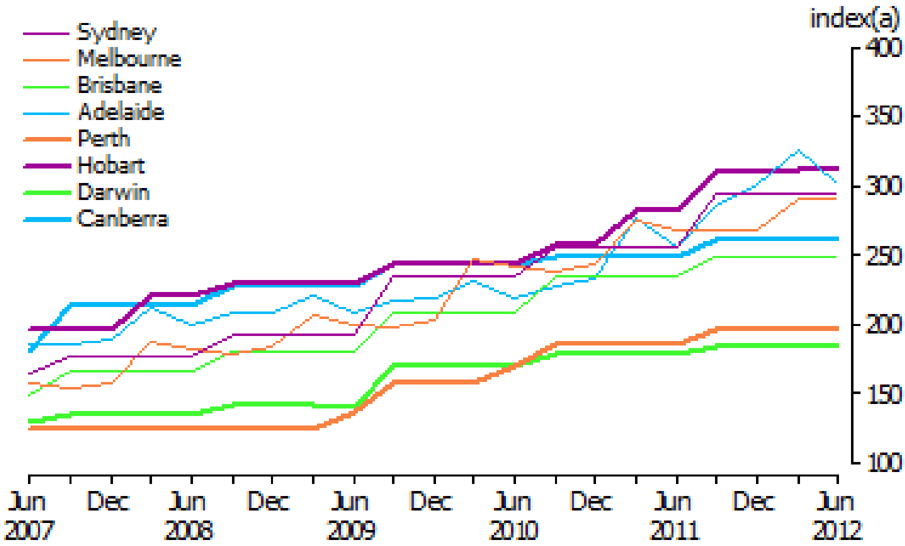

Figure 5: ABS Consumer Price Index, Australia, Jun 2012

This evidence gives confidence to the future for biomass plants, particularly as this market is untapped for the rice industry. With the projected outcomes suggesting inflated prices, it is a double-edged sword when looking at the increasing electricity prices that lead to increased potential profits. If a biomass plant is produced, it not only reduces future electricity costs, it also allows high returns when placing electricity back into the grid.

Rice Hulls as Bioenergy

Visiting India presented many possibilities with bioenergy, but the surprise for the author was the extensive use of rice hulls for bioenergy. The vast majority of hulls are used for bioenergy, the only limiting factor is the price plants will pay for the hulls. Rice hulls for bioenergy is somewhat old technology in India and has been fully developed and commercialised. The vast adaption of biomass plants has seen rice hull prices escalate from a low value base to a highly sought product. Companies now contract years in advance and stockpile fearing further price hikes.

Currently, rice hulls in Australia are used in a few ways. Firstly, they are added to stockfeed. Although there is some nutritional value to the rice hull, it is generally added as a part filler to act as a binding product for feed rations. Some rice hulls can be utilised as an organic matter (OM), spread over fields depleted of OM with an aim to revitalise the soils, improve water retention and generate microbiological processes. Transport of hulls is expensive due to their lightweight and as a result, this process generally only occurs within close proximity to the mills. A third option is to transport them to a remote location and burn them in an open environment. Another use that the hulls have is for bedding for the dairy industry, particularly rearing bobby calves. The hulls provide good insulation from the cold soil and provide an absorbent product to keep the calves dry. The end product can be used as a manure/mulch spread over pastures, providing additional benefit to the dairy farmer.

Despite some profit from the sales to dairy farmers and feed mills, an exact figure is hard to come by. Suggestions are that the hulls themselves cost the industry money due to the significant transport cost and purchasing of land and alike to dispose of the product. These current industry solutions suggest there is scope for a plant of some sort to utilise this product and provide value-adding opportunities for the milling company.

Sunrice has three mills located at Leeton, Coleambally and Deniliquin. Deniliquin and Leeton are significantly larger and combined have a milling capacity of over one million tonnes. With an average paddy size expected into the future of approximately 950,000 to 1,000,000 tonnes and hulls making up 14-26% of the harvest paddy weight (Bautista, Algas & Gagelonia, 2010), there are potentially approximately 200,000 tonnes of rice hulls to be utilised each year. The energy content of rice hulls ranges from 14 to 16 MJ/kg (Bautista, 2010). If we use 15MJ/kg for this purpose, 15,000 MJ/t equates to 4.16 MWh. Therefore, 200,000 tonnes x 4.16 MWh/t = 832,000 MWh. A plant is likely to only run at 80% efficiency. Therefore, the total MWh would be 665,600. The average megawatt hour sells for $35/MWh in NSW (Australian Energy Market Operation, 2014). So the total value of electricity produced would be $23,275,000. This equates to 102,000 homes per year.

This figure is greater than Sunrice's annual electricity bill. There would obviously be a significant start-up cost and a large amount of capital required to fund such a project. The other issue to consider is that the price Sunrice pays for its electricity would undoubtedly be less than the average price in NSW. Sunrice utilises off-peak and industry prices to keep its electricity bill as low as possible, but this does not mean the market cannot be manipulated to sell into the grid at low peak times and use the energy in the mills during peak times with inflated prices.

Despite the fact that rice hulls are not the main aspect of this report, the researchers visited strongly suggested this was a bioenergy source currently not fully utilised by the industry. Most countries visited were fully utilising the hulls in this way and there seems to be tremendous scope and significant opportunities to tap into this resource.

Rice Straw for Bioenergy

Rice straw creates more complications when looking at it as a bioenergy source. The plant that would generate electricity from rice hulls is different from that of a rice straw plant. The efficiencies for rice straw, as mentioned above, are reduced, with straw around 60-75% efficiency depending on technology. There are two other main obstacles to consider when looking at straw as a biomass resource:

- Logistics
- Consistency of product

Straw is a very low-density biomass resource and freight costs severely hinder the potential of straw to produce electricity. The issue lies with the difficulty between capital expenditure on a biomass plant and its relevant size compared to transport costs of the straw and the proportion of the transport costs that are subsidised. In other words, there is a point where it is more viable to build a second plant further away from the original and use straw from a certain radius that is of a viable distance.

Upon visiting Ely power plant in England and looking into their sister company Anglian Straw, which provides the straw to the plant by purchasing it off farmers and baling and transporting if required, the likely viable radius for them to justify transporting straw was within an 80 kilometres radius. This distance was generally not required as they were acquiring the 200,000 tonnes per year within this radius and so saving costs, with the closer straw to the plant obviously of greater benefit. The 200,000 tonnes was powering the 38MW plant, producing 270 Gigawatt Hour (GWh) per year. The amount paid per tonne of straw was not available but local farmers suggested the price would be around $70 Australian.

The added question that has to be asked, when looking at biomass extraction, is the nutrient requirements of the soil and the following crop and the relative cost this incurs in extracting these products rather than incorporating it back into the soil. This was a debate that was obvious and opinions would differ greatly between agronomists and farmers alike, who struggled to put a monetary value on replacing the required macro and micronutrients removed with the straw. For this study, this is not considered in great detail, as the relevance of this report is looking into value adding of straw to utilise the double cropping program most farmers are adopting. The removal does come at a cost; however, it is the comparison of the alternative of burning to value adding that is relevant for this study topic.

The second point to consider is consistency of product. In visiting a dedicated straw biomass plant in Punjab, India, this was one of their greatest challenges. Bermaco Energy owned and operated a rice straw biomass plant near Ghanaur. The 12 MW plant was one of two currently in full operation with plans to build further plants across Punjab and other rice growing regions of India. They were receiving government assistance to construct the plants, as the reduction in rice straw burning has been a major initiative of the Indian government. However, the efficiency of the plant and whether it was profitable, without help from the government, was unable to be established.

Figure 6: Bermaco biomass plant, Ghanaur, India. (A Vagg, 2014)

In talking with some within the industry, the technology is only just emerging now to allow rice straw biomass plants to run effectively enough to be viable, but the investment in technology was obviously occurring at Bermaco. To alleviate the troubles they were encountering with the size and shape of the straw, which was leading to difficulties in the burning process, they were chopping and shredding the straw into fine, consistent particles and also adding other green manure waste to the process. This would be anything from green waste from councils to cow manure. It seemed to be effective but as a result, the stand-alone rice straw plant did not seem to be feasible with the older technology.

The silica content and left over waste from the process was also something that would be of concern. Currently, the plant was burying the waste material in old clay mines that have been excavated to produce bricks. This is a successful temporary measure but long term not a sustainable enterprise.

Biogas

In visiting the school of Energy Studies for Agriculture at Punjab Agricultural University, Ludhiana, biogas seemed a possibility on not only a large-scale business, but also a farm-operated source. Dr Sarbjit Singh Sooch (Sooch, 2013) demonstrated the research that had been carried out over the last five years, looking into biogas production from rice straw. The straw is to be used as a substrate as it is the enzyme and microbial activity that creates the process to generate the gas.

To create this process in a village at limited cost, a dome shaped underground container is constructed, around 2.5 metres wide by four metres high. These are usually made from brick and cement. There is a valve at the top that releases the gas, which is stored in a bladder type product or can even be burnt directly from the plant. At the bottom of the plant is a one-way valve for water input. Rice straw is layered approximately half a meter thick and then a layer of cow dung is placed on the straw, then the same process is repeated until the plant is full. The dung is used, as it is a cheap source of microbes and in a village situation in India, is a very viable source that provides the necessary means to produce the gas.

Once the plant is filled with water, the fermentation process starts and gas extraction occurs approximately a week later. One plant can produce five to six cubic metres of biogas a day for four months, all produced off approximately one tonne of straw. This is enough to provide gas to cook and run basic appliances for a number of homes in a village. This was very basic but effective and the gas burnt clean, had no odour and produced a consistent blue flame.

Figure 7: Biogas trial utilising rice straw, Punjab Agricultural University, India. (A Vagg, 2014)

This type of plant would serve little purpose in Australia and possibly not a viable return. There were larger biomass plants in India using rice straw to produce enough gas to supply a large dairy and all the workers and managers' houses. This type of system may suit Australian conditions better.

There is a case to suggest a biomass plant on farm would be most cost effective. The source of fuel is cheap and within a close proximity and the end product could be easily utilised on farm. There are numerous rice producers running bores and lift pumps on LPG gas, as well as stationary engines and generators. The theory to create a plant that can then provide a proportion of gas to power these products seems to fit. However, a viability exercise is hard to establish as the cheaper options, as opposed to the complicated yet efficient means, are hard to compare.

Still a co-digestion of rice straw with some other waste material is likely to create the most efficient end product. The mix product needs to be a dung or similar cellulosic organic material that will function effectively in an anaerobic situation (Sooch, 2013). As far as the author is aware, currently no such system is in place in Australia, particularly utilising rice straw. However, with further increases in gas and fuel prices, the cost/benefits need quantifying to allow an estimate of the financial viability of such a project.

A New Approach to Bioenergy

In discussions with Craig Jamieson (August, 2014) of IRRI, Philippines, who has been working extensively in the field of rice straw utilisation and value adding, it appears the next transition to look for a bioenergy source is to approach the issue from another angle. In looking for a solution, the constant limit that researchers and projects seem to encounter is the significant load of silica present within the rice straw. These amounts vary from around 12% to 18% silica content (Chadha, 2014) and in the burning process within a furnace, the silica creates issues with wearing and degradation of components as well as restricting the by-product to very limited uses.

Essentially, the silica is unable to be effectively broken down to any source that renders it a non-issue in the bioenergy process. The thinking has now changed to extraction of the silica early in the process, eliminating this problem, creating high value products from the rice straw while still having a biomass product viable to be utilised for bioenergy or biogas.

Dr B.S. Chadha (August, 2014) from Guru Nanak Dev University in Amritsar, India has just published a report titled 'Novel Biotechnological Processes for the Production of High Value Products from Rice Straw and Bagasse'. Essentially, this project looked at extracting high value products out of the straw at an early stage and then using the remaining product as a biogas. High value products such as cellulose, hemicellulose and, most importantly, lignin are extracted. Firstly, these three components are separated during pre-treatment.

Cellulose makes up 35%-40% of rice straw and is extracted mostly as a solid, whereas some is extracted as a sugar-rich hydrolysate. The majority of hemicellulose is also released as hydrolysates. From there, the cellulose and hemicellulose are utilised by selective hydrolysis resulting in the release of xylo-oligosaccharides that are polymers of a sugar, and ethanol as the end product.

The lignin is separated through membrane based nano-filtration technology during the thermo-chemical pre-treatment of the straw. This process also opens fibre structures of agro-residues, allowing carbohydrates in plant cell walls, particularly the cellulose and hemicelluloses, to become accessible to enzymes, releasing fermentable sugars (Chadha, 2014).

From here, lignin can be sold for one of its many uses. It is a nontoxic, versatile product that is used in products including a raw material for agricultural chemicals, dispersant in cement applications, dust suppressant for roads, silica chips for computers, raw product for tyres, carbon fibre production, antioxidants, raw material for plastics and polymer foams, grease and even slow release fertilisers. The possibilities seem endless.

It is this change in direction of technology adaption, with reference to bioenergy, which may well be the breakthrough that will progress the viability of rice straw as a bioenergy product and hence make it a viable enterprise to pursue for industry and business alike.

Conclusion

The issue faced by rice growers in Australia, with regard to stubble load management, has provided little to no alternative to the industry, other than burning, until recent investigations into stubble management and value adding. Still, the issue of how to deal with a straw load of approximately 10 tonnes to the hectare, and how to remove it within a couple of weeks, to utilise the available soil moisture and to obtain a double crop, is limited.

Currently, the ability to burn is no doubt the most instantly available solution to Australian rice farmers. However, this is unlikely to be the case at some point in the future and so an alternative source must be found. When dealing with the rice stubble problem, it can be characterised into two distinct groups, individual farmer solutions and industry solutions.

Individual farmer solutions are numerous, yet limited in their feasibility. This is shown by the solution in California, where a couple of farmers have negotiated contracts with the fire department to supply straw after a bushfire to aid in revegetation. This is a successful business in California, but if every grower were to move into the market, the price would crumble and rendering the enterprise unviable. This is also the case for mulching and suppling mushroom farms, broilers and similar uses. Similarly, this is the case for construction site and development runoff control and to a lesser extent, rice straw as an animal feed source.

If the whole industry was to move to just one of these business initiatives, the market would be flooded and the price would collapse. Instead, it is a ‘scatter’ approach that is most likely to work best, particularly as some solutions may work for some growers, while others will be suited to another solution. This has been evident around the world. For example, only rice growers close to dairy, feedlots or high intensity livestock would consider strawlage as a solution. To transport a low value feed hundreds of kilometres would not be viable unless unforeseen circumstances such as a drought and highly inflated feed prices arose.

The production of bioenergy, however, has the potential to be an industry wide solution, provided the technology is correct and the process is well researched and clear. There are, however, many complications that cannot be overlooked. Bioenergy production involves a large capital expense and the energy market continually shifts, as does government policy on renewable energies. For bioenergy production from straw to proceed, there are steps to be taken to ensure its viability.

Firstly, the science must be sound. Although some older technology has appeared to fail, newer technology has paved the way for biomass energy production from straw to be successful. Secondly, pricing and output must be contracted to secure the required returns to make this viable. Ideally, the time-frame for return on investment should be secured as many have fallen foul of changing energy prices and policy. However, the potential is significant and is a resource that has not been fully utilised in Australia to date.

Recommendations

After discovering the advancements and adaption that has taken place across the globe in terms of rice straw utilisation, through either initiative or government policy, it is apparent that Australia is lagging behind. However, there are steps that can occur to take advantage of this situation. While other countries have done the legwork, the Australian rice industry is primed to take advantage of their research and development with regard to value adding rice straw. Some of the recommendations that will see the industry prosper in the field of value adding rice straw into the future include:

- Consultation with renewable energy experts as to the adoption of technology into the rice industry with regard to biomass plants and awareness. Also lobby government to fund or offset works to progress this path.

- A cost benefit analysis of potential rice hull and rice straw biomass plants located at the rice mills at Deniliquin, Coleambally and Leeton.

- Consultation with livestock industry about strawlage potential within the current systems the livestock industry operates. Look at possible adaption to align their feed requirements with strawlage seasonal availability.

- Advise and consult to the rice industry, particularly concerning R&D findings, and to collate the research that has occurred over previous years.

- Continue to build relationships with international researchers and advocates to ensure the technological gap, which exists with other countries, continues to diminish and adaptions to current overseas practices can be as seamless as possible.

- Obtain consultancy for cost benefit analysis to build a model biomass plant, both at an on farm scale and at an industry level and determine what likely outputs can be achieved.

- Engage with fire departments, ski field operators, national parks and councils as to the potential of rice straw as a re-vegetative aid potential.

References

- Ashbaugh, J. (July, 2014). Personal communication. Premier Mushrooms. Colusa, California, USA. www.premiermushrooms.com.
- Australian Bureau of Statistics Household Energy Use and Costs (2014) www.abs.gov.au
- Australian Energy Market Operation (2014) *Average Price Tables* www.aemo.com.au/Electricity/Data/
- Australian Energy Market Operator (2012) *Economic Outlook Information Paper* – National Electricity Forecasting 2012
- Bird*,* J. A., Eagle, A. J., Hair, M. W., Zilbert, E.E., Van Kessel, C., (2002) *Long-term studies find benefits, challenges in alternative rice straw management.* California Agriculture, Kearney Agricultural Centre, UC Davis. www.escholarship.org
- Brzozowski, C., (2013) *Erosion Control Wildfire and Flood, The Severity of the Fire Season is Growing. So is the Aftermath*. www.erosioncontrol.com
- Cal Recycle. (2014) *Agricultural Residues: Compressed Rice Straw Products (Part 5).* California, USA www.calrecycle.ca.gov
- California Rice Commission (2014). *The Rice Straw Market.* California, USA. www.ricestrawmarket.org
- Chadha, B.S., (2014) Novel Biotechnological Processes for the Production of High Value Products From Rice Straw and Bagasse'. *Department of Microbiology, Guru Nanak Dev University*, Amritsar, India.
- Dobermann, A. and Fairhurst, T.H. (2002) *Rice Straw Management. Better Crops International*. Vol 16, Special Supplement.
- *FAOSTAT:* (2011) *Production-Crops, 2010 data*. Food and Agriculture Organization of the United Nations.
- Helal, Dr. A., (4 August, 2014). Personal Communication. Egyptian Chamber of Industry and Engineering, Managing Director Rice'n'Care. www.ricencare.com Cairo, Egypt.
- Jamieson, C., (August, 2014). Personal Communication. IRRI – International Rice Research Institute (IRRI), Philippines. Consultant on bioenergy
- Moran, A. (2014) *Submission to the Renewable Energy Target Review Panel* Institute of Public Affairs. Melbourne, Australia.

- Nadar, A., (2010) Rice Producers' Guide to Marketing Rice Straw*, Department of Agriculture, University of California. USA.* Extension Farm Advisor.
- Nadar, G., Robinson, P.H., Swanepoel, N., Davy, J., (2014) *Rice 'Strawlage' – A feed for drought induced Feed Shortages?* Co-operative Extension, University of California, Davis, USA.
- Pearson, B., (2014) No End in Sight for Soaring Electricity Prices – *The Australian Newspaper*, (19th February, 2014) www.theaustralian.com.au
- Phir, R.K., Newlands, M.D., Dyer, T.D., (2003) *Sustainable Waste Management.* Thomas Telford Publishing, London.
- Rice Straw Fibre Roll (2014). *Kristar Enterprises Inc., Santa Rosa, CA, USA* www.kristar.com/index.php/ricestraw-fiberrolls/specialdownloads
- Roth, L., (2014) Personal Communication. Technical Services Nutritionist with Provimi, North America. Email Correspondence (July, 2014)
- Scheew, W., (2009) *Recycling of Rice Straw – An Entry Point to Sustainable Rice Production.* 2nd ECHO Asia Agricultural Conference, Chiang Mai, Thailand.
- Sooch, S.S., (2013) *Ready-Recknor of Biogas Technology,* Senior Research Engineer, School of Energy Studies for Agriculture, Punjab Agricultural University, Ludhiana, India.
- Sunrice Annual Report (2014) Annual Report costings, 91

Plain English Compendium Summary

Project Title:	Rice Straw Utilisation
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Objectives	• Investigate alternative uses for rice straw around the world • Identify the most likely alternatives to be adopted in Australia • Determine if these alternatives will fit into the Australian rice production system • Formulate a cost/benefit analysis for the industry
Background	The Australian Rice industry produces some of the highest crop yields in the world. As a result, the by-product of this is a huge stubble load, which is difficult to manage. Additionally, the silica content of Australian rice straw is significantly higher than most around the world. The current practices of burning stubble to allow a double cropping rotation are not likely to continue too much further into the foreseeable future due to environmental constraints and changes in policy. Few alternatives for stubble management are practised within the Australian rice growing industry; therefore, a ban on stubble burning could severely jeopardise the viability of the industry.
Research	Research was conducted in USA, New Zealand, England, France, Egypt, Turkey, India and the Philippines through interviews, meetings, field visits and conferences
Outcomes	There are many initiatives that may be adopted by Australian farmers, however, the possibilities need to be adapted and thoroughly investigated to determine the capability to fit in the Australian farming system.