Cotton Gin Waste Use to offset Non-Renewable Energy Sources

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INTRODUCTION

Tandou is a major Australian agribusiness focussed on the large scale irrigated production of cereal crops and cotton. The Tandou cotton gin is located at Lake Tandou and contains 2 Upland saw gin stands and 8 Pima roller gin stands and is used exclusively for ginning cotton produced by Tandou Farm. Cropping operations at Tandou Farm were severely affected by the recently ended drought and the 36 000 bale cotton crop produced by Tandou Farm in 2010 was the largest that has been processed at the Tandou gin since 2004.

The reliance on LPG for the cotton ginning process and the price pressures that show little sign of easing and strong signs of continuing increases coupled with a wider push to improve the 'carbon footprint' of operations has lead Tandou to investigate potential reductions in the use of non-renewable energy sources used at the processing plant. To these ends a small capacity building project grant application was submitted to the Australian Government's Cotton Research and Development Corporation

The Australian Government's Cotton Research and Development Corporation is working with industry to address opportunities highlighted for improvement in the 2003 – 2008 Strategic R&D plan. This report is focused on evaluating the benefits associated with offsetting the energy used during processing, by supplementing Liquefied Petroleum Gas use with available renewable biomass produced as a by-product of the cotton ginning process.

Present Situation

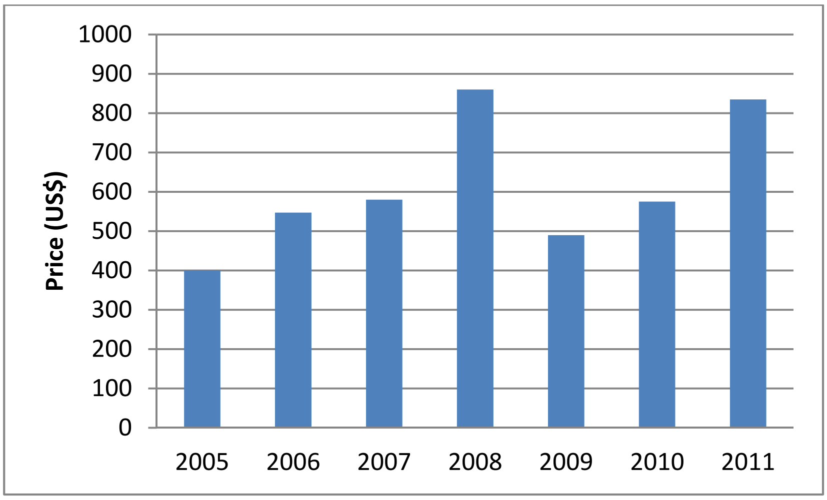
The Tandou cotton gin, located near Menindee in NSW's South West, uses two Samuel Jackson Dryaire Heaters to provide hot air for recirculation through the drying phase of the cotton cleaning process. These heaters provide hot air in parallel for the two processing lines and are both controlled via the control room from the one temperature sensor. They are set to control a hot air stream of between 40 – 100 ^{o}C and have modulating valves to govern the Liquefied Petroleum Gas (LPG) flow required to achieve this temperature.

In addition to the 2 Dryaire units used in the drying towers, there are 2 smaller Samual Jackson heating units used for cotton transfer, inside the gin. These smaller heating units operate within the same temperature regime as the larger primary heating units. Also located inside the gin are 2 Humidaire units which are steam generation units and operate above 100^{o}C.

Liquefied Petroleum Gas Cost

In recent years the cost of natural resources such as LPG have been increasing at a rate that is reflecting the increasing demand for such commodities, this cost is likely to continue to increase as demand for LPG continues to be strong. The price of LPG has increased by over 90 % in 6 years[1] as indicated in table below, this trend is not likely to subside in the future. The demand is driven by the push for green energy production, of which LPG has applications within the electrical energy market for peak demand management.

TABLE 1: LPG HISTORICAL COST - SAUDI ARAMCO CONTRACT PRICE (AUGUST) - PROPANE



The storage of LPG onsite is a small although important risk. The risk of limited or no supply should also be investigated. A delay of 2 weeks or more, allowing for emptying prior to ordering, could lead to a situation where the processing plant is without LPG for hot air production. The effect that this would have should be evaluated.

[1] http://lpgaustralia.com.au/site/industry_data.php

AVAILABLE FULES

The Cotton Gin process produces a number of by-products, most of which are suitable for combustion. These by-products include the Cotton Stalk, Cotton Seed and Cotton Gin Trash. All three of these products are considered renewable energy and are all but freely available onsite. Both the volume required to meet the energy requirements within the processing plant and the opportunity cost associated with the current location of the product and inherent value that is existing, will be investigated.

COTTON STALKS:

Cotton Stalks are collected though the irrigation channel pumping points around the property, through a system of gross solids removal from the water as it flows through the channels and their bar screens and are stock piled in location. It is estimated that this waste amounts to approximately 700 ton per annum. The remote location of this waste must be taken into account and will add a cost to its use.

COTTON SEEDS:

Cotton seeds are removed during the cotton ginning process. They equate to approximately 52-53% wt/wt of the processed cotton bale from the field and at present are collected in a storage facility and sold as stock feed at a price of between $200-$150 / ton at the farm gate.

GIN TRASH:

Gin Trash is a by-product of the ginning process, at present it is ducted through cyclones and into a storage hopper for bulk transfer to the property for composting. The gin trash produced through the ginning process for the two different types of cotton that are processed, Upland and Pima, are 11 and 15 % respectively. This equates to 17 t of Upland Gin Trash per day and 15 t of Pima Gin Trash per day due to the lower processing rate of Pima.

FUEL CHARACTERISTICS:

The characteristics of each fuel differ, according to its makeup. These characteristics include, and the ones we are chiefly interested in are it's the energy content, the inherent water content and the ash content. The energy content of biomass of a cellulose structure is generally similar on a dry basis, although can vary by around 30%, this is measured in Joules per unit mass and indicates the amount of energy that is released during combustion per unit. The water content is an important factor as this reduces the effective amount of energy that is available to the process as during the combustion process this water is required to be evaporated off reducing the energy available for the heating. Ash content is a measure of how the makeup of the fuel will proceed through combustion, a biomass with a low ash content will generally produce more heat per unit mass as more of the product is proceeding to combustion, this also effects combustion equipment as it is an indication of how much ash will be produced during the process.

FUEL TESTS FOR COTTON WASTE:

The characteristics of the fuel were tested at HRL Technology who specialise in determining the characteristics of fuel for combustion. The tests undertaken were to AS 1038.5-1998 Coal and Coke - Analysis and Testing - Gross calorific value. The results can be seen in Table 2 and indicate that the Cotton Seed has a higher calorific value while maintaining a low ash content, this is due the higher oil content of this material. The stalks and gin trash represent a typical lower quality fuel which is to be expected.

TABLE 2: ANALYSIS RESULTS - COTTON WASTE

DESCRIPTION	MOISTURE CONTENT %	ASH CONTENT %	NET CALORIFIC VALUE (MJ/kg)
Pima Cotton Seed	9.6	4.1	19.3
Upland Cotton Seed	8.7	3.4	19.3
Dried Cotton Stalks	11.3	10.5	14.5
Cotton Gin Trash	8.0	10.0	15.5

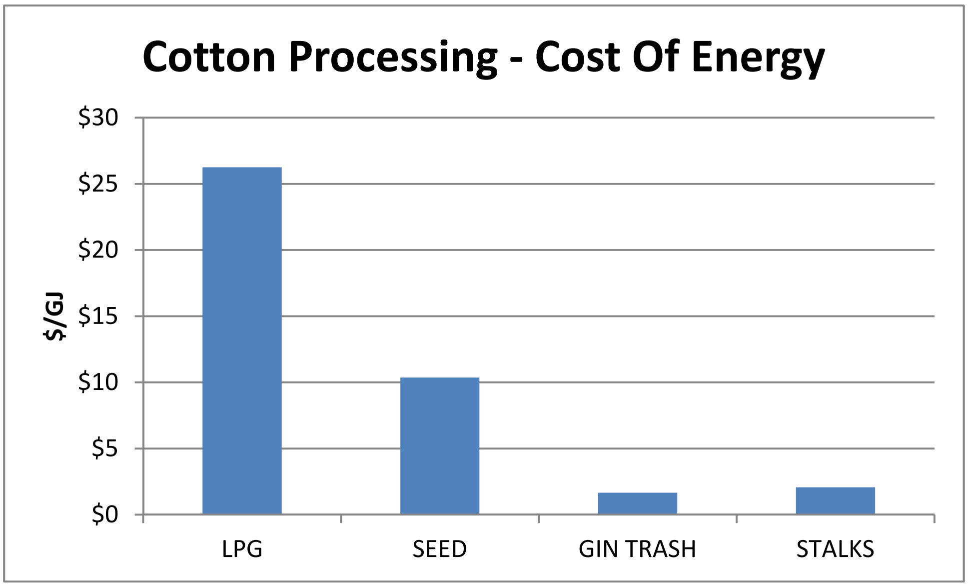
Energy Value:

A method of normalising the cost of energy feedstock is an important way of reviewing varying types of fuels on the same basis. The method used here will be to evaluate the cost of each feedstock on an inherent energy basis. In order to do this the value of the fuel at the point of use, including the value that the fuel has as an opportunity cost if for example the fuel had value sold off site. This evaluation is done on a cost per energy basis ($/GJ), refer to Appendix 1-3 for the determination of these values.

The following graph represents the cost of use of the energy onsite. The higher the cost the more expensive the hot air is to produce. This graph indicates that at present the LPG option is by far the most expensive option available to the processing plant and as discussed this is likely to continue to rise more rapidly than the biomass options. The cotton seed already has a market as stockfeed and this is represented with its increase in value over the cotton gin waste and stalks. Although the stalks have a similar cost to the gin trash, their location relative to the plant is a disadvantage which is represented in its slightly higher cost.

Gin trash is clearly shown here to be the best option, it has little current value, is available at the place of need and is valued at 15 times less than the current fuel being used.

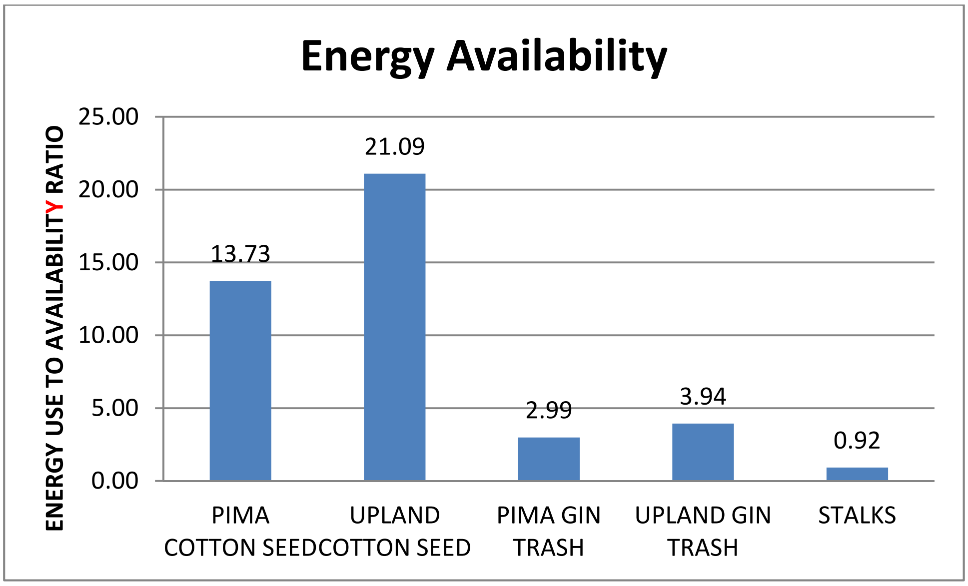
TABLE 3: COTTON PROCESSING - COST OF ENERGY



ENERGY AVAILABILITY:

The availability of energy within the biomass waste is evaluated in table 4 below. This graph indicates the ratio of energy required to that available and takes into account the inefficiency in a combustion system of approximately 80%. In all cases with the exception of the cotton stalks, there is in excess of energy available compared to what is required to meet the heating used in the ginning process.

TABLE 4: ENERGY AVAILABILITY RATIO



ENERGY SOURCE:

The feedstock that stands out as being the most suited to supplying the energy needs of the ginning process is the Gin Trash. This by-product is available at the point of use, is relatively easy to handle, has in excess of the energy required and is at present a waste product that would otherwise have to be handled.

Equipment

The cotton ginning process requires a hot air supply of 40 – 90^{O}C relatively dry stream of air to effectively dry the cotton in the drying tower phase of the process. Given the low ignition temperature of this material there must also be no sources of ignition, be that elevated temperature within the stream itself or hot embers. There are a number of options available to achieve this, including direct combustion into the air stream, the hot water heat exchange, steam heat exchange and air to air heat exchange, the merits of these will be reviewed.

Direct Combustion

Direct combustion is considered to be the simplest and cheapest option available. A system combusting directly into the air stream would work in much the same way as the LPG Hot Air Generators, although with much less control over the impurities and potential for carryover of hot embers. This system is unlikely to be favoured as there are many potential negative impacts on the quality due to the products of combustion and the risk of igniting the cotton with embers.

Pro	**Con**
Lowest Capital Expenditure	No physical protection between combustion and cotton
Simple construction	Oxygen in air stream depleted as a result of combustion
Simple Maintenance and Operation	Discolouration of cotton

Hot Water System

A hot water system would produce heat by combustion of biomass, this heat energy would then be transferred to a low pressure water phase to around 90 – 95 °C. This water would then be recirculated through a heat exchanger where it would be used to warm the air phase passing through the exchanger. This method of operation eliminates the potential for both combustion products adversely affecting the quality of the product and potential ignition sources from coming in direct contact with the cotton and hence is a better option than the direct combustion. This system would also be relatively easy to run and maintain. The disadvantage with such a system is that due to the small difference between the temperature of the hot water and the hot air trying to be generated the heat exchangers required are relatively large.

Pro	Con
Low Capital Expenditure	Hot Water to Air heat exchanger required would be large due to small pressure drop
Simple System Design and Operation	
Simple Maintenance and Operation	
Safe operation with cotton	
Easy to Retrofit into existing infrastructure	
No Depletion of Oxygen in the atmosphere.	

Boiler System

A boiler system would again heat the water using the biomass although instead generating a high pressure steam, this steam contains significantly more energy per kg produced, reducing significantly the size of the heat exchanger required. This system again removes the direct contact with the produced hot air stream and the combustion. The disadvantage with a steam system is the high level of operator skill required to operate the system, the increased maintenance, the regulations associated with operating a pressure vessel and the safety factors that need to be taken into account when dealing with steam.

Pro	Con
Moderately Simple System Design and Operation	Increase in complexity in system requiring trained staff to operate
Safe operation in cotton facility	Increase in maintenance
Easy to retrofit into existing infrastructure	Safety considerations.
No Depletion of Oxygen	Higher capital expenditure.

Hot Air Generator

A hot air generator again produces energy by combustion of biomass. From this production the heat is simply exchanged with a secondary process air stream, in turn heating this stream up. Like both the hot water and steam systems above this separates the combustion stream and the final hot air stream, although without the need for additional heat exchangers and the necessity to deal with water or steam. The hot air generators are limited to generating air to approximately 90 °C.

Pro	Con
Simple System Design and Operation	Systems sizes are limit and may require multiple units
Safe operation in cotton facility	The limit of hot air production is around 90°C
Relatively Easy to retrofit into existing infrastructure	
No Depletion of Oxygen	

EQUIPMENT SELECTION

The hot air system is both the system that is the safest and easiest to operate and maintain, while also being suited to the requirements of hot air production within the processing plant. It is also relatively low in capital cost in comparison to steam and hot water. The table below is a budget for the works and represents a system designed to integrate with the existing hot air supply to the plant. It is anticipated that some work will need to be undertaken to ensure that site specific needs are reviewed, such as fire suppression requirements and waste management associated with this install.

CAPITAL EXPENDITURE - 1 MW			
Hot Air Gen (500 kW) x 2		$	160,000
Shipping		$	20,000
Civil Works		$	45,000
Plumbing (inc fire)		$	15,000
Mechanical and Electrical Install		$	20,000
Ducting		$	40,000
Consultants (fire, HVAC, civil)		$	20,000
	TOTAL	**$**	**320,000**

PROCESS DESIGN:

It is proposed that the Hot Air Generators work in series with the existing gas systems. Appendix 7: Process Design provides an overview of the proposed process. The Gin Trash would be diverted from heading to the cyclone above the silo collection for discharge to the field to a cyclone that feeds directly into the hoppers feeding the Hot Air Generators, this diversion would take place automatically when the level of Gin Trash within the hoppers was low.

The two Hot Air Generators both being capable of producing 500 kW of heating would work in parallel and would require heating set points set differently to each other to enable one unit to provide base load and one unit to provide peak load, in order to reduce the load on one boiler this duty and standby could be swapped intermittently. The hot air produced by the two hot air generators will then be feed into the recovered hot air stream from the factory (see appendix 9: Tie In Location), dampeners may be required to ensure that enough air is drawn from the Hot Air Generators. This would lead to a system that only produced hot air by the use of LPG when the biomass Hot Air Generator was not producing sufficient hot air.

CONTROL AND AUTOMATION

The control of the hot air generation will require a setpoint, which at present is set within the control room for the gas hot air generators. There should be no reason to change the location or method of setting the temperature required for production. This same output can be used as the setpoint for the biomass hot air generators. Depending on the setup it may be necessary to have some additional control if two units are required in parallel.

Proposed Location

The proposed location is based on a number of factors. The location selected has the following benefits over other locations viewed onsite. This location is close to a supply of cotton gin waste as the auger that collects the waste from the cyclones is local and it is anticipated that diverting to an additional cyclone above the hoppers for the Hot Air Generators should provide easy and automatic loading of the hoppers. An alternative location to this is closer to the silo above the waste truck, although this option will increase the distance to the factory for the hot air supply.

The supply of hot air to the factory from the proposed location is directly in line with the proposed tie in point at the factory. There is also existing support structure for the hot air ductwork. Services including power, water and fire will have to be investigated, although these are not anticipated to be an issue.

Product Feed:

The feeding of the boiler with the Cotton Gin Waste is the most difficult to evaluate and there was little literature on the topic. There are suppliers claiming that they run furnaces of cotton waste although details were hard to come by. The most appropriate way forward would be to have material tested by potential suppliers and have performance guarantees agreed upon based on results. This is unlikely to cause this project not to proceed forward and there is alternative of producing briquettes prior to use within the boiler, these may also have value elsewhere given the excess cotton waste that it is anticipated will be produced.

Ash Removal:

It is anticipated that the units processing in the order of 150 kg/hr of cotton waste, based on laboratory analysis will produce around 10 % by weight ash, or around 15 kg/hr peak production of ash. Provision should be made to allow for automated augering of this product to a skip bin, this bin will have to be monitored and emptied appropriately. Consideration should be given to this bins design and the final location of the waste as the waste will remain smouldering for a period of time after leaving the furnace.

Fire Protection:

The exhaust gas from the hot air generation system should be vented through an~~d~~ appropriately designed bank of cyclones, this design should be conservative so as to minimise the chance of an ember leaving the system through the exhaust gas.

The budget for the works include the enclosing of the equipment to ensure that there is minimal chance of the cotton that surrounds the plant coming in contact with a source of ignition from this proposed system.

Maintenance:

The system will require maintenance to ensure that the heat exchange surface does not become fouled with ash or other material as a result of the combustion process reducing the efficiency of the boiler. It is not anticipated that the maintenance requirements for this system would require shutdown during a normal season. The supplier should indicate how this maintenance is undertaken safely and effectively and options to reduce the interaction required such as automated cleaning systems should be considered.

Temperature Loss:

The external pipework proposed is unlikely to loose enough energy during operation to warrant insulation. The existing system is not insulated and hence insulating this element of the system is unlikely to improve the overall efficiency.

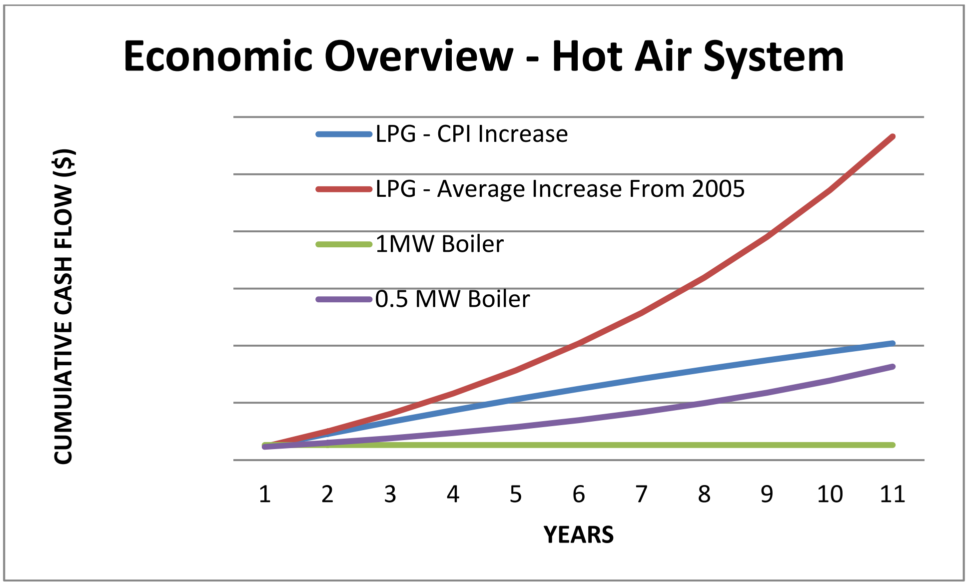
ECONOMIC EVALUATION:

The following economic evaluation is designed to be a high level review of the most suitable piece of equipment. Assessing this equipment sized both for base load requirements only and for full supply. The equipment selected for this review is the Uniconfort Hot Air Generator for Solid Fuels. The largest of these units is rated at 580 kW of usable hot air. Based on this the two options to be investigated are meeting a base load of 580 kW only and using gas to cover the peak demand periods and the other option being install two 580 kW units for a total of 1,160 kW to cover both base load and peak demand with the biomass.

Due to the significantly short payback period associated with the 1,160 kW option only a high level economic review was performed. This review looked at the cumulative cost of continuing as is, with LPG only increasing at 3% per annum and also with LPG following the last 5 years of trend and continuing to increase by 15% per annum. Also reviewed was the option of only providing base load energy requirements while still having to maintain the gas to meet the peak demand, which equates to approximately 30% of the energy requirements being meet by LPG.

The review below in Table 5 represents the net present value of four options developed for this review.

TABLE 5: ECONOMIC EVALUATION OF THE OPTIONS



CONCLUSION:

From the investigation undertaken it is clear that the waste streams produced as a by-product of the cotton ginning process can support moving away from the reliance on LPG to supply heating needs within the cotton ginning process. It is also clear that at best the cost of LPG is sporadic and at worst it is a commodity with historically steep cost increases. The technology to produce a hot air stream is neither complex or overly capital intensive and hence risk that exists with employing this approach are minimal and ultimately the designed proposed maintains the existing system. Questions remain as to the suitability of Cotton Gin Trash to the feed systems associated with the hot air generation systems and it is recommended that advice from suppliers is sort on their experience and/or testing of the waste stream.