Alternative energy sources for cotton production in Australia

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Abstract: Agriculture requires energy as an important input. Within highly mechanised agricultural productions systems such as the Australian cotton industry, energy inputs represent a significant cost to growers. In this paper, current uses of alternative energies, grower interest and perceptions of alternative energies and obstacles and opportunities are surveyed. The potential of traditional and alternative energy supply for agriculture and cotton production in Australia is also evaluated. It is found that in the cotton growing regions of Australia, the preferred alternative energy sources may be solar or bioenergy, rather than wind energy. The potential of biofuels and bioenergy production from cotton by-products such as cotton trashes and cotton seed oil is also examined.

Keywords: Agriculture, cotton, energy, biofuels, bioenergy

INTRODUCTION

Farming is often an energy intensive operation. Within highly mechanised agricultural production systems such as the Australian cotton industry, energy inputs represent a significant cost to growers and are typically 20% to 50% of total operating cost. Chen & Baillie (2009) showed that the direct energy inputs for cotton production in Australia ranged from 3.7 to 15.2 GJ/ha. When the embedded energy of fertilisers and chemicals is included, it is estimated that the life cycle energy consumption is around 60 GJ/ha (Chen et al, 2013).

The increasing uses of energy resources are one of the major challenges to agriculture. Continuous high fuel and electricity prices and the needs for significant reductions in greenhouse gas emissions make the improvement of farming energy efficiency essential. Exploration of new alternative and renewable energy sources is also vital.

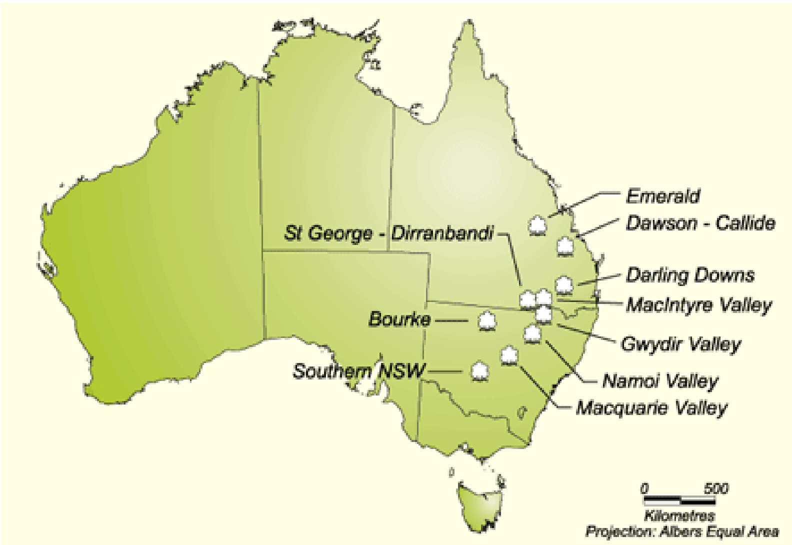

Figure 1: Cotton growing areas of Australia

COTTON INDUSTRY IN AUSTRALIA

In Australia, cotton is mainly farmed in the two states of New South Wales and Queensland (Fig.1). Each year, depending on the market and climate conditions, 1 to 4 million bales of cotton may be produced, with the long-term average for the past 10-15 years being around 2 million bales for 250,000 ha of planting area per year. Currently, the cotton yield in Australia is in average 1,907 kg (8.4 cotton bales) per hectare. This figure is almost two and a half times the world average of 747 kg/ha. Around 80% of Australian cotton is irrigated. Most (98%) is also exported.

In addition to the production of cotton lint, one hectare of cotton farm in Australia also produces some 2.5 t cotton seed (valued at around 2.5t/ha*$300/t = $750/ha), 2 t straw (at present, these stalk wastes are usually returned to the field to increase the soil organic matter), and 0.4 t cotton gin trash (valued at around 0.4t/ha*$10/t = $40/ha).

ENERGY SOURCES

Agriculture and food systems rely on a variety of energy sources, including renewable and non-renewable resources (Table 1). At present, fossil fuels, in the various forms, supply most of the energy required by the mechanized agriculture that feeds the world. Overall, Australia's energy consumption has increased at an average annual rate of 1.8 per cent over the last ten years. The supply of oil in Australia is also already on the decline and Australia is becoming increasingly dependent on imported oil and petroleum products. Moreover, Australia's electricity costs have increased by 80% in the last 5 years, and may be expecting a further increase of 20% or more in the next few years.

Table 1: Classifications of Energy Sources

Limited (Non-renewable)	Unlimited (Renewable)	Biological Renewables
Oil	Solar	Wood
Coal	Wind	Energy crops
Natural gas	Hydropower	Biomass fermentation (ethanol)
Liquefied petroleum gas (LPG)	Tidal and wave energy	Bio-diesel
Coal seam gas (LNG, CNG)	Geothermal	Biogas (Anaerobic digestion)
Nuclear power (Uranium)		Animal and human power

To produce 1 bale of cotton, Chen & Baillie (2009) found that up to 300 L of fuel equivalent of primary energy may be consumed and 900 kg of greenhouse gases emitted.

There are two main ways in which energy costs can be managed. The first is to look at energy efficiency on farms. Chen & Baillie (2009) found that the total energy inputs can be significantly influenced by the management and operation methods adopted. Because the cost of nitrogen fertiliser is a reflection of world energy prices, maximising the efficiency of fertilisers and the use of legumes (to produce nitrogen) will also save significant indirect "embodied" energy (Chen et al, 2010).

ALTERNATIVE FOSSIL ENERGY SOURCES

Identification of alternative energy sources in light of significant and likely increases to the cost of traditional energy sources is very important and will also position the Australian cotton industry to well respond to these challenges.

The main volume alternative energy in Australia may be natural gas which is abundant in Australia and can be used for both electricity generation and other purposes. Furthermore, natural gas as an important current and future energy source has significant environmental benefits over both coal and oil in terms of lower greenhouse gas and other emissions. When sourced from local gas supplies, the cost of compressed natural gas (CNG) could be as low as 30% of the cost of diesel, and 50% of the cost of LNG. Some machinery modifications may however be necessary and current research is being focused on the conversion technology for diesel engine to use these energy sources, particularly the design of vehicle fuel and tank systems.

RENEWABLE ENERGY SOURCES

Renewable energy is an important direction for the future. The renewable energy sources include solar, wind, hydropower, biomass, biodiesel, bioethanol, biogas and geothermal power. At present, renewables contribute 10% to Australian electricity generation. This is dominated by hydro-electricity, bagasse (sugar cane waste), wood and wood waste, which together accounts for 85% of renewable energy production. Wind energy, solar energy and biofuels (which include landfill and sewage gas) accounts for the remainder of Australia's renewable energy production. Most solar energy is used for residential water heating and accounts for 1.8% of final energy consumption in the residential sector. In 2008/09, renewable energy production increased by 6%.

Since some renewable energy technologies are mature and commercially available whilst others are little more than concept ideas, different actions will be needed to expand their market share during the transition development phase to a decarbonised world (Bundschuh et al, 2014). Several technologies such as off-shore wind or biomass gasification are technologically proven but market development is limited by cost or performance considerations. These will require investment in demonstration plants to provide confidence in the technology to both potential users and resource consenting agencies. Obtaining resource consents from local planning authorities for a new technology can also be an expensive and time consuming process. Other contract and regulation needs, such as for securing biomass fuel supplies, obtaining water rights, supplying and maintaining equipment and seeking air emission permits will also need to be addressed. Overall, the two key barriers to renewable energy project implementation tend to be related to cost comparisons with traditional energy supplies or difficulties in obtaining resource consents and plant construction approvals.

Compared to petro-diesel, biodiesel gives considerably lower emissions of particulate matter (PM), carbon monoxide (CO) and hydrocarbon (HC). Biodiesel has however somewhat worse cold-flow properties. Reduced power may be less important because tractor engines are often operated in part-load. Previous research has shown that biodiesel blends of 20% or less would not change the engine performance in a noticeable way. This has included the cottonseed oil (Leenus Jesu Martin et al, 2011). Blends of up to 5% biodiesel in conventional diesel are now permissible in Australia without any labelling changes or notification to the consumer. For higher blending, it may be necessary to modify the machinery, particularly the fuel delivery system. A second fuel tank and other modifications to machinery may be required.

Research and use of renewable energy is on the rapid rise in Australia and globally. Despite of the current arguments, the long-term future for renewable energy is positive since the prices of fossil fuels will continue to rise as the resources are depleted while the prices of renewable energy will continue to decrease. For example, the electricity price in Australia has been increasing at a rate of 10 to 20% per annum in the last couples of years, while the price of solar PV has been steadily decreasing at a rate of 10 to 40% per annum in the same period of time.

ALTERNATIVE AND RENEWABLE ENERGY SOURCES FOR COTTON INDUSTRY IN AUSTRALIA

A number of alternative energy sources are available for cotton industry in Australia. Overall, Australia has the highest average solar radiation per square metre of any continent in the world. Thus, the cotton farming regions are highly suitable for the development of solar projects.

Wind power is potential renewable electrical energy source suitable to areas with average wind speeds above 5 m/s. However, Australia's wind energy resources are located mainly in the southern parts of the continent. Because most of the cotton farming regions are located inland and have a lower average wind speed of around 3m/s, wind energy is thus generally regarded as not suitable in these areas.

Australia's potential bioenergy resources are large and diverse. These may include under-utilised resources in crop residues, forest residues and waste streams. In the cotton farming regions, there are significant potential of locally produced crops and crop wastes which can be used to produce bio-energy, including cottonseed for biodiesel, cotton stalk and cotton gin trash for ethanol and biogas or direction combustion, sugar bagasse for combustion, corn and sorghum for ethanol production etc.

Overall, in the cotton growing regions, the preferred alternative energy sources may be solar or bioenergy, rather than wind energy. The viability of alternative energy is also subject to uncertainty in the government policies. In many cases, additional government support and financial incentives would still be required for renewable energy to compete with more polluting traditional fossil fuels. Depending on feed-in tariffs, photovoltaics may require between 4 and 10 years to recoup their investment.

In addition to the cost of production, other factors may also influence the viability of alternative energy. For example, the wind is not always available and predictable. Biodiesel is not quite suitable for use in the winter of cold regions in Western NSW and Queensland, and may require some machinery modifications.

The potential and economic viability of some of these options are further discussed below. These include: producing bio-diesel from cottonseed, producing bio-energy (ethanol or methane, or direct combustion heat) from both cotton stalk waste and cotton gin trash.

Producing bio-diesel from cottonseed

For 250,000 ha of cotton planting area, assuming an average annual production of 2 million bales (valued at 2 m * $500/bale = $1b) of cotton and some 0.6 million tonnes of cottonseed as the by-product, and 19% oil content of cottonseed, it can be estimated (Table 2) that Australia can produce up to 114 ML of cottonseed biodiesel, or up to about 3 times of cotton direct on-farm fuel demand assuming average 150L diesel use per ha (Chen & Baillie, 2009).

Table 2: Potential uses of cotton seed and cotton stalk waste to produce bio-energy

	Potential amount of available energy	**Potential contribution to direct on-farm energy demand**	**Potential contribution to life cycle primary energy demand**
Biodiesel from cottonseed	450 L/ha	1.5-5 times (average may be around 3 times)	20-45% (average may be 30-35%)
Ethanol or methane biogas produced from cotton stalks	450 L/ha ethanol or 150 m^3 or 100 kg/ha methane biogas		10-20%
Energy from direct combustion of cotton stalks for cotton drying	20-30 GJ/ha or $500-750/ha to replace LPG, or $250-350/ha to replace natural gas	30 times of average cotton drying energy need, depending on moisture removal	30-60%

The cost of production of biofuels is dependent on the quantity and geographic location of the biomass, plus what existing infrastructure can be used and how much biodiesel is produced. After accounting for the equipment and labour cost, the total production cost of cottonseed biodiesel (B100) may be estimated as $2.04/L, which is 25% higher than $1.63/L of Canola biodiesel and 36% higher than the current petro-diesel price of $1.50/L. This is largely due to lower oil content of cottonseed. The option of selling the cottonseed ($750/ha income) is also more profitable than the option of producing bio-diesel at the current market prices.

GROWER SURVEY

As part of the 2013 Cotton Grower Practices Survey, assessment of current adoption of alternative energy options was conducted. Questions were designed to assess current use of alternative energies, grower interest and perceptions of alternative energies and obstacles and opportunities for their adoptions.

The survey was mailed to 1,000 people identified as cotton growers. Replies were received from 350 people. After further analyses, 167 responses were considered valid, representing over 10-15% active cotton growers in Australia and therefore provided a reasonable representation of the cotton growing community.

These results show that there was already some adoption of solar energy and current adoption of other alternative energy sources was very low. Of the 123 growers who responded to this question, 21 growers (20%) indicated that they were currently using solar energy, 4 growers (4%) LPG gas, 8 growers (8%) biodiesel, 6 growers (6%) ethanol, and 1 grower (1%) wind energy.

The results also show that with the exception of biodiesel and solar, the majority of cotton growers felt that alternative energies were not an option for them, regardless of the form of energy. The key factors the affect the adoption of alternative energies were: price, availability, ease of use, environmental risks, environmental benefits. Of these, price, availability and ease of use were identified by as highly important by the significant majority of respondents.

CONCLUSION

Agriculture requires energy as an important input to production. In the Australian cotton industry, diesel has been identified as the predominant energy source with electricity also making a significant contribution. It has also been identified that the key factors affecting the adoption of alternative energies include price, availability, ease of use, environmental risks, environmental benefits. Of these, price, availability and ease of use were ranked as highly important by the majority of growers.

Specific applicability of alternate energy sources in the Australian cotton production regions has been evaluated. Although the oil content of cottonseed is relatively low at 19%, it has been estimated that it has the potential to produce up to 115 ML of cottonseed biodiesel per year or 450 L per ha or up to about 3 times of cotton direct on-farm fuel demand. The annual ethanol and methane biogas production via fermentation or digester bioconversion of cotton stalk waste is also calculated as up to 112 ML ethanol or 38 million m^3 methane biogas. The drying energy demand of cotton ginning operation can also be provided by just a few percent of the available combustion energy of cotton straw or gin trash, avoiding the current reliance on LPG or natural gas.

After accounting for the equipment and labour cost, the total production cost of cottonseed biodiesel (B100) has been found to be around $2.04/L, which is 25% higher than $1.63/L of Canola biodiesel and 36% higher than the current petro-diesel price of $1.50/L. Cotton seed for bio-diesel option may only become attractive when a higher fuel price ($2.2/L) is achieved.

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