BENEFITS OF ONSITE GASIFICATION OF COTTON BURRS FOR POWER PRODUCTION AT COTTON GINS

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Abstract

The decision by EPA to regulate green house gases (GHG) and significantly reduce GHG emissions from coal fired power plants (CFPP) will likely result in reduced availability of electricity in the near future. A technology exists to produce electricity from power plants fueled with cotton burrs. The use of excess cotton biomass (burrs) as the fuel to produce useable energy with a gasification-based conversion technology is not new. Cotton gins will realize immediate benefits from the use of burrs to fuel on-site power plants using gasification. Gins will become a source of reliable electricity and heat energy during the gin season and beyond. The expense of burr disposal will be eliminated and replaced with additional revenue streams from the gasification process. Biochar produced as a byproduct of gasification may be sold as a commodity or value-added product. Excess electricity produced at the gin may be sold back to the grid. Renewable energy benefits may result in additional savings and benefits. Credits for green energy and carbon sequestration may also contribute to the cotton gin's revenue stream.

Introduction

Cotton gins accumulate a large amount of cotton gin trash (burrs) at the end of each ginning season. The cotton burrs produced from a gin during a given season have the capability to reduce or eliminate a gin's reliance on utility companies for their electrical and heating needs. Electrical rates are projected to rise as population increases result in greater demand for electricity. Electrical rates are projected over a 20 year period by using Crystal Ball, which is simulation software that works in conjunction with Microsoft Excel. The prices are projected based on analyzing electrical rates from the past 30 years that were collected from the United States Energy Information Administration (2009). The average current price that is available to commercial customers is $.10/KWh.

Through the use of a fluidized bed gasifier, a biomass that is predominately associated with having little to no monetary value enables a cotton gin the ability to provide itself with a means of power generation that is both economically feasible and environmentally friendly. A fluidized bed gasifier will be used to convert the cotton burrs into a low calorific value (LCV) gas which is then used to power a generator. When cotton burrs are combusted using conventional steam generation methods, it produces CO_2 and clogs the ventilation systems. The clogging phenomenon is referred to as "slagging" and is caused by the ash produced from the burning of cotton burrs melting and fouling the systems. Cotton burrs have a much lower eutectic point than traditional fuels. The fluidized bed gasifier minimizes slagging by thermally converting cotton burrs in a controlled oxygen environment at a temperature of 1,400 degrees Fahrenheit. Recovery of the waste heat can be used for drying seed cotton, and the option of electrical cogeneration through the use of a steam-powered turbine (Parnell, 1985.) The Environmental Protection Agency (EPA) is currently in the process of regulating green house gases (GHG) and will be enforced by law. Coal-fired power plants account for approximately 49% of the U.S.'s electrical power supply, as well as a large portion of the United State's GHG emissions (EIA, 2009). By reducing the amount of electrical energy generated by the CFPPs, electrical rates will rise and have an effect on not just the cotton farmers and gins, but also the consumers.

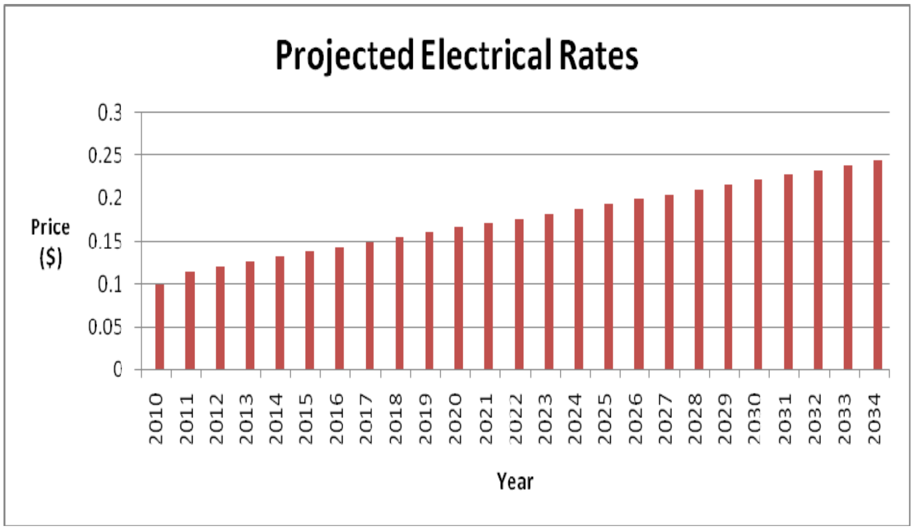

Figure 1: Projected electrical rates derived from 60 years of EIA data.

Parnell et al. (1985) stated "gasification is the most promising thermal conversion technology for cotton gin trash." He goes on to mention gasification's creates a simpler and more efficient means for removing carbon with cyclones and the life of the metal components in the system are extended due to the low oxygen environment. He also promotes the use of a fluidized bed gasifier because it can conduct thermal reactions at controlled temperatures (< 1472ºF) to reduce slagging and fouling. Parnell went on to simulate estimated cost for operation, transportation and initial investments needed for a small scale cogenerating power plant using cotton burrs as fuel.

Activated carbon is produced as a by-product of the gasification process and shows potential as an additional source of income. About 20% of the entering biomass leaves the Texas A&M University gasifier through cyclones as activated carbon. The carbon leaving the gasifier has an iodine number of approximately 300 mg I/g. This is below the standards for industrial grade activated carbon ranging from 600 – 1100 mg I/g, however, the iodine value of the activated carbon produced by the gasifier can be raised through mild chemical or steam treatments (Capareda, 1990).

Emsoff et al. (2006) demonstrated models and algorithms that determine optimal season length (L) in percent utilization (%U) as illustrated in Equation 1. This research was used to determine ginning costs in relation to ginning rate. Fuller et al. (1993) developed the %U model for cotton ginning where a cotton gin operating at 100%U would gin 1000 hours per season and operate at 80% of its rated capacity (GR) to determine the number of bales ginned (BG) in a single season, as shown in Equation 2.

$$L = BG / (GR \times 0.8) \quad (1)$$

$$BG = GR \times 0.8 \times 1000 \times \%U \quad (2)$$

Materials and Methods

Cotton burrs contain an approximate energy content of 7,000 BTU/lb (LePori, 1985), which is comparable to coal which contains an energy content of 10,000 BTU/lb. The process of gasification results in energy losses due to heat, char remaining a solid that must be removed from the LCV gas, and energy loss from the generator. An energy conversion rate of 10% (Parnell, 1985) is used to determine the final output of the generator. Gin trash production at various size gins was calculated based on stripper cotton and the use of a lint cleaner yielding burrs after ginning at 4000 pounds per bale.

When calculating a cotton gin's seasonal output, a critical variable for consideration is the operating hours per season. Percent Utilization is used in correlation with the amount of hours operated per season based on a percentage. With a base utilization factor of 100%, a cotton gin is operating for 1,000 hours per season. The utilization factor is then multiplied by an 80% efficiency factor to account for operating down times such as module changes and maintenance. With the number of cotton gins on the decline, the remaining gins are operating for longer periods of time. By taking the aforementioned into account, the simulated gin used for the calculations is given a utilization factor of 150%, which leads to 1,500 operating hours per season.

Burr yield is dependent on the method used for harvesting cotton. When using a cotton picker results in an approximate yield of 150 lbs. of burrs per bale of ginned lint. Another harvesting method and one of the most common methods that is used in the Texas Panhandle, is through the use of a cotton stripper with a cleaner. The stripper with a cleaner yields 400 lbs of burrs per bale of ginned lint. An outdated, less commonly used method of harvesting the cotton is a stripper without a cleaner which yields 800 lbs of burrs per ginned bale of lint. The simulated cotton gin is located in the Lubbock, Texas area where the common harvesting method is with the use of a stripper harvest with a cleaner that yields 400 lbs of burrs per bale of ginned lint. The following equation calculates the total amount of cotton burrs produced by using the previously mentioned parameters.

[40 bales/hour * 1,500 hours/season * 400 lbs. burrs/bale * 80% eff.**]** / 2,000 lbs/ton = 9,600 tons/season

System Sizing

Simulation and operations research methods are used to analyze the benefits of producing electricity and heat for drying with an onsite, biomass fueled power plant relative to traditional natural gas and electricity obtained from the grid supplied by coal fired power plants (CFPP). It was determined that the new biomass fueled power plant system recently patented would require $1 million per MW of capacity. Gin capacity at 100 percent utilization combined with an estimate of 50 kWh/bale resulted in a power requirement of 1 MW for a 20 bph gin, 2 MW for a 40 bph gin, and 3 MW for a 60 bph gin (Table 1).

Table 1: Gin Trash production based on utilization rates. 100% Utilization = 1000 hours gin operation/season. 200% Utilization = 2000 hours gin operation/season

Gin rating (bph)	Utilization (%)	Bales / yr	CGT (tons/yr) @400lb/bale	Megawatt (MW)	Operation (hrs)
20	100	16,000	3,200	1	1,280
20	200	32,000	6,400	1	2,560
40	100	32,000	6,400	2	1,280
40	200	64,000	12,800	2	2,560
60	100	48,000	9,600	3	1,280
60	200	96,000	19,200	3	2,560

Energy Production

This rate of gin trash production will enable a stripper gin to produce enough electricity using burrs as fuel to sustain its operations throughout the gin season and have excess power to sell back to the utility. Electricity costs from outside power companies can be eliminated and additional revenue can be generated for the gin with the sale of excess power. Table 2 shows the revenue potential for excess power sales.

Table 2: Energy production and excess power revenue for the gin at a rate of $0.10/kWh. Excess power not required by gin sold back to the grid through net metering. Increases in the cost of electricity are likely in the future.

Gin Rating (bph)	Utilization (%U)	Megawatt (MW	Operation (hrs)	Excess Power (MWh)	Revenue ($/yr) (@ $0.10/kWh
20	100	1	1,280	280	28,000
20	200	1	2,560	560	56,000
40	100	2	1,280	560	56,000
40	200	2	2,560	1,120	112,000
60	100	3	1,280	840	84,000
60	200	3	2,560	1,680	168,000

Bio-char production

Biomass may be fed into the gasifier at various rates based on the desired energy production level, ranging from 0.8 MM BTU/sqf to 1.5 MM BTU /sqf. The feed rates calculated in table 3 were based on 1 MM BTU/sqf. As the synthesis gas is produced, it is processed through a two-stage cyclone series to remove char before use in power generation. Table 3 also quantifies the bio-char which is produced during gasification.

Table 3: Biomass feed rate for various gin sizes and utilization rates. Based on 1 MM BTU /sf.

Gin rating (bph)	Utilization (%)	Megawatt (MW)	Feed rate (lb/hr)	Feed rate (lb/min)	Char (lb/hr)	Char (lb/yr)
20	100	1	**5,000**	83	1,000	1M
20	200	1	**5,000**	83	1,000	2M
40	100	2	**10,000**	166	2,000	2M
40	200	2	**10,000**	166	2,000	4M
60	100	3	**15,000**	250	3,000	3M
60	200	3	**15,000**	250	3,000	6M

Cotton gin bio-char production is another potential for significant additional revenue for the cotton gin and producers. Produced due to the oxygen deprived environment within the gasifier, it retains significant energy content. Composed mostly of carbon, it makes a superb soil amendment, to increase organic matter content of soils. With an iodine number of 300, it is inadequate in its raw state for marketing as an activated carbon, but other research has shown that cost effective steam treatment may improve the iodine number significantly for marketing as activated carbon. Markets would include waste water treatment facilities, textile mills, power plants, and biomedical/hygiene companies. With activated carbon sales ranging up to $3.50/pound, this gasification byproduct may be a major revenue stream for the gin and producers.

Results

Gasifier power plants have a relatively high initial cost. The cost is related to the rated output, with each MW of output having an initial cost of approximately $1,000,000. With the 40 bph simulated gin requiring a minimum electrical output of 1.6 MWh, a 2 MWh power plant is needed that will have an initial cost of $2,000,000.

The financial analysis for the project is simulated over a twenty year period using a 40 bph gin, with cash flows and expenses calculated at the end of each year. The loan used for this project is a $2,000,000 loan, with no down payment, and amortized over a period of 20 years. The loan is compounded annually at a conservative interest rate of 9.00%. Income is taxed based upon an average marginal tax rate of 28% (IRS). The marginal tax rate is dependent on the level of income, therefore it changes from year to year and that is why an average rate is applied. Labor expenses include the salary of one manager, one mechanic, and two general laborers that work a total of 2080 hours summing $403,000 annually in the first year adjusted 2.24% annually to account for inflation. Additional taxes and insurance on the power plant itself are assumed to be 2.00% of the initial costs of the power plant.

Energy consumption data was gathered from the Texas Cotton Ginners Association from a 2009 survey of Texas cotton gins (TCGA, 2009). The data reveals the average electricity consumed per bale of ginned lint is 46 kWh. With the larger gins tend to have higher energy efficiency than the smaller gins, so 40 kWh is used for the simulated 40 bph gin, which is then used to calculate a total of 1.6 MWh of electrical consumption per hour of operation. TCGA also reports that the average heating costs per bale of ginned lint is $2.00 per bale. By using these parameters, sums of $240,000 for electrical expenses and $120,000 for heating expenses were calculated.

Net returns are calculated individually for each year of operation and depicted in figure 2. Total revenues include the money saved that year by not having to purchase electricity or gas, tax benefits from the facility's depreciation, and the money received from selling the extra electricity generated. Expenses consist of the annual loan payment, labor costs that increase at the rate of inflation, and taxes and insurance. The above graph provides a visual representation of the yearly cash flows over a period of 20 years. Year 1 of the investment represents 2010, with year 20 representing 2030. With the power plant deemed as depreciable for a period of 15 years, the tax credits received end after period 15 which explains the minor dip in the net cash flow for year 16.

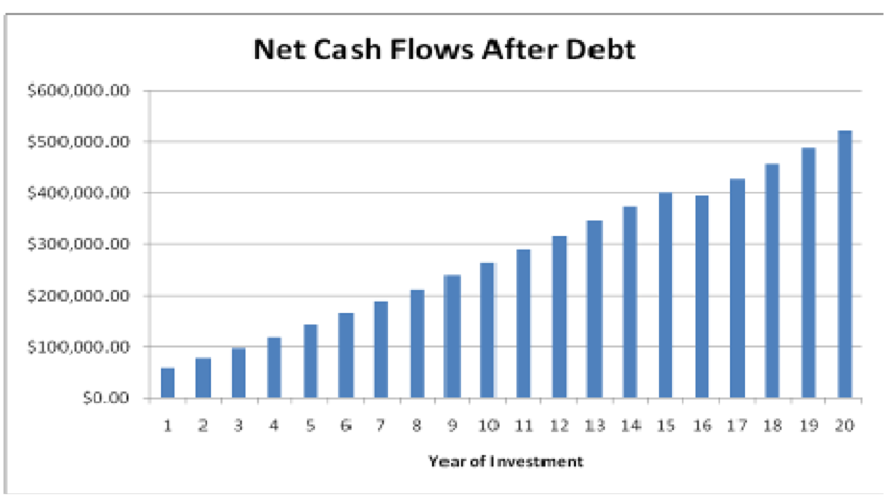

Figure 2. Net cash flow of cotton gin due to power plant benefits after debt payments are made.

Summary

On-site power production though gasification of cotton burrs presents many appealing opportunities for ginning operations. Primary, cotton burrs are transformed from a liability to an asset. It has been shown that gasification can alleviate a gin's electrical and fuel costs using the syngas produced to generate electricity or as fuel for drying. Secondly, diversification can be a huge benefit for ginners. Ginning cotton will no longer be the gin's sole means of generating revenue; additional electricity can be sold to power companies during the off season as a supplemental source of income. Additionally, the biochar by-product produced can potentially be marketed as a soil amendment or, with minimal processing, as activated carbon. Multiple incentivizes will spur the use of green energy through renewable sources offering tax breaks and subsidies. Most importantly, cotton gins have the opportunity to achieve real energy independence which is likely to make the difference in operating in times of reduced electricity or not. As energy prices continue to increase, and demand for energy increase, the likelihood of energy rationing is all too real. All of these benefits could provide economically feasible for onsite power production though gasification and deliver energy independence to cotton gins.

Future Research

Further simulation is required to find the extent of the profitability for onsite power production through gasification. Further analysis must be done on the marketability of the electricity to power companies including, potential buyers, optimal energy production and potential energy contracts and on the marketability of the biochar as both a soil amendment and potentially more profitably as activated carbon. The Texas A&M Department of Biological and Agricultural Engineering is constructing a mobile prototype of the fluidized bed gasifier for further research on operation and demonstration of its benefits at remote sites.

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