Optimal Capacity and Profit Maximization Level for A Biomass Refinery, A Supplemental Source of Fuel

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Abstract: The feasibleness of a cotton gin waste (CGW) that produces bio-fuels is explored. By utilizing cotton gin trash and supplemental feedstock such as can trash, enough megawatt hours of energy can be produced to satisfy peak and sub-peak energy for power requirements. Furthermore, findings have confirmed that the amount of carbon displaced by a power plant relying on biomass energy as source of electricity rather than traditional coal is an additional offset that makes the business model even more attractive. For reasons stemming mainly from the availability of cotton gin trash in the site area, it has been confirmed that use of biomass already on site at agri-forestry processing centers to manufacture bio-products will also minimize transportation and handling costs. Therefore, at the core of this study is the determination of whether an operator of a power plant chooses to use supplemental biomass in the form of can trash for the production of electricity when there is insufficient cotton gin waste due to a bad season. The decision is based on whether the profits derived from the additional megawatt hours from additional biomass are enough to offset the transportation and harvest costs associated with the can trash biomass. A profit maximization model simulating the production and sale of biomass electricity suggests that while lowering the transportation and harvest costs through subsidies does influence an operator's decision to import, it has a negligible effect on the plant capacity and efficiency. Furthermore, findings in this study suggest that a subsidy applied to the peak and sub-peak prices of megawatt hour prices do in fact have a substantial affect on the capacity and profitability of a plant producing electricity from biomass.

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Introduction:

Biomass was used extensively by humans not only as a source of food but also energy. Starting in the 19th century it had been replaced by coal and natural gas and petroleum crude oil. For the past several decades, however, there has been growing interest in the use of biomass as source of fuel and its usage is expected to increase as an energy resource and feedstock for the production of organic fuels and commodity chemicals. Biomass is one the few renewable, naturally abundant resources that can be used to reduce the amount of fossil fuels burned and GHGs emitted. It reduces the amount of greenhouse gases through carbon sequestration through the photosynthetic process (Klass, 1998). Energy produced from biomass has a number of benefits that require closer examination.

The most obvious benefit is that of carbon displacement relative to other traditional sources of power such as coal and natural gas. It is estimated that coal power plants account for roughly 50% of electricity generation in the U.S. and produce 90% of CO_2 emissions from electric utilities (U.S. Department of Energy, 2000). Co-firing only 3% of energy bio-mass fuel at just one mid-sized coal power plant would have the equivalent CO_2 reduction impact of over 41,000 large (1 kW) solar panels or taking 17,000 cars off the road (Common Purpose Institute, 2008). Biomass residues are the organic byproducts of green plants, crops, and other vegetation used for things such as food, fiber and forest production. High in carbon and hydrogen, these residues offer enormous potential for bio-fuel applications once properly processed. Cotton production generates a number of residues including seeds, leaves, and stems which are referred to as cotton gin byproducts (CGW). In fact, research shows a bale of cotton gin trash contains more BTUs of energy than it takes to dry a bale of cotton. Due to the high market value of cotton seed for oils, they are removed from the processed cotton and what is left is cotton gin waste (CGW).

CGW has a number of existing applications. In the past, there was little economic incentive for producers to explore practical uses for CGW. It was either thrown back on the crops as a type of fertilizer, processed into animal feed. Recently, however there has been increasing interest in processing them into commercial products. Seeds already have been separated as a commercially viable by-product. Additionally, CGW is being used as hydro-mulches, packaging and insulation materials or converted into briquettes to be burned for fuel. In addition to these applications there are also a number of companies that desire to convert CGW into inputs for electric power. In fact, investment in biomass and waste-to-energy in general is projected to increase from $14 billion in 2010 to $80 billion by 2020 (Bloomberg New Energy Finance, 2012).

CGW as a source for bio-fuel is a topic that requires closer scrutiny for a number of reasons. First, because of the amount of displaced carbon achieved from CGW derived bio-fuels, coupled with its other considerable ecological benefits especially relative to traditional coal or petroleum based electricity, conversion of CGW into electric power offers many potential advantages as CGW product. A cotton gin waste potentially could be involved in four separate economic activities: ginned cotton, cotton seeds, electric power and carbon offsets for conventional power companies. It is estimated that Cotton is grown on around 11% of the total cropped area in the country.The residue is CGW that constitute as much as 3 times of the cotton produced.

Second, determining the appropriate plant capacity will ensure that profit maximization goals can be met by keeping costs low while also selling the energy at a sustainable market price. As plants get bigger, transportation and harvesting costs get higher and product prices get lower. Therefore there is a need for a moderately scaled plant that can realize higher prices for electricity and possibly move into a niche market.

Third, an important consideration in attempting to utilize agricultural waste as a source for bio-fuel is that it becomes necessary to ensure that sufficient biomass exists and that there is enough supplement of biomass nearby to compensate for those seasons when there is insufficient CGW. Unless the plant is very large and can import from outside the region or can easily store biomass from year to year – or several years – as with corn, planning for short biomass drought years must be a part of planning for all agricultural residues. Therefore the need for a contract to ensure that a power plants energy demands are fulfilled becomes necessary. The contract sets an amount of deliverable megawatt hours during peak and sub-peak times. Failure to meet the requirements results in a monetary penalty. Of course, the contract also provides the gin the security of selling its entire energy product in advance.

Statement of the Problem:

With an in depth study of the carbon footprint of CGW-derived products versus other choices, a proper assessment of the net savings or losses from using CGW can be established. Furthermore, a better understanding can be gained of the applicability of government mandated taxes and credits. Once the appropriate carbon analysis has been completed a profit model can be established that will assess the economic viability of bio-waste to energy station. This model will address the specific questions of the necessary issues of profit maximization, conversion efficiency, cost/benefit ratios, and plant scale required to make the commercialization of bio-waste to energy feasible under normal and abnormal conditions.

Public Policy and Initiatives

For several decades there has been growing awareness and concern of GHG's and their impact on the environment and on climate change. Several initiatives have been proposed to reduce pollutant emissions, namely carbon, and have been met with differing levels of success. The most ambitious and wide reaching is the Kyoto Protocol. Adopted in 1997, the main objective of the protocol is the stabilization of greenhouse gas concentrations in the atmosphere and that "such a level should be achieved within a time-frame sufficient enough ... to enable economic development to proceed in a sustainable manner" (Article 2, The United Nations Framework Convention on Climate Change. November 2005). The measure was signed and ratified by 191 nations with the only remaining one being the United States.

The American Clean Energy and Security Act of 2009 (ACES) was a bill, which emulated the European Union Emission Trading Scheme. The bill's purpose was to establish an emissions trading market whereby utility companies and manufacturing firms would have the ability to trade pollution allowances in an effort to create profit motivated mechanisms to reduce carbon emissions over a given time period**.** It included a provision that "required big electric utilities to rely on renewable sources for 6% of their energy in 2012, rising to 20% in 2020" (Key Features of the American Clean Energy and Security Act, Environmental Defense Fund, 2012). Renewable sources of energy include wind, solar and biogas and bio-fuels among others. **"**The vote was the first time either house of Congress had approved a bill meant to curb the heat-trapping gases scientists have linked to climate change**"** (Broder, J, 2009). Though the bill was never passed it did bring congressional attention and debate to the issue of reducing carbon emissions and the viability of a national cap and trade program or some other variant to meet carbon reduction targets while encouraging innovation by private companies to reduce emissions. Legislation that has passed to reduce pollutant emissions is the California's Global Warming Solutions Act of 2006. The Act set forth groundbreaking regulatory standards, which among other things aimed to utilize 33% renewable energy by 2020 and reduce total carbon dioxide emissions by

80% by 2050 (California Environmental and Protection Agency, California's Climate Plan, 2009).

CGW Versus Other Fuel Sources

A typical power plant in the U.S. uses coal to provide the majority of electricity generation. In fact, "coal power plants account for approximately 50% of generation in the U.S. and produce about 90% of CO2 emissions from electric utilities" (U.S. Department of Energy, 2000).

To put the carbon emissions in numeric terms, a coal power plant is responsible for emitting 56.9 lb-C/MBtu. This figure can be interpreted as a carbon intensity ratio and it is both higher than an oil (47.2 lb-C/MBtu) and natural gas unit (31.9 lb-C/MBtu) (U.S. Dept. of Energy EIA, 1997). In comparison, a biomass fuel source such as a CGW would avoid additional carbon emissions at a rate of (0.0008 lb-C/MBtu). This reflects the subsurface sequestration effects or the amount of carbon that is being absorbed into the ground as the cotton grows. (U.S. Dept. of Energy EIA, 1997)

While historically coal has been the cheapest (74-88 USD/MWh) and most abundant of the fuel sources (California Energy Commission, 2007) most modern coal power plants don't have the capacity to deliver the energy demands throughout the entire day.

Those times during the day when a plant's capacity to provide electricity has been exceeded are called its peak hours. To accommodate for this it can either increase the scale of its operations, which is typically expensive and takes a long period of time or it can find other sources of energy to supplement itself.

Natural gas has been used historically to displace coal during peak hours. Prices for natural gas prices have been unstable and traditionally high. Recent advances in gas extraction are likely to lower prices but to levels still higher than coal. At the moment it is uncertain how natural gas extraction, reliability and electricity prices will be affected; or even if liquefied natural gas (LNG) will eclipse much of the gains for electric power generation. Currently natural gas is expensive at 313-346 USD/MWh vs. biomass at 47-117 USD/MWh (California Energy Commission, 2007), and it also produces 15% of the total carbon dioxide emitted from power plants (U.S. U.S. Dept. of Energy, 1997). Recent advances in technology and new legislation regarding carbon emissions have made the search for the most cost efficient alternative energy source of interest to both industry and government. With this in mind the need for alternative sources of electricity production during peak hours becomes clear. In light of this, other renewable sources energy have been explored, they include: wind, geothermal, solar, and biomass. Geothermal facilities are usually expensive and release harmful gases trapped in the surface of the earth. While wind and solar are carbon neutral, they don't have the ability to store carbon from the atmosphere into the ground (called carbon sequestration) that biomass has. In addition to the carbon sequestration argument, biomass has an energy capacity factor of 80%, compared to that of 36% for wind and 22.5% for solar (U.S. Department of Energy, 2000). These figures support the ability for biomass to be significant not just during peak hours but also as a base alternative to coal. CGW is also the cheapest of alternative energy options, costing \$40-\$80/MWh with solar at \$270/MWh and \$47-\$115/MWh for wind (U.S. Department of Energy, 2000). CGW is also an abundant source of biomass with about 1.47 metric tons which is equivalent to power generation of around 3071 GWh. recovered across the cotton belt each year (Biomass Energy, 2011). To better understand conditions in the Southern High Plains, cotton gins here can be roughly grouped into three sizes: 20 bales/hr, 40 bales/hr, and 60 bales/hr (Farmer, 2011). The energy content of CGW has been estimated at 8758 MJ per ton (citation needed). Texas on average produces 6,266 bales of upland cotton annually. Based on a thirty percent turnout this amounts to 1,570 thousand tons of CGW after it has been processed (USDA-NASS, 2001-2008). "The energy content of gin trash is estimated at 8758 MJ/ton" (Farmer, et al., 2011). Using a conversion rate of about 25% from the gasification and combustion process, electricity generation of one bale of CGW results in approximately 1MWe. Taken as a whole, CGW derived energy sources could deliver approximately 4,791 MWh, equivalent to the amount produced by around one hundred thousand tons of corn as ethanol.

Previous Work on CGW as Fuel Source

Curtis et al. (2003) showed that the energy content of a ton of CGW was 15 mm BTUs. This reported value is used to determine the energy content of the feedstock, thus resulting in the available supply of energy that can be obtained from CGW. Some technical parameters of gasification and pyrolysis specified for CGW are based on lab experimental data obtained by the department of Biological & Agricultural Engineering, Texas A&M University (Capareda, 2009).

A typical figure used in calculations for bio-gasifies is 1 ton of dry matter CGW per hour per MWe produced, in which an ideal 25% efficiency of overall conversion process from CGW to power is used; 60% and 20% of dry weight yields of bio-oil and char respectively for pyrolysis, and bio-oil heat content is 72000 Btu/gal. Other factors for bio-oil production are based on "Bio-oil Commercialization Plan" (Cole Hill Associates, 2004). The estimated capital costs for typical gas turbine-based CHP system are based on Technology Characterization: Gas Turbines (Energy Nexus Group, 2002), which includes the performance parameters, fixed and operation & maintenance costs for setting up difference sizes of gas turbines as electricity generated from bio-oil.

Biomass based gasification is a process by which biomaterial is partially combusted in the absence of air to produce Carbon Monoxide (CO) and Hydrogen (H). This extracted gas can be fed into a gas turbine to produce electricity. The entire gasification system is relatively inefficient as the material has to be heated initially in fluidized bed which on its own requires a lot of energy, and the collected gases must then be re-burned to produce energy which has its own efficiency losses. Based on the experimental results conducted by A&M University, gin trash can be converted to electricity at, at least a, 25% efficiency rate. Nevertheless, since it produces energy from material that were causing disposal problem, and eliminates heating, electricity consumption from grid, it is a more than acceptable option for waste disposal and energy generation . Pyrolysis on biomass has outstanding generating efficiency, also transporting and storing bio-oils outperform the same processes on syngas/natural gas, which is the main competitor of bio-energy in the study region. In addition, according to Phillip C. Badger (2004), modular bio-oil plants can be taken to site and directly convert biomass into bio-oil, and is cost effective at relatively small scale (100 dry tons per day). Under current technology, the modular bio-oil plant can handle multiple feedstocks, such as agricultural crops and residues, hog and cattle manure solids. The summary of advantages for z bio-oil plant is: (1) relative simple technology; (2) multiple feedstock capability; (3) multiple products with multiple markets; (4) financial security for investors; (5) cost effective at a small scale.

Methods and Materials:

Discretized values of CGW and rangeland grass in MWh

A linear programming model solved using Lingo software package will be used to find the optimal capacity, hours of operation, and total megawatt hours of production while maximizing profit and solving for the optimal capacity for each of six different groups plants.

The model employed will discretize the probabilities of total megawatt hours derived from both cotton gin byproduct and supplemental sources of biomass materials such as rangeland grass. Furthermore, those distributions are discretized into eight separate states for megawatt hours for each of six different groups of gin trash availability and rangeland grass expressed as potential electric energy output.

For example, group M's (the baseline group in Table 4.1) total megawatt hours from CGW can be broken down as follows: 88,650 MWh occurs 5% of the time; 80,055 MWh, 5%; 73,365 MWh, 15%; 68,350 MWh, 25%; 55,780 MWh, 25%; 42,185 MWh, 15%; and 34,870 MWh, 5% and 20,330 MWh 5%. In other words, 5% of the time the region will experience either a very good season or bad one in terms of rainfall and crop harvest. The intermediate seasons have a higher degree of probability resulting from a greater chance of more moderate amounts rainfall. The other five groups considered (G, J, L, Q, & R) have different levels of electricity production from CGW based upon the total availability of CGW in that respective area; but those close in size realize proportional results in terms of plant scale choice and overall profitability. Table 4.1 breaks down the total megawatt hour production for each of Additionally, to prevent a breach of contract from undersupply of cotton gin waste bio-energy, supplemental biomass in the form of rangeland grass is also included. The technical parameters of rangeland grass to BTU conversion are assumed to be the same as for CGW as they are both lignocellulosic materials. The data for the total amount of rangeland grass was obtained from the USDA (USDA, 2011) for Lynn and Lubbock counties. The lbs./acre figures are broken down by the types and locations of the grass and is given for favorable, normal, and unfavorable years.

This energy output is based on the total amount of rangeland grass in tons available within a 10 mile radius of group M, in this case and can be broken down by favorable, normal, and unfavorable seasons: 14,881 occurs 5% of the time; 14,881 5%; 10,400 15%; 10,400 25%; 10,400 25%; 10,400 15%; 6,815 5%; 6,815 5%. Given that only about 30% of the rangeland grass can be practically recovered, this translates to total tons from supplemental sources as: 4,464 5% of the time; 4,464 5%; 4,464 15%; 3,120 25%; 3,120 25%; 2044 15%; 2,044 5%; and 2,044 5%. A conversion factor of biomass MWh = ((TONS*.15)*4.395)) was used to calculate the total megawatt hours derived from one ton of grass. Where biomass is in total megawatt hours, TONS is total available tons of grass, .15 is an energy conversion factor added to make the model more realistic, and 4.395 is a tons to btu to megawatt hour conversion. Or one ton of grass delivered to a plant ultimately produces .66 MWh (.15*4.395).

Megawatt hours of electricity derived from this supplemental biomass for group M can be discretized into the output: 2,942 MWh occuring 5% of the time; 2,942 MWh, 5%; 2,942 MWh, 15%; 2056 MWh, 25%; 2056 MWh, 25%; 2056 MWh, 15%; and 1347 MWh, 5% and 1347 MWh 5%. These eight groups follow the same structure as the cotton gin byproduct states in that a probability is assigned to a very good year (much rainfall) through a very bad year (little rainfall). Table 4.2 illustrates the MWh production from rangeland grass for group M: to maximize profit given the probability distribution discussed earlier. Sales of electricity are sorted into four baseline prices for each MWh: the number of MWh sold during high peak times is MWP, MWh sold at secondary peak times is MWSP, number of MWh for the plants own power production is OWN , and the number of MWh sold during any incidental times is IC. A penalty shortage is S and occurs when the plant is unable to meet the contractual demands. The maximum profits are aggregated over the eight states of nature and then summed.

Equation 4.1 limits the amount of tons of rangeland grass available in a given state to 30% of the total amount imported. This is a constraint that allows for a more practical assessment of the accessibility of the grass. Equation 4.2 constrains the total amount of peak megawatt hours from both CGW and grass to the capacity (C) of the plant times the number of contractual peak hours (PCTRCT) which is 945. Equation 4.3 constrains the total amount of sub-peak megawatt hours from both CGW and grass to the capacity (C) of the plant times the number of sub-peak contractual peak hours (SPCTRCT) which is 2000. Equation 4.4 defines fixed costs (FC) to be a function of the capacity of the plant. Equation 4.5 is a conversion and constraining factor for tons of rangeland grass to MWh (TB). It simply states that the MWh from grass cannot exceed the total available tons of imported supplemental biomass and uses a factor of 4.5 MWh for each ton of grass imported to calculate MWh from tons of grass. Equation 4.6 limits the total electricity produced minus the amount short to an amount no greater than the total available electricity derived from CGW and grass. Equation 4.7 constrains the total amount of MWh derived from CGW and grass to the capacity of the plant multiplied by the total number of operational hours. Equation 4.8 constrains the total amount of electricity produced to the capacity of the plant multiplied by the number of operational hours of the plant. Equation 4.9 constrains the amount of own power production to the capacity of the plant multiplied by the hours of operation. Equation 4.10 constrains the total amount of MWh that a plant is short each period to the capacity of the plant multiplied peak and sub-peak contract hourly demands subtracted by the number of peak and sub-peak hours of electricity produced, respectively. Equation 4.11 limits the total amount of electricity from CGW and grass to the total amount of electricity that a plant is capable of producing. Finally equation 4.12 limits the amount of own MWh that a plant uses to a factor of .16337 multiplied by the capacity of the plant.

Explanation of technical parameters

The average 2006 retail energy prices of \$128.6/MWh in Texas with daily peaks running over \$150/MWh, peaking prices run conservatively at \$130/MWh (i.e. 13^{C}/kWh). There are notorious peaking power spikes over \$300 while off peak retail prices operate between \$35 to \$50 per MWh. An operator targeting both the highest daily peak and a ‘low’ peak can realize mean prices in the range of \$70 to \$90 per MWh over the day. Based on retail rates above, we use \$130/MWh delivered at the highest peaking power prices (MWP). Nine hundred and forty five hours per year is allowed, which coincides with deliveries of five hours per day for 27 weeks (17 in the summer and 10 in the winter) at this highest peaking price. Another 2000 ‘secondary peak’ (MWSP) hours is allowed at a rate of \$60/MWh to be available by contract across the year. A penalty price (S) of \$125/MWh is assigned for any outside purchases to meet shortfalls as they arise. Finally, power sold off peak as incidental power (IC) returns \$25/MWh, which is closer to the wholesale price for coal. A small premium is assessed to on site production for immediate use at the gin of \$30/MWh (OWN).

To assess the optimal capacity and profit maximizing levels, five other high peak (MWP) price levels will be examined: 140\$/MWh, 150\$/MWh, 160\$/MWh, 170\$/MWh, 180\$/MWh. At these different price levels, the corresponding profit levels and capacity are evaluated while holding sub-peak prices constant. The goal is to understand under what conditions these plants exhibit higher sensitivity to changes in prices and to what extent their profits and capacity change while keeping other decision variables constant as the decision to import supplemental biomass is undertaken.

Results:

I considered six different groups of 2-7 gins and solved the above model for each group. All gins are within 60 miles of Lubbock, TX and are identified in Figure 2.1. The profitability and capacity of each of the plants was assessed at different levels of peak prices. In this scenario transportation costs are set at \$15/ton and harvest costs are set at \$5/ton with a subsidy set at 0\$. Recall the set of variables and their values chosen for this model are as follows.

Capacity and Profit for Group M

The purpose here is to identify one specific profit maximization capacity point for a moderately sized group. With that point obtained the next step is to calculate the profit per megawatt hour installed and also the fixed costs. The study will proceed to hold all other variables constant while then changing the transportation and harvest costs in order to simulate a subsidy geared at making it less expensive to import rangeland grass. This will provide insight as to when an operator would decide to import and how that would affect capacity and profits. Because each group varies so greatly in size and accessibility to rangeland grass and CGW, I expect there to be widely divergent patterns in increases to capacity. The simulation is based on an aggregated total maximum capacity over eight states of nature based on the predicted amount of rainfall given very poor and very favorable conditions. It incorporates both CGW and rangeland grass as production inputs and these amounts vary over the eight states.

In figure 5.1 and table 5.1 below, the change in the capacity of the plant is modeled as peak prices range from $130/MWh up to $180/MWh.

Texas Tech University, Michael J. Walker, May 2012.

Table 5.0: Summary of parameters.

Variable	Value	Significance
Peak Contract Hours	945	Number of peak hours in one year.
Sub Peak Cntrct. Hrs.	1000	Number of sub-peak hours in one year.
FACTOR	.16637	A conversion factor based on technical data.
Variable Unit Cost	$5.5	Cost of labor, materials, etc.
Transportation Cost	$15-$35	Cost to transport one ton of grass from range.
Harvest Cost	$5-25$	Cost to harvest one ton of grass on range.
Subsidy	$0-$35	Any subsidy included.
Megawatt Peak Price	$130-$180	Price per peak MWh peak hour of electric.
Megawatt Sub-peak	$90	Price per sub-peak MWh of electric.
Price		
OWN Power Price	$30	Value per MWh for plants own usage.
Incidental Sales	$25	Price per MWh sold at off pk. and sub-pk. hrs.
Shortage Penalty	$125	Penalty cost per MWh if unable to meet contract.
Available tons of grass	2942-1347	Amount of tons imported each period.
	tons	
Fixed cost	(4000000/(1.2	Cost of plant and endogenous to capacity.
	*C+5)+65000	
Capacity	Endogenous	Size of plant. Determined by overall profitability (MWe).

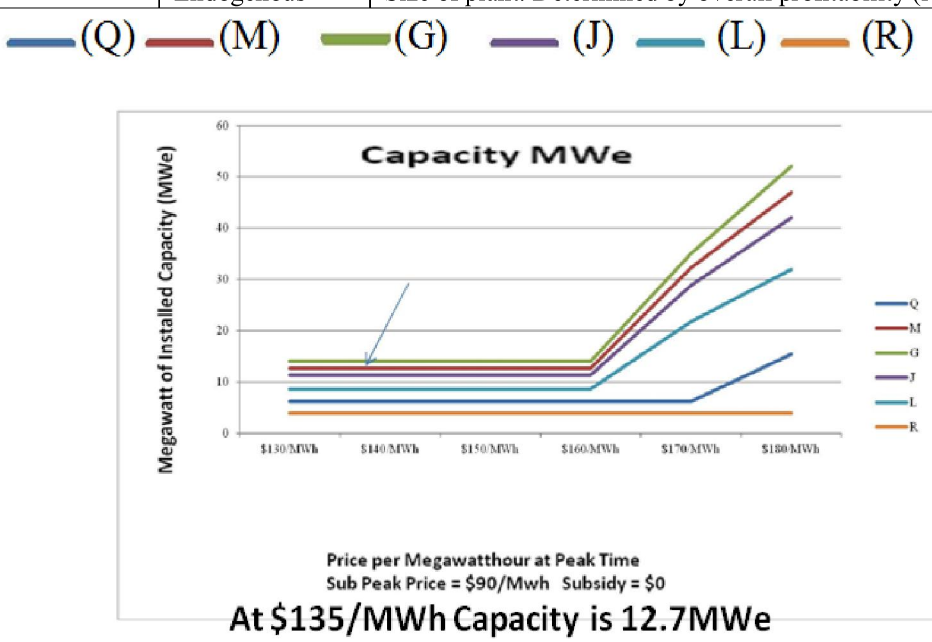

Figure 5.1: Capacity of groups as peak price changes.

Table 5.1: Change in capacity as peak price changes.

Peak Price	$130/MWh	$140/MWh	$150.00/MWh	$160.00/MWh	$170.00/MWh	$180.00/MWh
Q	6.18	6.18	6.18	6.18	6.18	15.39
M	12.66	12.66	12.66	12.66	32.23	46.9
G	14	14	14	14	35	52
J	11.35	11.35	11.35	11.35	28.81	42
L	8.62	8.62	8.62	8.62	21.73	31.95
R	3.94	3.94	3.94	3.94	3.94	3.94

What is striking is how at around $165/MWh all groups experience a drastic increase in capacity. In fact there appears to be a steady increase in a capacity for all plants with more remarkable shifts up around the $165/MWh point. The shift up occurs sooner and more frequently the larger the capacity of the plant. This could be a result of increasing economies of scale and widening gaps between marginal revenues and costs.

The point labeled at 12.7 MWe capacity for group M is taken as a reference in order to conduct a singular analysis. At this point the peak price is about 135/MWh and sub-peak price is $90/MWh (as it is through all these simulations). Given the annual peak contract requirements of 945 hours and 2000 sub-peak this results in total megawatt hour production of 37,400.

The increase in profitability is also substantial at $165/MWh for all groups as shown figure 5.2 below:

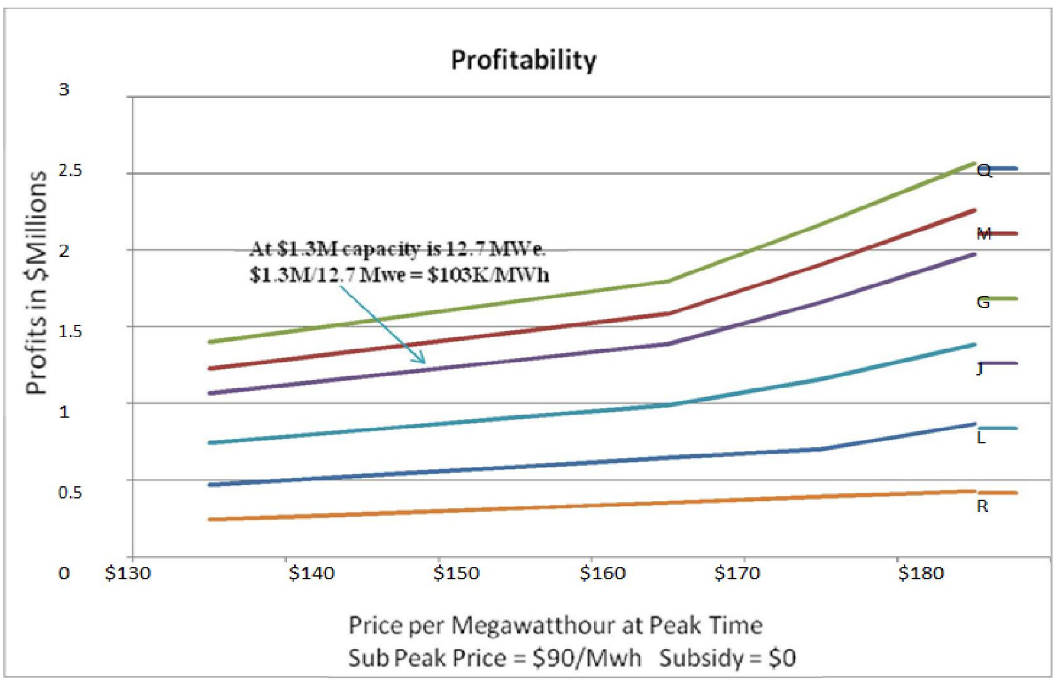

Table 5.2: Change in profitability for different peak prices.

Peak Price	$130/MWh	$140/MWh	$150.00/MWh	$160.00/MWh	$170.00/MWh	$180.00/MWh
Q	$470,619	$529,101	$587,583	$646,065	$704,547	$867,894
M	$1,228,141	$1,347,818	$1,467,496	$1,587,173	$1,908,145	$2,261,510
G	$1,401,075	$1,534,017	$1,666,958	$1,799,899	$2,171,734	$2,568,708
J	$1,068,151	$1,175,415	$1,282,679	$1,389,944	$1,662,677	$1,974,890
L	$744,977	$826,524	$908,070	$989,617	$1,160,216	$1,385,464
R	$243,073	$280,393	$317,714	$355,035	$392,364	$429,716

In order put this study into perspective, group M is selected to carry out a cost/benefit analysis. A price of $135/MWh is chosen because it is somewhat close to the average Texas megawatt hour price of $124.10

(U.S. Energy Information Administration, 2010). Because this is an average Texas price, it does not reflect the true peaking price which is unquestionably much higher. In any event, for the sake of comparison and to be conservative in the analyses, a similar price of $135/MWh was selected from this model to run some basic simulations on capacity and marginal profits. Also there are no price subsidies for renewable energy sources. Again, it is important to note that only this highest peak price changes. The results are bound to be conservative due to the fact that $135/MWh is only a peak price and reflects only those prices for 945 hours out of the year. From figures 5.1 and 5.2 we can see at this price ($135/MWh) the capacity of group M is approximately 12.7 MWe and the profits are $1.29M. This equates to a marginal increase in profit per unit of installed megawatt capacity of $103K ($1.3M/12.7 MWe). Fixed costs at this level are $10.7M (4000000/(1.2*C+5)+650000)*C) (recall equation 4.4).

Decision to Import:

Next, I hold the price of $135/MWh and all other values constant except transportation and harvest costs. This will allow me to consider the impact of the producer's decision to import grass in order to avoid the penalty of $125/MWh. This will be done in order to understand how capacity and profit are affected by the added ability to import rangeland grass in any period. Recall that eight different states of nature are considered ranging from very good (bumper crop) to very bad (drought). The figures below reflect the decision to import tons of supplemental biomass (rangeland grass) for group M in each of eight different states given a set transportation and harvest cost with a subsidy of $0/MWh. The price per was ton determined given the availability and demand for the grass in that state and was calculated using profit reports from regional ranchers who normally sell it as hay for livestock. For the first trial (figure 5.3) a transportation cost of $15/MWh and a harvest cost of $5/MWh were assigned. These values are intentionally very low and, for the purpose of this study, can be regarded as subsidized costs. The prices of the rangeland grass are reported in table 5.3 where of interest is that in period 4 the price of the grass is at its lowest while in period 8 the price is at its highest.

With a transportation cost of $15/ton from the rangeland to the plant and a harvest cost of $5/ton, the decision to import is made in four of the states. Three of them when prices of grass were relatively low (2, 3, 4) and in the last state (8) when the supply of CGW was low. In period two 4,464 tons of grass were imported when the price is at $45/ton. In periods 3, 4, and 5 the decision was made to import 3,120, 3,120, and 2,044 tons of biomass respectively. Only in period 8 was a penalty incurred for 1,477 MWh thus resulting in a loss $184,625 with the penalty of $125/MWh. The capacity of the plant is 12.6 MWe with these parameters profits are $1.3M. Figure 5.3 below illustrates the decision to import given a $15/ton transportation and a $5/ton harvest cost:

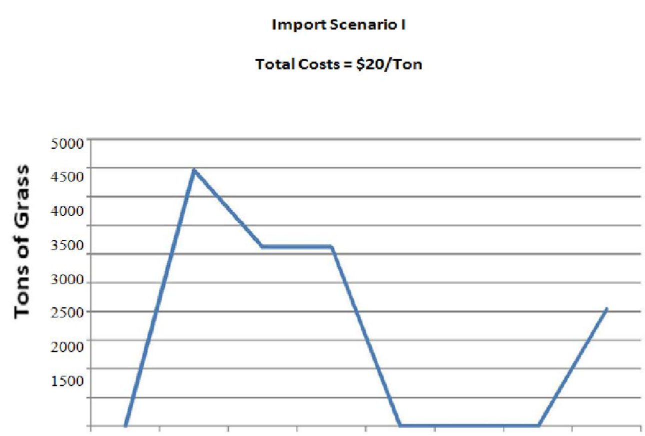

Figure 5.3: Decision to import tons of supplemental biomass scenario I (transportation cost = $15 & harvest cost = $5).

Period	Bumper Crop	2	3	4	5	6	7	Severe Drought
Subsidy	$0	$0	$0	$0	$0	$0	$0	$0
Transportation	$15	$15	$15	$15	$15	$15	$15	$15
Harvest	$5	$5	$5	$5	$5	$5	$5	$5
Price/Ton								
Grass	$47	$45	$36	$14	$70	$138	$175	$195
Import	0	4464	3120	3120	0	0	0	2044

Table 5.3: Decision to import scenario I (transportation cost = $15 & harvest cost =: These values for capacity and profit levels are the same as in figure 5.1 and 5.2 because all of the parameters are exactly the same. This is to serve as the baseline model and capacity and profit level will be analyzed with ever increasing transportation and Harvest costs.

Now with increasing the transportation costs to $25/ton and harvest costs to $15/ton it is evident from figure 5.4 that the producer's decision to import is greatly affected. Now instead of importing in four of the eight periods the decision is made to only import in the third period and the last period. There are now penalties in two periods. Again in the last period when there is a deficiency of 1,477 MWh and another in the second period of 1,158 MWh. It is seemingly less costly to simply incur the penalty rather than to pay for the extra biomass to avoid being short. Capacity remains unchanged at 12.6 MWe and there is a modest decrease in profits of $2,044. Figure 5.4 below illustrates the effects on the decision to import given a $20/ton increase in transportation.

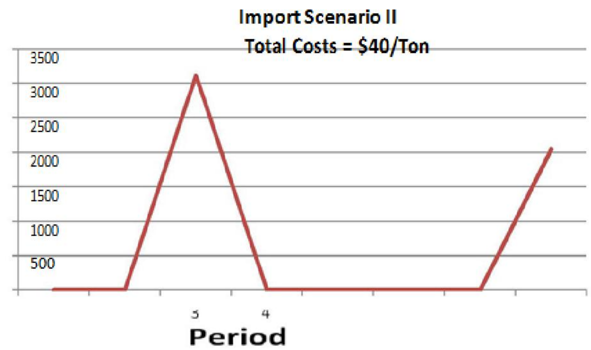

Table 5.4: Decision to import scenario II (transportation cost = $25 & harvest cost = $15).

Group M								
Period	Bumper Crop	2	3	4	5	6	7	Severe Drought
Subsidy Fixed at	$65	$65	$65	$65	$65	$65	$65	$65
Transportation								
Fixed at	$25	$25	$25	$25	$25	$25	$25	$25
Harvest Fixed at	$15	$15	$15	$15	$15	$15	$15	$15
Price/Ton	$47	$45	$36	$14	$70	$138	$175	$195
Import	0	0	3120	0	0	0	0	2044

The total cost to import of $60/ton can be interpreted as an unsubsidized cost for the purpose of this study as it is closer to the real cost of biomass delivery over this distance and local harvest conditions. In this scenario, the only state in which biomass is imported is the last period (8). Here, given the much higher transportation and harvest costs, it makes it less cost effective to import in all but the last period when the drought is most severe. Capacity again remains at 12.7 MWe and profits slightly decrease by $2,045 from the previous model (figure 5.4). Again there is a penalty resulting from a shortage of 1,477 MWh in period 8 and another in the second period of 1,158 MWh. resulting in a combined total loss of $329,375.The brief summary is that subsidizing harvest costs does not increase the amount of bio-energy produced by much at all. To improve the demand for supplements and increase operational scale, raising simply the value of the highest peak electricity price (945 hours our of 7000) has a much larger impact on overall scale (and therefore environmental benefits) and on profits.

Conclusions

The motivations for agri-business industry in to enter the bio-fuel industry are made are strong for a number of reasons. One of these is the clear abundance of cotton gin waste and other sources of biomass such as cotton trash and manure located here. More than 60% of population of Pakistan in engaged in agricultural activities. As per World Bank Statistics around 26,280,000 hectres of land is under cultivation in Pakistan. Cotton region in the world, which makes transportation and other handling, costs relatively cheap. Additionally, technology such as gasification and combustion make feasible the efficient conversion of biomass residuals into products such as bio-fuels and bio-oils. Another very important reason stems from the emerging Policies, which financially incentivize power plants to reduce carbon emission by adopting alternative sources of energy.

This creates a carbon offset market whereby more efficient firms, utility providers in this case, can profit from firms who are currently surpassing their carbon emission levels. Over time, this system is intended to bring down overall levels of emissions to mandated standards. This type of policy brings attention to the concept of carbon accounting. Agents now begin to consider the advantages of one type of energy source against another in terms of reducing their carbon emissions. In this method of analysis, bio-fuels are the clear winner as they not only capable of emitting less carbon than coal and natural gas but also extracting carbon from the atmosphere through carbon sequestration.

An important starting point in considering a bio-fuel platform as a power supplier is its efficiency, measured by capacity and profitability, utilizing bio-fuel from CGW under various uncertainties. The uncertainty examined here is rainfall and the amount of harvested cotton obtainable each year. A power company using CGW that is unable to meet its contractual electricity requirements, resulting from a bad season, is subject to penalty.

Previous work considered using rangeland grass as a supplement to meet the shortages in only the two driest years (states of nature). It incorporated the additional electricity derived from supplemental sources into the model and offset these against penalty shortages to determine optimal capacity. The conclusion was that the ability to import supplemental biomass in the worst two states had no significant effect on the plant's capacity. This work extends previous work by endogenizing the producer's ability to import in any one of the eight states if it is more profitable to do so. Given these findings, the focus then shifted to subsidizing the MWh peak price to determine how this affected capacity.

It was determined that a peak price subsidy had a far more profound effect on capacity than a transportation/harvest subsidy. Capacity more than doubled with a much smaller peak price subsidy than a transportation/harvest subsidy. Additionally, profits more than tripled while the average fixed cost of the operation declined. The incentive to create sufficiently sized plant to take advantage of the large scale is made clear by these findings. At the very least, the studies support the fact that future public policy measures wishing to adopt a viable alternative energy program should evaluate an array of issues not the least of which are proper subsidized spending and carbon offset considerations.

The main limitation of the model used in this study is the data set. With most of the information coming from a number of different sources questions arise as to the data collecting methods and the reliability of their techniques. Yet until a specific technology is chosen – or a set of technology combinations located, these added precisions are not feasible.

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