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The economic potential of switchgrass as a viable biofuel alternative

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The economic potential of switchgrass as a viable biofuel alternative

by

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Program of Study Committee:
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Jinhua Zhao
Lee Burras

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This is to certify that the master's thesis of

Jennifer E. Reutzel

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy

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During my two years of exposure to and work on this project, I have learned more than I ever could have hoped about the potential that bioenergy crops holds in the quickly evolving world of sustainable, "green" energy, knowledge that only served to further my interest in the field. I feel incredibly fortunate to have had the opportunity to work on this research topic, as well as on the Chariton Valley Biomass project itself. My heartfelt thanks goes to all the people connected with the project I have had the privilege to meet over my two years at Iowa State for the insight and additional knowledge they have imparted, and to my family for the unbounded support and encouragement they provided me.

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ABSTRACT

To be commercially viable as a bioenergy feedstock, switchgrass must be cost-competitive. Switchgrass production and delivery costs are calculated for the Chariton Valley Switchgrass Biomass Project located in the Chariton Valley, Iowa. Sensitivity analyses are performed to determine which variables have the greatest impact on cost. Switchgrass production costs would require higher than expected market prices, and therefore various incentive payment options are considered. The incentive payments attempt to encapsulate the positive environmental attributes from the production of switchgrass as well as using switchgrass a clean energy coal substitute. A modified CRP payment, carbon payment and green tag payment are all considered, and their relative advantages and disadvantages are discussed. The modified CRP payment and the green tag payment are shown to have significant potential for offsetting high switchgrass costs of production.

CHAPTER 1. INTRODUCTION

There has been a serious consideration of larger-scale commercial opportunities for green energy use in both the public and private sectors in recent years. A variety of different green sources have been considered and developed. Wind, water, photovoltaic, and solar power seem to be the focus of most green energy initiatives in large commercial practice. However, the use of biofuels as a renewable energy option is growing rapidly in stature.

The term "biofuels" includes such value-added fuels as ethanol, methanol and biodiesel. Such fuels have already established a relatively strong and developed market. The U.S. ethanol industry in particular is the fastest growing energy industry in the world (Dinneen 2004). However, there is a lesser known category of bio-based energy sources. Significant research continues to be done on utilizing a renewable biomass energy crop as a substitute for coal. A wide variety of herbaceous crops and fast-growing trees have been studied to determine which cultivars offer the greatest production and energy potential. In most cases, the high yielding perennial grass species produce the most desirable outcomes. Determining which variety of grass would work best depends on geographic location and other specific agronomic concerns. However in many projects, one particular species, switchgrass, exhibited superior energy and conservation attributes, along with excellent compatibility to conventional farming practices (McLaughlin 1999).

Understanding the economic potential of switchgrass as a biofuel alternative has important implications for clean energy generation and feasibility. Both the public and private sectors have funded research designed to investigate the costs of producing switchgrass relative to other conventional energy sources. Continuing research remains important to determine most accurately the costs of production of these sources.

The production of switchgrass as an energy source presents unique facets for examination because its production would be agriculturally based, i.e. grown and harvested just like any other agricultural commodity. The farmers decision whether to raise the crop would be connected to its production costs. In a competitive agricultural marketplace, most farmers would only choose to produce switchgrass if their profit margins are at least equal to those from their next-best alternative. Before switchgrass can be utilized by industry as a widespread bioenergy crop, farmers must be able to profitably supply it.

The first purpose of this master's thesis is to examine the economic potential of switchgrass as a viable biofuel alternative by estimating its on-farm costs of production, storage and delivery. The second purpose is to address specific government and market-based policies and/or subsidies that would further improve on-farm profitability. The focus of the analysis of these policies will be centered on incentive opportunities available through altering Conservation Reserve Program (CRP) payments, through utilization of carbon payments for carbon sequestration by switchgrass, and through utilization of green payments as compensation for the environmental benefits associated with using switchgrass. These income incentives will be important in determining if farmers are able to ensure a net income at least equal to that associated with raising their next-best alternative.

The Chariton Valley Biomass Project is a switchgrass research venture in south central Iowa funded by a grant through the U.S. Department of Energy. The project will serve as a case study model. All production costs are based on switchgrass production occurring in this area.

CHAPTER 2. THEORY AND LITERATURE OVERVIEW

Positive externalities and their role in profitability could come with the use of switchgrass contribute to its economic viability. A theoretical discussion of externalities follows.

Externalities

By definition, an externality arises when an argument in the production or utility function of one individual enters into the production or utility function of a second individual, the effects of which are not considered by the first individual when making choices. It can be thought of more generally as an effect that occurs when the production or consumption of a given good by one economic agent affects a second agent, but this effect is not taken into account by the first agent in his production or consumption decisions. It is commonly referred to as a "spillover" effect, in that the externality effects of producing or consuming the good "spill over" and impact an unintended second party. Representing the true costs or benefits of this spillover effect in the production or consumption decisions of all affected parties has the potential of a significant effect on their subsequent choices.

Both positive and negative externality effects are possible. If a farmer has cattle grazing in a pasture, and motorists driving by the pasture notice and take pleasure in the beauty of the rural scene, then a positive externality is being generated. The cattle are generating external aesthetic benefits that are not going to be reflected in their market value. Conversely, say a hog confinement owner began running hog manure from his confinement operation into a nearby recreational water body used by the public. The health hazards and other associated environmental problems would be considered a negative externality affecting all individuals using the water body. The confinement owner would not be accounting for the cost to those individuals when choosing whether or not to dispose of the hog waste in that way.

Positive and negative externalities exist in the use of coal versus switchgrass. The cheap cost of coal does not reflect the negative environmental effects generated by its use. The more expensive cost of switchgrass fails to include the environmental benefits brought about by both its production and its use at the power plant. All externalities add either costs or net value to their use; therefore it is important to include them in an analysis between the two.

The use of coal by power plants generates many negative environmental externalities. Gases such as sulfur oxides and nitrogen dioxides released in the burning process contribute heavily to acid rain and smog. They lead to respiratory health hazards in addition to substantial environmental damages such as the altering of pH levels in waterways and soils. There are indirect effects on both plants growing in affected soils and animals that rely on both the plants and the water to survive. Approximately two-thirds of all the sulfur dioxides and one-fourth of the nitrogen dioxides in Earth's atmosphere are released from power plants burning fossil fuels like coal for electric power generation (Almanac of Policy Issues 2002).

By far, the most substantial gaseous by-product (by weight) of burning coal is carbon dioxide. Classified as a greenhouse gas and acting the primary contributor to the effects of global warming, carbon dioxide (CO_2) enters Earth's atmosphere on a much more rapid scale. For example, one average-sized 500 MW coal plant (large enough to power a city of around 140,000) would use approximately 1.43 million tons of coal to produce enough electricity for one year. The coal would annually generate approximately 10,000 tons of sulfur dioxide, 10,200 tons of nitrogen oxide, and 3.7 million tons of CO_2 (Union of Concerned Scientists

2004). Given that 90% of the 1,090 million short tons of coal that were consumed in the U.S. in 2003 alone for electrical power generation, this would translate to approximately 1.8 billion tons of CO_2 being released in that year. Needless to say, CO_2 has now become a significant atmospheric presence (U.S. DOE, *U.S. Country Analysis Brief*, 2004).

Switchgrass production offers a counterpoint to coal's CO_2 expulsion. Switchgrass takes in CO_2 from the atmosphere as part of its life cycle and can sequester, or hold it in its system. Coal releases CO_2 as it burns, while switchgrass captures CO_2 as it grows. When the switchgrass is harvested and then burned to generate energy, it releases CO_2 in the same way coal does. However, burning switchgrass is considered more of a carbon-neutral feedstock. The carbon the switchgrass takes in helps to offset the carbon it releases when it is burned. This is in direct contrast to coal, which when burned is considered a net carbon emitter. In addition, because switchgrass is a perennial grass that maintains a permanent root system, soil organic carbon sequestered below-ground can remain there even after harvest (Bransby 2002).

From an environmental standpoint, switchgrass represents a very real possibility for sustained renewable energy generation. From an energy standpoint, researchers have found it to be one of the best biomass substitutes for coal. But can switchgrass be cost-competitively grown by producers? Further, if necessary, could it be subsidized effectively to ensure its profitability? Two papers are helpful in examining these questions.

The Conservation Reserve Program as a Means to Subsidize Bioenergy Crop Prices (Walsh):

Walsh et al discuss the financial opportunities of using the federal Conservation Reserve Program (CRP)—established in the 1985 Farm Bill—as a means to create financial incentives for bioenergy crop production. CRP promoted environmental stewardship on less productive or potentially environmentally sensitive farmland. Its goal was initially to create a land conservation incentive by offering rental payments in exchange for farmers agreeing to abstain from using the land. Conservation must be maintained, and no economic benefit can be accrued to the farmer from use of the contracted land.

Bioenergy production (focused on switchgrass), however, is based on growing conservation crops. These crops naturally maintain the integrity of CRP's conservation and environmental objectives. If farmers were allowed to grow conservation crops like switchgrass for profit on their CRP land, and in return were given a reduced percentage of their full CRP rental payment, the payment could serve as a de facto subsidy payment for the production of bioenergy crops and increase their competitiveness relative to fossil fuels. This scenario, however, would differ from the "standard subsidy scenario" because the government would actually benefit as well, reaping the cost-saving benefits of paying out a reduced rental payment on those CRP acres (the federal government explored such an idea for the 1995 Farm Bill as a way to reduce the program's cost, but the plan was dropped in the final version).

Walsh et al attempt to estimate the potential of reduced CRP payments for increasing bioenergy crop competitiveness. They used both switchgrass and short rotation woody crops as their bioenergy crop models. Data was gathered from the mid-Plains states, where switchgrass production is best supported. They assumed switchgrass production on all suitable CRP acres (defined as all CRP acres in land capability classes 1-4) within the geographical range. Taking the full CRP rental rate as the opportunity cost of putting the land into bioenergy crop production, they assumed farmers will choose to raise such crops only if their expected income is at least equal to their opportunity cost (Equation (1)). In Equation (1), the CRP rental rate is represented by R and the bioenergy crop price is represented by BP. The bioenergy crop yield and production cost are represented by Y and C, respectively.

$$R = (BP \cdot Y) - C \tag{1}$$

The authors discuss two different approaches to utilizing the CRP payment. They first discuss the option of a deficiency-type payment. The deficiency payment would equal the difference between the established CRP rate and the profit they earn from the biomass crop. The maximum deficiency payment the government would pay out was defined to be full CRP rental payment (the payment situation that would occur if farmers broke even and there was no profit).

The authors also consider the idea of a set rental reduction payment. This payment along with bioenergy crop profits would have to equal at least the full CRP payment without crop production in order to be a successful production incentive. This predetermined reduced payment percentage option has the added benefit of guaranteeing a set program cost to the government, depending on the percentage chosen.

This research only evaluates the predetermined CRP reduced payment and not the modified deficiency payment. Therefore, empirical results presented from the Walsh paper will only be for the predetermined reduced CRP payment.

Utilizing two sample reduction rates of 20% and 40% and sample total crop harvest totals of 9.1M Mg and 45.5 M Mg (approximately 10 and 50 million tons, respectively), they found the crop prices needed to create a state of indifference for producers between crop production with the CRP subsidy and accepting the full CRP rental payment. Table 1 shows their results.

Walsh et al estimate that when there are a total of ten million tons of switchgrass available for sale in the national market, a switchgrass producer yielding four tons/acre off his land and receiving 80% percent of his CRP payment (i.e. a 20% reduction rate) would need a switchgrass farmgate price of $21.82/ton. By the same token, the same producer with the same payment and yield but operating with a national switchgrass yield of 50 million tons would yield a price of $27.27/ton. The authors note that these prices do not include transportation costs to a user facility, which is estimated to add between $5-$10/ton depending on the distance traveled.

Table 1: Estimated Farmgate Prices Under CRP Reduction Rates (Walsh Table 2)

Switchgrass						
	20% CRP Reduction Rate			40% CRP Reduction Rate		
Yields	4 tons/ac	5 tons/ac	6 tons/ac	4 tons/ac	5 tons/ac	6 tons/ac
At 10M tons:	$21.82	$20.00	$19.09	$23.64	$21.82	$20.91
At 50M tons:	$27.27	$25.45	$21.82	$30.91	$28.18	$25.45

The authors go on to discuss the likelihood of achieving these prices. They note that bioenergy prices hinge on not only yield but on total crop supply (in other words, full participation by all eligible CRP contractors). Their work estimates switchgrass prices needed to make production profitable when large scale production is already assumed, and they show the reduced payment to be a viable bioenergy subsidy.

Developing Switchgrass as a Bioenergy Crop (McLaughlin)

McLaughlin et al provide an extensive overview of many of the different facets of research going into determining exactly if and how switchgrass will be made a commercially viable bioenergy crop. The authors provide an in-depth examination into various molecular and agronomic aspects of the switchgrass species, the details of which will not be discussed here. The relevant points taken from the work are the economic potential of switchgrass on a commercial level.

Similar to Walsh et al, McLaughlin et al emphasize the fundamental importance of any bioenergy crop to be able to compete, both as a stand-alone crop in addition to as a green fuel. As a production crop, it must be able to at least match the net income possible from the land's other potential use(s), and must do so in a stable and consistent way. Producers need assurance that not only will raising a bioenergy crop be profitable, but that it will be profitable consistently over time. Uncertainty and any subsequent risk involved in its ability to provide them with a stable income will have a significant effect on their desire to raise a crop. As a fuel, its quality must be able to rival other more traditional energy sources in addition to other green sources.

After including a detailed presentation of the current status of switchgrass agronomic research, McLaughlin et al move to an overall review of commercial implications and considerations connected with switchgrass production. They first establish whether there is a need within the biomass-based fuel source market to warrant commercial production. Biomass wastes (for example, wood and agricultural residues), which are much cheaper and less labor-intensive to supply, would be considered switchgrass' initial rival. For this reason, the authors place important consideration on these sources in establishing an initial biomass market.

Biomass wastes are estimated to be capable of supplying between 18 and 60 percent of the production potential possible by raising energy crops on currently idle land. In addition, switchgrass production dedicated specifically for energy usage would also offer more stable control over feedstock supply, as well as over the quality and price of the supply. As a result, the ability to develop switchgrass into a competitive energy crop is considered important for future renewable energy market development (McLaughlin 1999).

McLaughlin et al also report on the findings of an earlier study by Walsh et al (1998) that sought to find average national bioenergy cost estimations. They report that Walsh et al's study found estimated average national production costs of bioenergy crops in general could range from \$22 to \$110/dry Mg (\$20 to \$100/dry ton) and transportation costs from \$5 to \$8/Mg (\$4.55 to \$7.27/dry ton), assuming an average 25 mile transport distance. These estimations encompass variables such as the geographic region of production, the type of crop produced (switchgrass being one of the possible options), and the type of estimation method used.

McLaughlin et al go on to further specify another interesting analysis. Table 2 shows the estimated national land area needed to be available for switchgrass production if different switchgrass price levels are going to be met. The authors assume a set switchgrass demand function (unspecified in their paper) to do so. Recall that these are national averages, across all regions.

Table 2: Comparative Land Area For Two Producer Price Levels

Price	Needed land	Biofuel quantity	Price	Needed land	Biofuel quantity
$35/ton	9.63M acres	49.5M tons	$50/ton	17.3M acres	86.9M tons

To achieve a switchgrass price of $35/ton, they estimate a total of 49.5 million tons of biofuel feedstock will be needed, which will necessitate a land commitment of approximately 9.63 million acres. At $50/ton, the necessary land commitment would rise to 17.3 million acres producing 86.9 million tons of biofuel feedstock. Note that both of these scenarios work out to an average yield of slightly over five tons/acre, regardless of switchgrass price level.

Conclusions

The empirical papers by Walsh and McLaughlin offer unique insight into U.S. biomass projects. Both provide estimates of switchgrass production costs. Interestingly enough, they also calculate the production level the switchgrass producers would have to reach in order to reach various switchgrass market price levels. They are excellent resources for use in comparison of results across different bioenergy projects.

Switchgrass Adoption

In addition to estimating switchgrass production costs and market prices, it is important to see how farmers decide whether or not to initially plant switchgrass production. Hipple et al interviewed farmers in the Chariton Valley area to determine what factors contributed most significantly in their switchgrass adoption decision. Interviews were conducted with farmers who grew switchgrass and as well as with those who did not.

Farmers' Motivations for Adoption of Switchgrass (Hipple et al 2002)

The Hipple study used a random sample of fifty two farmers—forty-seven men and five women—in the Chariton Valley area. The study used an ethnographic survey of farmers' individual beliefs and values regarding switchgrass production. Some of the farmers sampled were already switchgrass producers while some were not. Some of the farmers not currently producing switchgrass were interested in learning more about production and how to get involved, while some expressed no interest at all. Extensive interviews were conducted with all participants.

Many of the farmers interviewed said they initially adopted switchgrass through the persuasive recommendations of other switchgrass farmers. Word of mouth was a strong initiator, especially from another local producer. Chariton Valley farmers were seen to have a high degree of trust for the ideas and projects of other locals.

The author also observed barriers that either stand in the way of switchgrass adoption or play a role in a farmer's decision to adopt. One of the primary barriers is the cultural individualism common to the area. Southern Iowa farmers are described as being very set in their ways and reluctant to consider new or alternative methods of farming. They may be more resistant to adopting switchgrass production because it would represent a departure from their current farming routine. A farmer speaking on behalf of Prairie Lands, the Chariton Valley farmers' switchgrass cooperative, also referred to their farmers' preference, stating that they like keeping things "as they've always been", with tradition for tradition's sake being important to them.

Also, the farmers in the Chariton Valley farm land known to be some of the most agronomically challenging in the state. This can add to their preference for leaving the land as it is. A significant portion of Chariton Valley farmland is already enrolled in the CRP. They may be less willing to try something new on this land because they feel the land is already of questionable crop value. Switchgrass adoption would pose a risk, and they may prefer to not to take a gamble. They may place a higher value on the guaranteed income of either a CRP payment or a traditional row crop harvest with the reassurance of government support payments.

On the other hand, for farmers who have chosen to adopt switchgrass, a major incentive they had for doing so initially was the valuable wildlife habitat it offered. Many farmers took advantage of the prime hunting cover switchgrass provides. At least one farmer interviewed spoke of being paid for leasing the land to an outside corporation for hunting purposes. Others interviewed took advantage of switchgrass' effectiveness as CRP cover and controlling soil erosion, in addition to being interested in raising it as an actual bioenergy feedstock and participating in the Chariton Valley biomass project.

Summary of Hipple et al findings

Hipple et al report that overall, profitability and long-term sustainability tended to be the first consideration for most farmers contemplating switchgrass adoption. They want to feel certain they will make a return on their investment, and that it will continue to be profitable to raise switchgrass. They also want to be sure switchgrass production fits in with their overall farming operation and that they feel comfortable with assuming any additional economic risk that comes with switchgrass adoption.

In addition to profitability, the authors found many other motivators for switchgrass adoption. While not monetary, they still played a significant role in their general decision process. Many farmers will weigh the decision against their own social beliefs and values.

They look to see how adoption reflects their feelings on the environment, on land stewardship, and on their own mission in life. They examine whether or not they feel like there is a true need for the production of the crop, and if it is fulfilling an important purpose by being produced. They could also consider how switchgrass production affects their local community and the rural economy. Most farmers interviewed stated that all of these questions influenced their decision-making processes in different ways. They all vary in relative importance over time and are considered as a whole, weighing the relative advantages and disadvantages.

The Hipple et al study provides an excellent study of what motivates a farmer's consideration of switchgrass adoption. Though profitability is a primary consideration in their decision, farmers seem very likely to take into account other more intangible considerations as well. Understanding what influences a switchgrass adoption decision is crucial to understanding how to make the decision a more advantageous one for farmers.

CHAPTER 3. CHARITON VALLEY BIOMASS PROJECT

The Chariton Valley Biomass Project is a switchgrass research venture partially funded by the U.S. Department of Energy. The project is located in southern Iowa in Appanoose, Decatur, Lucas and Wayne counties. Its primary goal is to "...demonstrate biomass (switchgrass) and coal cofiring technology with a vision of developing markets for energy crops in southern Iowa." (Chariton Valley Peer Review 2003) Essentially, researchers wish to determine if and under what conditions it would be feasible for local farmers in the Chariton Valley area to raise and sell switchgrass commercially as an alternative energy crop. The project is currently overseen by the Chariton Valley Resource Conservation and Development office in Centerville, Iowa. It has also brought together the formation of a local switchgrass farmers' cooperative group, Prairie Lands, Inc., as well as a team of over a dozen both public and private research groups.

The Ottumwa Generating Station located in Chillicothe, Iowa, is the Iowa power plant participating in this pilot research. It is owned by Alliant Energy® and is the third largest generating station in the state. The plant could use switchgrass as a substitute for up to five percent of the coal used. At commercialization, the project could involve up to 500 Chariton Valley farmers as producers and utilize up to 200,000 tons of switchgrass per year raised on an estimated 50,000 acres of land (Antares 2002). Switchgrass could generate 35 MW of power at the Alliant plant when burned at the 5% co-fire rate (Hipple 2002).

A two week test burn was successfully completed by Alliant in December 2003. A second, longer, test burn is scheduled for the winter of 2005-2006.

CHAPTER 4. SWITCHGRASS COSTS OF PRODUCTION

Switchgrass Description

When the Oak Ridge National Laboratory began researching potential bioenergy feedstocks in 1978, they were looking for crop species that would encapsulate many different characteristics. A good feedstock would have relatively high energy production potential and low ash content when burned. It would also be high-yielding, fast-growing and resilient in a variety of different growing environments. After extensive testing of more than 30 different herbaceous crop species throughout the 1980's, researchers selected switchgrass (McLaughlin 1999).

In addition to having all the desired attributes, this perennial grass crop was easily adaptable to conventional farming practices and offered many additional beneficial environmental and conservation characteristics. One of switchgrass' greatest assets is its deep root system, which can reach over ten feet deep. This root system creates improved soil water infiltration and gives it greater capacity to hold nutrients and sequester carbon. It also allows switchgrass to serve as a superior protector against soil erosion, a problem that can plague farmers growing traditional annual cash crops without such permanent root systems. Above ground, switchgrass fields serve as excellent habitat for a wide variety of wildlife, providing both home environments and protective cover (Bransby 2002).

Switchgrass is a very low-maintenance perennial crop, requiring less chemical application than traditional row crops. In the establishment year, farmers plant switchgrass from February to March for frost seeding, or mid-April to late May for spring seeding. No nitrogen is used in the first year to allow the switchgrass a better opportunity for firmer establishment (weeds are especially harmful in this first year when the stand is taking first hold). Also in the first year there is no harvest taken to allow the stand to take root. Aside from the probability of a potential reseed in the second year to strengthen the stand, no reseeding is necessary.

Once the stand enters standard yearly production, only fertilizer and herbicide applications are needed. The stand will reach two-thirds of its potential height in its second year, and is considered fully developed by its third. Switchgrass harvest begins in the second year and can be done using standard hay harvesting methods—mowing, raking and baling the grass for collection (Teel et al, 2003 (a) and (b)).

All of the above characteristics allowed switchgrass to be selected as the bioenergy crop with the most potential for commercial success. More detailed discussion of switchgrass and its agronomic and environmental attributes can be found in McLaughlin, Bransby, and Burras. Specific production descriptions used in this analysis can be found in Appendices A and B.

Estimating Switchgrass Costs of Production

Budget projections for switchgrass production are broken down into three different stages: the initial establishment costs, the projected reseeding costs, and the annual standard production costs. Establishment costs include the pre-seeding machinery costs (disking, harrowing, mowing, etc.), seed costs, and any chemicals/fertilizers used. In some cases the switchgrass stand may not establish or will establish too thin. Reseeding costs will factor in the probability that a field will need to be reseeded and will include any equipment and additional seed and chemical/fertilizer needed to do so. Finally, the annual production costs represent the typical yearly costs for machinery, chemicals and fertilizers, and harvest costs.

Costs are calculated both on a per-ton, as well as a per-acre basis. Each of these three production budget stages will be discussed in more detail in following sections.

General Budget Assumptions

All machinery/equipment costs are from Duffy et al (2004). Labor use estimates are derived from Hanna (2001). Both of these represent the most up-to-date cost estimations available for the Chariton Valley region. In the case of machinery costs, both the power unit and implement charge are included, as are both fixed and variable costs. A 6.0% amortization factor and a 7.0% interest rate on any operating expenses are used in the calculations. In addition, a frost seeding scenario is assumed. As noted, switchgrass can also be seeded in the spring, but frost seeding is the dominant seeding method. The switchgrass average stand life is assumed to be ten years. A wage rate of $10/hour is assumed for all labor.

Due to differing land rent charges, switchgrass costs were estimated assuming production on both cropland as well as grassland. Different land charges were used to reflect this distinction. Cropland rent was assumed to be $98/acre and grassland, $55/acre. These values are based on farmland rents for the four Chariton Valley counties (Edwards et al 2004(b)). It is important to note that though an average land charge was used for each of the two land types, there is still land heterogeneity within each type. That is, within each land type a given acre could have varying productive potential using the same inputs but given different producer skill sets or other outside variables.

Additional production assumptions will be discussed in their appropriate sections. Appendices A and B provide a complete breakdown of calculated costs for each section.

Establishment Year: Year 1

Table 3 shows the estimated switchgrass establishment year costs for both cropland and grassland, respectively. In the establishment year, equipment is needed for land preparation, planting, and fertilizing/spraying. Ten lbs. of pure live seed (PLS) are used (cost estimates are based on the usage of the Iowa Cave-In-Rock seed variety), and standard application of fertilizers (N, P and K), chemicals (atrazine, 2,4-D and Roundup®), and lime is assumed (see tables). The switchgrass is not harvested in its inaugural year because it is not hardy enough to do so (the assumed ten-year stand life does not begin until the following year, the first year of allowed harvest). The costs are calculated on both a per-acre and per-ton basis, and then are prorated using a default 6.0% amortization factor for eleven years. The costs can then be evenly distributed forward to each of the subsequent ten production years. A detailed budget breakdown of the costs found in Table 3 can be found in Appendices A and B.

Table 3: Switchgrass Establishment Costs ($/ton):

Land Type	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
Cropland	$15.15	$7.57	$5.05	$3.79	$3.03
Grassland	$14.00	$7.00	$4.67	$3.50	$2.80

Reseeding Costs: Year 2:

Table 4 shows the estimated reseeding costs of a switchgrass stand for cropland and grassland, respectively. Reseeding occurs when the full seeding from the establishment year does not fully establish. It is not always necessary to reseed, so this cost is adjusted by the expected probability that a reseeding becomes necessary (Teel et al, 2003(b)). The calculation done here assumes a default reseed probability of 25%.

Reseed costs must also include the additional PLS needed (7 lbs.), as well as the associated planting/spraying machinery, and the standard fertilizer and herbicides (no land preparation is necessary) and here as with the establishment year there is no switchgrass harvest). The totals are then multiplied by the reseed probability factor to determine an appropriate expected cost value. The total cost value is again prorated at a default value of 6.0%, this time at ten years out to determine the reseed cost per year.

Table 4: Switchgrass Reseeding Costs ($/ton):

Land Type	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
Cropland	$2.96	$1.48	$0.99	$0.74	$0.59
Grassland	$2.23	$1.11	$0.74	$0.56	$0.45

Annual Production Costs:

Table 5 illustrates the estimated annual production costs for cropland and grassland, respectively. Switchgrass receives annual fertilizers (N, P and K) and is treated with herbicides (atrazine, 2,4-D). The costs of these chemicals as well as the machinery to apply them are included in the budget. Interest on production operating expenses is set at a default 7.0%. Note that, per standard practice, the amount of fertilizer application will vary with yield due to different P&K removal rates. All annual harvest costs are also included in these estimations. Square bales are assumed, each weighing approximately 950 lbs.

Table 5: Switchgrass Yearly Production Costs ($/ton)

Land Type	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
Cropland	$90.05	$52.54	$40.04	$33.79	$30.04
Grassland	$68.55	$41.79	$32.87	$28.41	$25.74

Finally, staging and loading costs are considered. A hay wagon is assumed to haul the staged bales from the field to the farm. The cost estimate is calculated to include the hay wagon carrying the staged bales from points of collection in the field back to the farmstead, and then returning to the field for another pickup. Note that cost estimates for baling, as well as staging and loading, are calculated on a per-ton basis, indicating that overall harvest costs will also be a function of yield (See Appendices A and B).

Total Production Costs:

Combining the prorated establishment and reseed costs with the standard annual production costs yields the total estimated production costs for switchgrass grown on both cropland and grassland. See Table 6 for a breakdown. As can be seen, total costs will vary substantially depending on switchgrass yield.

Table 6: Total Annual Switchgrass Production Costs ($/ton)

Land Type	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
Cropland	$108.15	$61.59	$46.07	$38.31	$33.66
Grassland	$84.77	$49.90	$38.27	$32.47	$28.98

Average switchgrass yield in Chariton Valley is currently approximately 2-3 tons/acre. Four tons/acre is what has been deemed to be expected out of the current growing conditions and seed cultivars. With continued research, the hope is to boost this yield closer to six tons/acre (Brummer 2004).

Sensitivity Analysis (Yearly Production Costs):

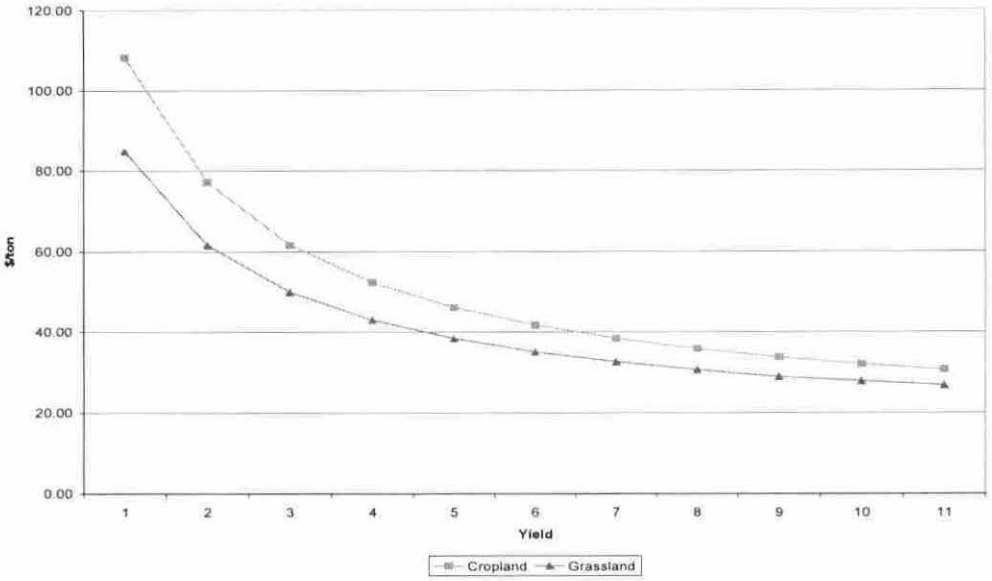
Yield:

Yield has the most significant impact on total production costs. Total production costs as a function of yield are represented in Table 6 for cropland and grassland, respectively, and are illustrated in Figure 1. At the lowest yield levels, even a small increase in yield has a dramatic impact. As yield improves, this affect is dampened as diminishing marginal returns set in. By the time a producer reaches the highest yield levels, total costs have leveled out. Establishment and reseed costs have been spread over a larger yield and only annual harvest costs (as a portion of annual production costs) continue to accumulate for each ton. As a result, each additional ton produced yields less of a marginal cost per ton reduction. See Figure 1.

Impact:

This result has both advantages and disadvantages from a producer's perspective. To illustrate this, examine the case of Chariton Valley producers. Any increase in yield they can achieve will dramatically improve their projected cost outlook. For the Chariton Valley fields, four tons/acre on average is thought to be an achievable switchgrass yield (based on soil type, topography, breeding, etc.) (Brummer 2004). For producers not consistently matching that yield, improving yields even by one ton/acre will allow significant reductions in their per-ton production costs.

Figure 1: Total Production Costs as a Function of Yield: Cropland and Grassland



Continued agronomic research can help producers towards this goal, as researchers work to improve yield performance through better selective breeding, etc. Over time, researchers hope to have the ability to boost average yields up to six tons/acre for the area. But producers individually can also have an effect on their yields through improved production management practices they can easily take on themselves (Brummer 2004).

On the other hand, at those same 2-3 tons/acre yield levels, any yield decrease can bring about a similarly dramatic effect, but a less desirable one. Producers are more economically susceptible to yield variations and shifts at lower yield levels, and even small yield decreases will increase costs of production significantly. The lower the yield the producer is averaging, the larger the production cost increase will be if his yields drop. With seasonal uncertainties—temperature, rainfall, etc.—always being a producer concern (even with the resilience of switchgrass as a crop species) this yield effect is an important one to note.

Land Value:

The land charge also has a significant impact on total production costs. Table 7 shows the effect of varying land charge, ranging from $0 to $150/acre. Within each yield level, total production cost adjusts noticeably as a function of the charge. As yields increase, the effects diminishes somewhat, but at the low-to-middle yields where current Chariton Valley production levels are falling, the land charge does make a difference.

Table 7: Variance in Land Charge

Land Charge	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
$0/acre	$51.27	$33.15	$27.11	$24.09	$22.28
$50/acre	$80.29	$47.66	$36.79	$31.35	$28.08
$75/acre	$94.80	$54.92	$41.62	$34.97	$30.99
$100/acre	$109.31	$62.17	$46.46	$38.60	$33.9
$125/acre	$123.82	$69.43	$51.29	$42.23	$36.79
$150/acre	$138.33	$76.68	$56.13	$45.86	$39.69

Impact:

Producers can expect to have some level of control over their land charge. By choosing acres to plant as switchgrass that have a lower land charge, producers can lower their production costs. But in doing this they may face a trade-off. Farmland prices derive much of their appraised value from productivity indicators such as soil type, propensity for erosion, general topography, etc. Choosing to plant switchgrass on low-valued fields would save them money in land charges, but the less productive land could keep yield low as well. Conversely, more productive land with a higher associated land charge will be more expensive but has the potential to generate higher yields. Choosing what land to devote to switchgrass production is a key tradeoff decision that producers must make. It will be up to each individual producer to evaluate and balance these two variables so as to have the best affect on their individual production costs.

It is also important to note that land charges in general have been significantly rising in recent years. Land is becoming increasingly valuable, and farmland prices and rental rates reflect this. Switchgrass production budget estimates for Chariton Valley generated previously in 2003 were revised in 2004, with the major change being in the estimated average land rent charge. Cropland especially appreciated in average rent charge. The average cropland rental for the four Chariton Valley counties was adjusted upward from $75/acre to $98/acre, and average grassland rental from $50/acre to $55/acre during that time frame. These increases show that though producers will always retain control over choosing which land they devote to switchgrass production, changes in land charges will still affect their total achievable production costs.

Table 7 shows the comparison between the varying yield levels at both $75/acre and $100/acre. This gives a good idea of what such an increase will do to total production costs. At two tons/acre yield, production costs rise from $94.80/ton to $109.31/ton with the land charge increase. At a higher yield of six tons/acre, the increase is smaller, from $41.62/ton to $46.46/ton. This illustrates that when choosing land for switchgrass production and weighing the tradeoff between choosing highly productive land or land with a low rent charge, the land charge a producer can manage will need to remain a carefully and individually evaluated cost.

Additional Variables:

In addition to yield level and land charge, other potentially influential variables were tested for their impact on total production costs on both cropland and grassland. Wage rate, amortization rate, seed costs, and reseed probability changes were all examined. The results of these estimations are shown in Tables 8 through 15. None of the variables create a significant cost difference. The high cost impact is still seen between yield levels, and within those levels the tested variables' effects were minor.

Table 8: Variance in Wage Rate on Cropland

Wage Rate	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
$6.00/hr	$106.53	$60.43	$45.06	$37.37	$32.76
$8.00/her	$107.34	$61.01	$45.56	$37.84	$33.21
$10.00/hr	$108.15	$61.59	$46.07	$38.31	$33.66
$12.00/hr	$108.96	$62.17	$46.58	$38.78	$34.10
$14.00/hr	$109.77	$62.76	$47.09	$39.25	$34.55

Table 9: Variance in Wage Rate on Grassland

Wage Rate	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
$6.00/hr	$83.15	$48.73	$37.26	$31.53	$28.09
$8.00/her	$83.96	$49.32	$37.77	$32.00	$28.53
$10.00/hr	$84.77	$49.90	$38.28	$32.47	$28.98
$12.00/hr	$85.59	$50.49	$38.79	$32.94	$29.43
$14.00/hr	$86.40	$51.07	$39.30	$33.41	$29.88

Table 10: Variance in Amortization Rate on Cropland

Amort. Rate	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
4.00%	$106.36	$60.70	$45.48	$37.87	$33.10
6.00%	$108.15	$61.59	$46.07	$38.31	$33.66
8.00%	$110.02	$62.53	$46.70	$38.78	$34.03
10.00%	$111.98	$63.51	$47.35	$39.27	$34.42

Table 11: Variance in Amortization Rate on Grassland

Amort. Rate	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
4.00%	$83.17	$49.10	$37.75	$32.07	$28.6
6.00%	$84.77	$49.90	$38.28	$32.47	$28.98
8.00%	$86.46	$50.74	$38.84	$32.89	$29.32
10.00%	$88.21	$51.62	$39.43	$33.33	$29.67

Table 12: Variance in Seed Cost on Cropland

Cost ($/lb.)	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
$5.00	$106.64	$60.84	$45.57	$37.94	$33.35
$6.00	$107.40	$61.21	$45.82	$38.12	$33.51
$7.00	$108.15	$61.59	$46.07	$38.31	$33.66
$8.00	$108.90	$61.97	$46.32	$38.50	$33.81

Table 13: Variance in Seed Cost on Grassland

Cost ($/lb.)	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
$5.00	$83.27	$49.15	$37.78	$32.09	$28.68
$6.00	$84.02	$49.53	$38.03	$32.28	$28.83
$7.00	$84.77	$9.90	$38.28	$32.47	$28.98
$8.00	$85.53	$50.28	$38.53	$32.66	$29.13

Table 14: Variance in Reseed Probability on Cropland

Probability	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
0%	$105.19	$60.11	$45.09	$37.57	$33.06
10%	$106.37	$60.70	$45.48	$37.87	$33.30
25%	$108.15	$61.59	$46.07	$38.31	$33.66
35%	$109.33	$62.18	$46.47	$38.61	$33.89
50%	$111.10	$63.07	$47.06	$39.05	$34.25

Table 15: Variance in Reseed Probability on Grassland

Probability	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
0%	$82.55	$48.79	$37.54	$31.91	$28.54
10%	$83.44	$49.24	$37.83	$32.13	$28.71
25%	84.77	$49.90	$38.28	$32.47	$28.98
35%	$85.66	$50.35	$38.58	$32.69	$29.16
50%	$87.00	$51.02	$39.02	$33.02	$29.43

Switchgrass Storage Costs

Production costs thus far have included only actual field production of the switchgrass itself. Logistically, after the switchgrass is harvested, producers must still store the switchgrass bales until they can be transported from their farms to the power plant. When utilized as an energy feedstock, switchgrass is optimally harvested only once per year. The power plant, however, would be co-firing the switchgrass bales year-round. They would need a steady, regularly-scheduled supply of bales, meaning that producers would need a location for storing the bales before they are hauled to the plant.

If the power plant is willing to provide storage for the bales on-site at the plant, producers would not need to factor storage costs into their own production costs. Most likely, however, this will not be the case. The plant is assumed to be more likely to leave bale storage to the producers. Producers are assumed to pay for their own bale storage. For these estimations, it is assumed that farmers would deliver switchgrass bales directly to the power plant without having to store them long-term on-farm only during harvest season. The rest of the year they would require a place to store the remaining bales until their future delivery.

Many options are available for switchgrass bale storage, all varying in price and their potential for protective cover. Information on various storage options available and their associated potential dry matter loss (the effectiveness of the structure at keeping the bales free of moisture) was available through previous Chariton Valley research (Brummer et al 2002). They are presented in Table 16. For more detailed descriptions of these storage scenarios, see Brummer et al 2002.

Table 16: Switchgrass Storage Scenarios

Storage Scenario	Dry Matter Loss (DML) %
Outside, unprotected on crushed rock	15%
Reusable tarp on crushed rock	7%
Open-sided pole frame structure on rock	4%
Hoop barn	4%
Enclosed pole frame structure on rock	2%
Pre-manufactured steel storage shed	2%

Recall that during the harvest season, producers have the opportunity to deliver switchgrass bales directly to the power plant which eliminates the need for more long-term, off-site storage. As a result, it is assumed that the switchgrass storage scenarios seen here would not have to house all the harvested bales year-round. A switchgrass harvest season can last for approximately two months. Therefore, it is assumed that the selected storage structure would be used for holding switchgrass bales ten out of the twelve months per year. This generates the assumption that roughly 82% of the total amount of switchgrass harvested in a year would require off-field storage.

In order to calculate the net cost of the above scenarios, the "actual" cost of each storage structure must be adjusted to reflect the additional cost incurred by factoring in its DML. This is achieved by taking the percentage of the switchgrass market price that is associated with the storage structure's DML and adding it back into the storage structure's cost (represented under the "Cost with DML" heading in Table 17). The adjustment essentially becomes an added cost representing the loss of quality incurred. An additional assumption is made, that switchgrass' initial market price (before the DML loss is factored in) is set at $50/ton. The total project cost is multiplied by 82% to reflect the estimated storage occurrence (for ten out of twelve months per year), which then yields the final structural project cost. The calculated storage costs for all storage structures can be found in Table 17.

Table 17: Estimated Switchgrass Storage Costs

Storage	Cost without DML ($/ton)	DML (%)	DML @ $50/ton	Cost w/ DML ($/ton)	Project Cost ($/ton)
Hoop Barn	$5.35	4	$2.00	$7.55	$6.19
Tarp	$5.03	7	$3.50	$8.53	$6.99
Unprotected	$1.07	15	$7.50	$8.57	$7.03
Open Pole	$6.62	4	$2.00	$8.62	$7.07
Closed Pole	$13.24	2	$1.00	$14.24	$11.68
Steel Shed	$16.10	2	$1.00	$17.10	$14.02

Transportation

The estimation of transportation costs is based on an estimation done in Brummer, et al (2002). In this estimation, transportation costs include the cost of moving switchgrass bales from the producer's on-farm storage facility to the delivery site at the power plant (transportation of the bales from the harvest field to the farmstead is covered in the harvest costs within the annual production budget). The estimate assumes a driver and a standard truck/semi-trailer to haul the bales.

The average travel distance to the power plant is estimated at 40 miles, or 80 miles roundtrip, representing the average distance of a Chariton Valley producer farm from the

Ottumwa Generating Station in Chillicothe. A standard semi-trailer truck capable of carrying approximately 18 tons of switchgrass is assumed. This translates to approximately 38 total switchgrass bales with each bale weighing 950 lbs. The driver's labor is valued at $12/hour. His wait time during the loading of the truck on-farm and the unloading of the bales at the power plant is estimated to be forty-five minutes each time, or ninety minutes for the total trip (Brummer et al 2002).

To estimate the cost of moving a truckload of switchgrass per mile, Edwards et al (2004(a)) was used. Edwards et al reported an average of $1.75/truckload/mile, within a projected range of $1.00 to $2.25/truckload/mile, for moving round bales by truck (a close estimate to this square bale scenario). In this calculation, $1.90/truckload/mile was used (due to the potential of fluctuating energy costs, it was thought to estimate high within the given range). The calculation can be seen in the following steps:

$$\textit{\$1.90/truckload/mile} * \textit{80 miles} = \textit{\$152/load or \$8.44/ton} \tag{2}$$

$$\textit{\$12/hour} * \textit{1.5 driver labor hours} = \textit{\$18/load or \$1/ton} \tag{3}$$

$$\boldsymbol{\textit{\$8.44/ton}} + \boldsymbol{\textit{\$1/ton}} = \boldsymbol{\textit{\$9.44/ton}} \tag{4}$$

Total Delivered Switchgrass Costs

Combining the total switchgrass production costs with the selected storage and transportation scenario costs produces an estimate of the total delivered costs associated with switchgrass production. The estimations found in Tables 18 and 19 (cropland in Table 18 and grassland in Table 19) represent the cost of producing switchgrass from the first establishment planting through to the delivery of the switchgrass bales to the power plant door.

Table 18: Switchgrass Total Delivered Costs for Cropland

Total Delivered Cost	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
Production Cost	$108.15	$61.59	$46.07	$38.31	$33.36
Storage	$6.19	$6.19	$6.19	$6.19	$6.19
Transport	$9.44	$9.44	$9.44	$9.44	$9.44
Total ($/ton)	**$123.78**	**$77.22**	**$61.70**	**$53.94**	**$49.29**

Table 19: Switchgrass Total Delivered Costs for Grassland

Total Delivered Cost	2 ton/acre	4 ton/acre	6 ton/acre	8 ton/acre	10 ton/acre
Production Cost	$84.77	$49.90	$38.28	$32.47	$28.98
Storage	$6.19	$6.19	$6.19	$6.19	$6.19
Transport	$9.44	$9.44	$9.44	$9.44	$9.44
Total ($/ton)	**$100.40**	**$65.53**	**$53.98**	**$48.10**	**$44.61**

Production Cost Conclusions

Total delivered switchgrass costs for both cropland and grassland will vary widely as a function of yield. This result emphasizes the importance of yield on production costs. Yields, and the cost differences associated with them, will make a significant difference in whether or not switchgrass can be a commercially competitive bioenergy crop. It is the primary variable for producers and researchers to address. Continued agronomic research can serve an excellent purpose in breeding higher-yielding cultivars. Improved producer management techniques will be important too. They can be used in both the short and long term as relatively easy ways to improve yield. Even minimal gains of only one ton/acre or smaller drastically affect the deliverable cost/ton.

The importance of yield also ties in to the importance of land charges and how they relate to the overall costs of production. Table 7 showed how production costs can be significantly affected by varying land charges. In addition, land charges can be an indicator to the productive potential of the land. High-priced farmland tends to be high-quality farmland, with the potential to produce higher yields. Switchgrass producers wanting to generate high yields to keep production costs low will have to determine what land is going to give them the highest yield potential at the lowest cost. Land selection is thus a key decision for producers, and must be made on an individual level.

It is also worth noting how the total deliverable cost of switchgrass is dominated by the actual production costs. In Tables 18 and 19, at two tons/acre yield, production costs total $108.15/ton and $84.77/ton on cropland and grassland respectively. Storage and transportation costs combined total only $15.63/ton in comparison. Between both scenarios, the production costs are approximately 85% of the total deliverable cost. This percentage improves as yield improves and production costs/ton come down, but even at higher yields production costs remain nominally higher. This remains true even after accounting for the effect that rising energy costs could have on transportation costs. This offers further support to the knowledge that actual production itself—through yield, etc.—is where the real production cost gains can be made.

CHAPTER 5. ADDRESSING THE HIGHER COST OF SWITCHGRASS PRODUCTION

Coal is one of the United States' most common energy sources. In the year 2000, the use of coal accounted for 32% of total energy production in the U.S., and over 92% of the coal consumed went to electricity generation (DOE AER 2000). One of the reasons for its popularity is that coal is a very inexpensive feedstock. It is the cheapest of the fossil fuels, making it the most common feedstock in most U.S. power plants. A reasonable estimate of the cost of coal today would be approximately \$16/ton (the average annual free-on-board cost of bituminous and sub-bituminous coal prices from 2001-2003 from the Energy Information Administration/U.S. DOE's coal price database).

For switchgrass to be commercially successful as a coal substitute, it must be able to compete with coal's low cost. Power plants will generally act as cost minimizers, choosing the raw fuel source that will give them the greatest Btu value at the lowest possible cost. Coal becomes their best feedstock choice in this context. Even in the most optimal scenario of budgetary assumptions—a low land charge, high yields, low input charges, etc.—the best switchgrass costs of production projection are still going to significantly exceed the cost of coal on a per ton basis. Refer to Tables 18 and 19 in the previous chapter to compare. At two and four tons/acre yields—currently attainable levels—switchgrass production costs are \$100.40/ton and \$65.53/ton, respectively.

For switchgrass to be a commercially competitive coal alternative, it will need to effectively compete with its price. The key question becomes how best to address the varying cost difference between the cost of switchgrass on delivery and the cost of coal.

Addressing the higher cost of switchgrass production

Three options exist to make switchgrass more competitive with coal. The first, most obvious option would be to work to simply lower farmers' costs of production. Methods of approaching this were discussed in the previous chapter. Though they are considered to be an effective way of controlling costs, further development of the methods are considered beyond the scope of this research and will not be considered further.

A second option available for consideration would be for the government to tax and/or regulate the negative environmental externalities brought about by mining and burning of coal. Strip-mining coal—the most common type of coal mining—is very hard on the soil. Affected soils become very acidic and struggle to support plant growth. Strip-mining also depletes wildlife habitats and can cause serious groundwater contamination by leaching harmful pollutants into the ground (U.S. Nuclear Regulatory Commission 2004).

The harmful environmental and health effects from air pollution stemming from burning coal are also widely known. Acid deposition caused by the release of sulfur oxides and nitrogen oxides into the air is directly attributable to the coal-burning process. The sulfuric and nitric acids formed when these the two gases then mix with water can cause serious ecological problems by damaging aquatic ecosystems, negatively affecting soil pH and growing vegetation, etc. Burning coal also creates negative human health effects by producing smog, a mixture of harmful air pollutants principally made up of ground-level ozone. The air pollutants released from combustion sources like coal-burning power plants react with sunlight to create ozone, which then becomes trapped in the atmosphere. Regularly breathing high doses of smog can lead to serious respiratory ailments, including reduced lung function and increased occurrence of asthma. These ailments especially affect young children (U.S. EPA Air Quality Bureau 2000).

Coal would become a relatively more expensive feedstock if the coal-mining industry and coal-burning power plants were forced to internalize the external environmental costs that coal generates. Effective and efficient ways of doing so—through taxes or other financial regulation of the coal industry—have been studied at length. It is an important option to address, but for this research purpose it will not be considered further.

A third option exists to help mitigate the costs associated with coal use and encourage the use of switchgrass. Just as the negative externalities of coal could be incorporated into its cost, the positive environmental externalities from both the production and use of switchgrass could be factored into its cost as well. There are incentive opportunities in existence that could prove to be adaptable for this purpose. Using them as switchgrass incentives provides an interesting way of indirectly subsidizing clean bioenergy production. It is on this option that the remainder of this thesis is focused.

Environmental Benefits of Switchgrass

Switchgrass, either as a vegetative crop or an energy feedstock, offers a variety of environmental benefits. It is a sturdy, warm-season perennial grass native to much of the Midwest. It has the ability to adapt to a wide variety of growing conditions, from exceptionally dry to almost marsh-like conditions. A switchgrass stand is easily adaptable to commercial farming, and its presence develops an excellent soil quality. For producers cultivating a stand over time, it offers all the benefits of a traditionally established grass. Because it is a tall prairie grass, it makes an excellent wildlife sanctuary. It has a deep, complex root system that is a superior guard against soil erosion—some stands have been shown to have roots greater than three and a half meters in depth (McLaughlin 1999). It can also act as a filter for runoff chemicals before those chemicals reach nearby waterways.

As an energy feedstock, it has been shown to be one of the best of the high yielding perennials grasses to use as a biofuel. It offers excellent, efficient burning and energy-generating capabilities. Burning switchgrass produces far less net carbon dioxide emissions and can bring about a reduction in sulfur and nitrogen oxide gases. It is estimated that burning 200,000 tons of switchgrass per year (the commercial goal amount set for the Chariton Valley project) would release roughly 500,000 *less* tons of carbon dioxide per year (Antares 2002). In addition, preliminary results from the Chariton Valley test burn in 2003 indicated drops in both sulfur and nitrogen oxide gases during the periods where switchgrass was being substituted into the feedstock (Comer 2004).

If any or all of these positive externalities could be incorporated into the value or overall cost of switchgrass relative to coal, it would bring about a more representative picture of *all* the costs of burning these individual fuel stocks. The additional environmental benefits to society by the use of switchgrass adds value to its use. There has been considerable discussion in economic literature on designing optimal methods of efficiently valuing positive externalities and recognizing them in the cost of the good. These discussions provided an excellent theoretical guide.

Three different ways of representing the positive externality effect of switchgrass are considered. They include a modified CRP payment to producers; a carbon payment made to producers by buyers in a carbon market in exchange for carbon sequestration; and a green payment, paid by consumers to the power plant as a clean energy premium on their electricity usage. All three of these will be discussed in the following chapters.

CHAPTER 6. CRP PAYMENTS

CRP Program

The Conservation Reserve Program is a land retirement government program established as a part of the 1985 Farm Bill. Its purpose was to encourage farmers to idle highly erodible land in exchange for an annual rental payment. Farmers would enter into ten-year government contracts agreeing to set the land aside. With cost-sharing assistance from the government they would establish permanent vegetative cover on it for protection. Farmers were required to abstain from deriving any economic benefit from the contracted land while it was enrolled in the program. Contracts that expired at the end of the full ten years could be re-enrolled by the farmer (U.S. DOA/CRP 2004, Walsh 1996).

In 1990, five years after the program was established, CRP was expanded further. In addition to including provisions for erodible farmland, it began establishing contracts for environmentally sensitive lands as well. Land providing needed wildlife cover or land surrounding sensitive water or watershed areas could now qualify for CRP sign-up. Contract agreements stayed the same—idle land was exchanged for a rental payment. More CRP acres were signed up than ever before as a result of this expansion (Walsh 1996).

As of July 2004, there were over 650,000 CRP contracts in the United States protecting nearly 35 million total acres of land (U.S. DOA/CRP Signup 2004). The state of Iowa had approximately 1.9 million of those acres, making it the sixth-largest state in terms of number of acres enrolled. The average CRP payment across all of Iowa's 99 counties is estimated at $103/acre (U.S. DOA/CRP Signup Statistics 2004).

Discussion of the CRP program in the 1995 Farm Bill debates in Congress centered around methods to reduce the program's costs, estimated at $1.8 billion in 1995 (Walsh

1996). A proposed solution was to allow modification of the CRP contracts to grant approval for certain specific economic uses. In exchange, farmers would receive a reduced rental payment. One of the economic uses discussed was the production and harvest of bioenergy crops. More specifically, farmers would be allowed to grow bioenergy crops such as switchgrass or short rotation woody crops on their CRP land for profit. In addition, they would continue to receive a reduced portion of their CRP rental payment.

Ultimately, this proposal was dropped from the final version of the 1995 bill. Even so, it would have represented a potential win-win situation for both the government and for bioenergy farmers. Energy crops tend to come in two major varieties—perennial prairie grass and short rotation woody crops, also known as fast-growing trees. Either of these varieties planted on CRP land still maintain the environmental integrity of the land conservation objectives the government seeks. Both are still considered conservation cover by CRP guidelines. The government could be reducing the program's overall cost by paying reduced CRP payments on bioenergy crop acres by allowing them to be harvested.

Farmers would also have the opportunity to profit. They could receive income from the sale of their crop in addition to receiving a continued partial CRP payment. Additionally, in the evolving energy marketplace where many renewable energy market prices are trying to become competitive with regular, cheaper fossil fuels, the reduced payment could serve as an effective production incentive for bioenergy crop producers. In a very unique way, the payment could become a "subsidy" while still reducing the overall amount of existing subsidy that the government pays out. In other words, the government would have a production incentive that would essentially save them money.

A Modified CRP Payment

Just how effective could a partial CRP payment be in creating an incentive for Iowa farmers to take their CRP land and switch over to raising switchgrass? The effects of a reduced payment on a producer's switchgrass production returns lie in the crop yield/acre attained and in the market price of switchgrass. In the Chariton Valley project area, the average CRP payment in the four counties is $74.55 per acre (U.S. DOA/CRP Signup 2004). In exchange for their payment, farmers are required only to mow the idle land. The estimated costs for mowing land in 2004 were $4.37/acre (Duffy et al 2004). Assuming a farmer mows the land twice per year, the cost to them is $8.74/acre. Taking this out of their full payment leaves Chariton Valley farmers an average net CRP income of $65.81 per acre.

For farmers to consider raising switchgrass, it is assumed they would have to be able to make at least as much net income from its sale as they would by receiving their standard full rental payment. Switchgrass net income would depend on both the yield and market price. At varying yield levels, calculating the minimum switchgrass market price at which farmers could "afford" to make such a production switch illustrates the effects that different partial CRP payment levels can have as a production incentive. For example, assuming a farmer could produce an average of two tons/acre of switchgrass, how great an effect could granting a 50% partial CRP payment have on their production decision? What market price would the farmer have to receive to make his net income from switchgrass and the CRP payment equal to his net income from leaving the land idle?

Switchgrass Breakeven Prices

Table 20 illustrates the switchgrass market prices needed at varying production levels for producers to be able to "break-even". The reported amount is the market price at which producers would receive an equivalent net income from either leaving their land in full CRP or choosing to produce switchgrass given the designated partial CRP payment level. The greater the payment percentage they continue to receive, the lower the switchgrass price per ton they can accept to continue to break even. Comparisons can be made to what could be considered a reasonable switchgrass market price to see how close the two fall.

To find the breakeven price, the income the producer is making/retaining must be equal to the income the producer is foregoing. In other words, the revenue added from selling the switchgrass coupled with the CRP land maintenance costs they are foregoing must be equal to the CRP revenue they are giving up coupled with the newly acquired switchgrass production costs they would incur. To calculate this, a partial budgeting approach is used where:

$$\begin{aligned}&[(\mathit{Yield} \cdot \mathit{SWG\ Price}) + (\mathit{CRP\ Maintenance\ Costs})] - \\ &\qquad [\mathit{SWG\ Prod.\ Costs} + \mathit{CRP\ Revenue\ Foregone}] = 0\end{aligned} \tag{5}$$

Substituting in an assumed yield and an assumed modified CRP payment level, the breakeven market price needed can be calculated. The maintenance cost of mowing an acre of CRP land is taken as a total of $8.74/acre (Duffy et al 2004). The switchgrass production costs can be calculated by using total production cost estimations for grassland production found in Table 6. Table 6 represents switchgrass production costs without the storage or transportation costs. The storage cost of $6.19/ton for hoop barn storage and $9.44/ton for transportation are individually multiplied by the producer's assumed yield to account for these costs.

Finally, the CRP revenue foregone can be found by taking the full payment of $74.55/acre and determining how much the payment is lowered by subtracting the partial payment. In other words, if a farmer could expect to keep 25% of their CRP payment if they moved to switchgrass production, they would give up the other 75%. If the average payment is \$74.55/acre, the farmer would give up 75% of that, or \$55.91/acre.

For example, assuming a modified CRP payment of 25% and a yield of two tons/acre, the switchgrass breakeven price is calculated using the equation found in (5) as follows:

$$[2X + 8.74] - [\{(105.70) + (2 \cdot 6.19) + (2 \cdot 9.44)\} + (0.75 \cdot 74.55)] = 0 \qquad (6)$$

Setting the equation equal to zero and solving for the switchgrass price X determines the switchgrass price that producers would need to receive in order to obtain the same net income they could expect from leaving their land idle in CRP. In this case, the breakeven price is \$92.07/ton.

The prices in Table 20 are calculated in the same manner:

Table 20: CRP Switchgrass Breakeven Prices

Percentage	2 tons/acre	4 tons/acre	6 tons/acre	8 tons/acre	10 tons/acre
25%	\$92.07	\$61.37	\$51.13	\$46.01	\$42.94
33%	\$88.96	\$59.81	\$50.10	\$45.24	\$42.32
50%	\$83.49	\$57.08	\$48.21	\$43.87	\$41.23
75%	\$73.43	\$52.05	\$44.92	\$41.36	\$39.22
100%	\$72.85	\$47.39	\$41.81	\$39.03	\$37.35

The necessary breakeven switchgrass prices vary dramatically. Given current Chariton Valley average production is approximately two tons/acre, Table 20 shows that the market price will need to be quite high regardless of the size of the partial CRP payment they are still allowed. Assume that the current average switchgrass market prices fall around

$45/ton. This price represents a reasonable estimate of the price farmers could expect to get for switchgrass if it were being sold as hay (Hipple 2002). Even receiving their full CRP payment and assuming the payment is the only additional "support", the switchgrass market price would still have to be nearly $30 higher—would need to meet at least $72.85—to allow switchgrass producers to simply break even.

At a yield level of four tons/acre, the breakeven switchgrass prices shift noticeably downward, ranging from $61.37/ton assuming 25% of the current CRP payment to $47.39/ton when producers are given a full payment. Four tons/acre is taken to be agronomically achievable right now for Chariton Valley producers. At $47.39/ton (when given the full CRP payment), the necessary market price is quite close to a realistic market estimate. At all higher yields, the breakeven prices are lower still. However, it is important to be mindful what yields producers could reasonably maintain.

Assumption Considerations

For these breakeven prices to be considered operational, it is important to remember a few things. First, these prices will be effective assuming that switchgrass producers are profit-maximizers. Farmers will make the decision to be switchgrass producers only if they can make a higher net income by doing so. While this seems reasonable, there are other factors that could weigh into their decision. For example, if producers are utility maximizers, net income may be only one of multiple considerations. For further discussion of alternative switchgrass adoption motivations, see Hipple et al (2002). A summary of the findings from the paper were discussed in Chapter Two.

In spite of the high potential for many switchgrass adoption motivations, this study will retain the assumption that farmers will primarily choose to adopt switchgrass based on their anticipated profitability. For the purposes of this analysis the designation works well. First, dealing with a utility maximizing assumption would severely complicate the ability to draw meaningful conclusions. Each producer would have their own decision-making value set. Also, while additional and potentially intangible values will play a role in a producer's decision, it is realistic to assume that net income would certainly be a primary consideration (Hipple et al 2002).

CRP as a Successful Incentive Vehicle

Table 20 shows how higher CRP modified payments have a substantial impact on a switchgrass breakeven price. Though retaining a higher payment percentage would be of most benefit to producers, the reality of doing so has to be considered. If the government allows CRP program modification to allow for a bioenergy incentive, will their primary objective be to reduce the cost of the CRP program, or to provide a meaningful bioenergy incentive? This choice will likely affect the level of modified payment allowed.

Based on Table 20, a CRP incentive payment would have to be at least 50% of a full payment for Chariton Valley farmers to see a meaningful effect. However, if the government's objective is to simply cut the program's cost, could that be expected? For example, if the government focus is to cut costs, perhaps they would only consider payments less than half of the full payment total, with 50% as their maximum payment scenario. If they were seeking to create a significant bioenergy incentive, they may be more likely to consider payments of at least 50 percent. Though selecting out these payment levels is purely speculation, it represents the importance of further interpreting the relative likelihood of the government actually allowing for various modified payment levels should consider a modified payment in the future.

It is also important to consider the likelihood of the CRP program remaining a consistent, politically viable vehicle to provide such an incentive. The CRP is an expensive government program. Policymakers are continuing to look for ways to reduce their financial commitment to it. Speculation is strong that the CRP program could be phased out completely at some point, perhaps even relatively soon. This is a concern when considering the ability of CRP to fulfill a dual role as a potential bioenergy incentive.

The objectives achieved through the CRP program are not only fundamentally important, they are increasingly relevant. CRP directly affects both land conservation and environmental stewardship issues, and indirectly affects the issues of improving water quality, reducing soil erosion, etc. If the federal government could modify the program in such a way as to reduce their financial burden, while simultaneously encouraging the expansion of green energy, it could increase the importance and value of the program. It could represent an incentive to producers to help make bioenergy production possible. The production base already exists. All that needs to be done is to make a concerted effort towards developing incentive sources such as CRP that could provide a cost supplement to producers at little to no expense to the federal government.

CHAPTER 7. CARBON PAYMENTS

The accelerating increases in greenhouse gas emissions and growing concern over global warming have caused the United States and the rest of the world to take a more earnest look at ways to mitigate the release of carbon dioxide into the atmosphere. A dilemma exists over how best to mitigate carbon release because carbon dioxide is the primary by-product of all fossil fuel-based energy production. Implementing emission regulations geared towards reducing carbon levels could have a potentially serious effect on energy prices, and thereby overall economic growth.

The U.S. exercises strict regulations over the release of harmful pollutant gases like sulfur dioxide, nitrous oxides, etc. In contrast, U.S. carbon dioxide emission reductions remain strictly voluntary. Even so, there are companies who are choosing to address their CO_2 emissions either for public image purposes or as a preemptive measure, thinking there may be a time in the future when CO_2 reductions may become required. To facilitate these companies' efforts, the establishment of independent carbon markets is coming to the forefront.

Carbon Markets

Carbon markets are a natural extension of existing pollution emissions markets that have been established in the United States. Regional markets host emission trading for pollutants like sulfur dioxides (by far the largest and most commercially successful emissions trading market), nitrous oxides and volatile organic compounds. (Antares 2004, Ard 2004). While the technical infrastructure of each of these trading markets may differ, the overall idea is the same. Most commonly, a government or private overseeing body will establish an emissions cap or baseline for all participating polluters. The cap is a limit to how much pollution each polluter is allowed to release. The level is traditionally related in some way to the emission level they currently release—either some percentage reduction of their existing total, a specifically assigned maximum emissions limit that is still a reflection of their production levels, or a reduction to an emissions total from a prior year picked to be their baseline.

Once the cap levels are established, polluters must meet this emissions limit or face regulatory penalty. They can meet their emission limit either by cutting their own emission production, or by purchasing pollution units ("credits") from the emissions market. These credits are put up for sale by other participating polluters who have succeeded at reducing their own emissions below their set target. Using a market allows for equalization of the marginal abatement costs of each participating polluter, creating an economically efficient outcome.

A carbon market differs significantly from other emissions trading markets in a notable way. The reduction of carbon dioxide emissions in the U.S. is a strictly voluntary undertaking. As such, participation in carbon markets is voluntary as well. Also unique to CO_2 abatement is that in addition to direct emission abatement, atmospheric CO_2 reduction can be achieved through carbon sequestration. Carbon sequestration is the method of capturing, removing and storing carbon dioxide already created and present in the atmosphere (DOE Office of Fossil Energy 2004). Sequestering can be achieved through the establishment of vegetative cover, which takes in CO_2. Since carbon sequestration can indirectly create the intended atmospheric reductions, the strategy can generate tradable CO_2 reduction units tradable in some carbon markets.

Chicago Climate Exchange

The most noted carbon market in the U.S. is the Chicago Climate Exchange. The Exchange is a cap-and-trade carbon market formally opened in October of 2003 and made up of voluntary member participants. All participants have agreed to a legally binding commitment of reducing their carbon emissions by 4% below the average of their 1998-2001 emissions by the year 2006. The market is based on trades of carbon unit credits achieved both through direct CO_2 emission reduction by the market participant, as well as through carbon sequestration techniques. Each tradable credit represents one hundred tons of CO_2. Currently the Exchange has over 70 members, including Ford Motor Company, Dupont, Dow Corning, Rolls-Royce and Motorola, along with many others. The University of Iowa and the Iowa Farm Bureau are also participating members (Chicago Climate Exchange 2004).

Switchgrass, carbon sequestration, and carbon markets

Using a carbon market similar to the Chicago Climate Exchange could give switchgrass producers a second financial incentive opportunity. Switchgrass offers a tremendous potential for vegetative carbon sequestration. It takes in carbon dioxide from the atmosphere to use as a fuel source through photosynthesis and stores large amounts of carbon in its root systems and plant body.

Different vegetation sequesters carbon at differing quantities. Trees are the largest carbon sinks, both because of their large physical size and their long stand life. Agricultural crops like corn and soybeans have the capacity to store carbon as well, but on a much smaller scale. Their root systems are much shallower. In addition, it is a crop's *long-term* storage effectiveness that matters when it comes to carbon market eligibility. Corn and soybeans sequestration levels depend on a farmer's land management of the soil. As a perennial grass, switchgrass' average carbon storage capacity falls somewhere between trees and row crops. Its actual capacity can vary depending on many factors including stand age, soil landscape, previous soil uses, overall soil management, depth of soil measurement for presence of carbon, and even weather (Burras 2002).

The most likely outlet through which Chariton Valley producers could sell sequestered carbon units would be the Chicago Climate Exchange. To do so they would need an accurate assessment of how much carbon their fields sequester. In the Chariton Valley, research into switchgrass' carbon sequestration potential is being conducted. Determining a precise level of sequestration while accounting for all the inherent variability is a difficult task. The Climate Exchange uses the average number of tons sequestered as a way to account for the variability and facilitate smoother trading. The average soil organic carbon in the Chariton Valley switchgrass fields would represent a baseline estimation on the level of sequestered carbon for trading on the Exchange.

Chariton Valley Carbon Sequestration

Based on research data, 3- to 14-year-old switchgrass stands have sequestered an average of 50 to 55 tons/acre of carbon. Soil organic carbon (SOC) increases at an annual rate of 0.75 tons/acre/year to a 10-inch depth, or 1.50 tons/acre/year to a 40-inch depth (Burras 2002). Trading at the Exchange is done using Carbon Financial Instruments (CFIs), which are bundles of 100 metric tons of CO_2.

The trading value of the CFIs on the Exchange board tends to fluctuate between $0.70 and $1.00 per CFI (Chicago Climate Exchange 2004). Therefore, if producers were being paid based on the total amount of SOC in the soil, a sequestration level of approximately 50 tons/acre could expect to receive between $0.40 and $0.50. If, however, producers were paid based off of their average annual increase in SOC (a much more likely scenario), the reported increase of between 0.75 tons/year and 1.5 tons/year would yield an essentially negligible payment.

For the purposes of acting as a viable production incentive, current carbon prices are very low. If switchgrass producers were to sell their sequestered carbon in a market like the Exchange they would get very little revenue. However, it is still valuable to see the effect a carbon payment could have if the payment prices were higher. Table 21 shows the effects of a carbon payment on various "breakeven" switchgrass price needed. The carbon payment breakeven prices are found in the same way as the modified CRP payment breakeven price scenarios in Table 20 in the previous chapter. In this case, the prices in the table are what the switchgrass price would need to be for producers to receive equal revenue from either leaving their CRP land enrolled and taking their guaranteed payment, or raising switchgrass and selling it as a biofuel while giving up their CRP revenue completely.

The left column of the table lists hypothetical carbon payment prices. Actual prices are far removed from these levels, but these payment scenarios show what the carbon payment level would need to be at to achieve a significant effect as an incentive. A $12/ton payment scenario was specifically included for consideration. A $12/ton payment is at the high end of a payment range currently being reported by EU analysts observing early contract trading in their regional carbon market (more extensive discussion of this market is found at the end of this chapter). Assuming that a similar payment was available to Chariton Valley producers, the same payment level was incorporated here.

All breakeven prices were again calculated using a partial budgeting approach. The table specifies the yield level and carbon payment level used for each price. The average

CRP payment and the switchgrass production costs that were used in the previous chapter for Table 20 were again used in this calculation. If trading were to take place, the amount of eligible carbon to be sold will likely be based on the average annual increase in sequestered carbon in the switchgrass soil. For this reason, the soil organic carbon (SOC) level was taken to be 1.5 tons/acre, the average annual increase per acre to a 40-inch depth as reported by Burras 2002. If sequestration was recognized only to a 10-inch depth by the Exchange, the SOC level used would be 0.75 tons/acre. A description of this calculation is found in (7), and an example using the $5/ton carbon payment level at 2 tons/acre yield is found in (8).

$$\begin{aligned}&[(\mathit{Yield} \cdot \mathit{SWG\ Price}) + (\mathit{CRP\ Maintenance\ Costs}) + \\ &\qquad (\mathit{SOC} \cdot \mathit{Carbon\ Payment\ Price})] - \\ &\qquad\qquad [\mathit{SWG\ Prod.\ Costs} + \mathit{CRP\ Revenue\ Foregone}] = 0\end{aligned} \tag{7}$$

$$[2X + 8.74 + 1.5(5.00)] - [\{(105.70) + (2 \cdot 6.19) + (2 \cdot 9.44)\} + (74.55)] = 0 \tag{8}$$

Solving for the switchgrass price X in (8) yields a needed price of $97.64/ton. All prices in Table 21 are calculated in a similar fashion.

Table 21. Carbon Payment Switchgrass Breakeven Prices

CO2 Pymt.	2 tons/acre	4 tons/acre	6 tons/acre	8 tons/acre	10 tons/acre
$5/ton	$97.64	$64.15	$52.99	$47.41	$44.06
$10/ton	$93.88	$62.28	$51.74	$46.49	$43.31
$12/ton	$92.39	$61.53	$51.24	$46.09	$43.01
$25/ton	$82.64	$56.65	$47.99	$43.66	$41.06
$50/ton	$63.89	$47.28	$41.74	$38.97	$37.31
$100/ton	$26.38	$28.53	$29.23	$29.59	$29.81

The first two yield columns are close to current Chariton Valley yields. At those yields, it would take a very high carbon payment to bring the switchgrass breakeven price down to a reasonable range. For example, at 2 tons/acre yield, even a $50/ton carbon payment still leaves a needed switchgrass market price of $63.89/ton to give farmers back an income equivalent to what they were getting from CRP enrollment. The outlook improves slightly as yield increases to 4 tons/acre, but until carbon payments would reach $100/ton, the switchgrass price would still remain very high.

Table 21 gives a good look at what impact carbon payments could have as an incentive to producers if they were at higher levels. The hypothetical payments are much higher than those being realized now. As was mentioned earlier, for example, one carbon financial instrument (CFI) on the Exchange, representing 100 tons of carbon, was selling at a high of $1.00/CFI. The lowest payment level included in the table was $5.00/individual ton of carbon. This is a significant difference. Even though the hypothetical payment levels are not ones that can be realized right now, they still provide valuable insight into what level a carbon payment would eventually have to reach if it was to become a viable switchgrass production incentive.

Federal subsidies for green energy alternatives, other than ethanol, are not always available. When the subsidies are available, they may not make a significant impact. Federal and state governments themselves have begun earnestly supporting market-based solutions to pollution control issues in recent years. Emissions markets like carbon markets—though they may be voluntary—will continue to evolve over time. As a result, the idea of utilizing a developed carbon market should factor into any approach to encouraging switchgrass production in Chariton Valley specifically, or even bioenergy crop production in general. Further discussion of this idea will be presented in Chapter 9.

International Carbon Trading Markets

Other countries have taken the initiative and developed their own carbon markets as well. The strong influence of the Kyoto Protocols abroad has further influenced the push towards development of these markets. Many of the countries creating the pilot markets are much more committed to the idea of serious carbon abatement, and in some cases have created mandatory industry participation. Developed industrial countries like Denmark (mandatory participation for specific industries) and the U.K. (subsidized, open and voluntary participation) consistently experience higher demand for abated and sequestered carbon, spurred on by new greenhouse gas emission regulations being piloted on domestic levels, determined by and adapted to each individual nation.

The European Union as a whole is also preparing to launch its own extensive trading market for all EU countries. It is slated to be fully operational by January 2005. Some companies who will be participating in this market have actually begun trading early by contractual agreement (actual allowances cannot change hands until the market's official open in January, though payment for allowances can take place early). They have even begun reporting on initial trade prices. Reports on these early contracts place the average payment at between 6.5 and 9.5 euros per ton (between $8.11 and $11.85 U.S. dollars), with an average trade size at 5,000 tons. Analysts predict trade sizes to increase to around 50,000 tons once formal trading is opened in January (Environmental Science and Technology 2004).

International Opportunities for U.S. Carbon

Unfortunately, these still-fledgling international markets would not present U.S. switchgrass growers with any additional carbon trading outlets. The trades are limited to participants in each country or region—no international trading—as well as further limited in some instances to designated industries. In addition, not all markets will accept carbon sequestration credits as allowable carbon abatement. Each market is designed differently and has different trading guidelines.

Developing international trading capabilities would be an ultimate goal (and a primary goal of the Kyoto Protocol), but currently there are many questions as to the way in which international carbon trades could be most efficiently made. One of the primary points of debate is how to establish a carbon tradable permit that would be uniform and consistent across all participating countries (Ellerman et al 2003). Reliable, accurate international data from all participating countries would be critical. This would require precise data tracking and accounting systems, as well as the establishment of a verification and enforcement system. Beyond this, select countries undertaking their own carbon trading scenarios on a domestic level presently establish their own methods of participation, of measuring carbon abatement, carrying out market transactions, etc. With issues such as these remaining to be addressed, there is too much dissimilarity between the various countries' programs to be able to effectively trade carbon credits beyond domestic borders at this time.

CHAPTER 8. GREEN TAG PAYMENTS

Green Tag Payment Description

The term "green payment" can be used to describe the dollar value associated with the added positive environmental attributes generated by using renewable energy sources like solar, wind, or biofuel power. A green tag payment is a more specific instance of a green payment. It represents the cost premium attached to the ability to purchase the relatively more expensive green power from a power provider. By definition, a green tag payment essentially represents an incentive concept where individuals who consume the most energy, pay the most.

Typically, a power plant will either generate or purchase green power to offset part of their production of normal "dirty" energy. In application, a green tag payment is usually voluntarily made either by the local consumers buying the power from the power plant, or by outside individuals who still want to encourage/subsidize the generation and use of green power. Outside individuals buying green power generally do so through the purchase of green tags through an independent green energy broker. Because this project will focus on the consumers who are actually using the green power, the green energy broker payment option will not be explored.

The concept of having consumers pay a premium for the ability to purchase green energy directly from their own power plant (what will hereafter be referred to as a green payment to the power plant) is a valuable policy option. Specifically applied to the Chariton Valley project, green power would allow local consumers purchasing power from the Ottumwa Generating Station to voluntarily pay a premium for the ability to purchase green power generated by the power plant's use of switchgrass. It would be billed to the participating consumers as an additional charge per kWh used, and would be paid to the power plant. The green tag incentive differs from a partial CRP or a carbon payment, both of which are direct incentive payments to switchgrass producers. Green tag payments, in contrast, would be an indirect benefit to producers by increasing the price the power plant could be willing to pay for switchgrass.

Alliant has an existing voluntary green payment program called *Second Nature*® that allows consumers to subsidize green energy. The program has three different participation levels where consumers can choose their desired level of financial commitment or green power generation. Alliant has established a premium level of 2.0 cents/kWh to cover the renewable portion of the energy generated. That is, if a consumer wants to pay a full premium—allowing them to have their energy purchase be 100% renewable energy—they would pay an additional 2.0 cents/kWh for every kWh they consume. The three participation levels allow consumers to choose from three corresponding payment levels varying according to the fraction of renewable power being purchased. Under their *Nature Sentinel*® product, consumers pay an additional 0.5 cents/kWh for 25% renewable power, their *Eco Watcher*® product yields 50% renewable power for an additional 1.0 cents/kWh, and for consumers who want 100% renewable power the *Earth Steward*® product requires a full premium payment of an additional 2.0 cents/kWh (Chariton Valley Peer Review 2003).

This payment can be translated to estimate the effect it would have on switchgrass producers. One dry ton of switchgrass contains approximately 14.5 million Btu's of energy (Walsh 1996). This converts to approximately 4,260 kWh of power. The degree to which a green tag payment can subsidize this power depends on the program participation level the consumer chooses, and how much the effects of the subsidy could be passed on to the producers.

For a consumer in the Nature Sentinel program paying 0.5 cents/kWh, this would work out to a $21.30/ton subsidy (0.5 cents multiplied by the 4,260 kWh/dry ton of switchgrass). Consumers in the Eco Watcher group paying 1.0 cents/kWh would be providing a $42.60/ton subsidy. Those in the Earth Steward program contributing an additional 2.0 cents/kWh would provide a support payment twice that size, or $85.20/ton. The values are also shown in Table 23.

Table 22: Maximum Subsidy Resulting From a Green Tag Payment

Participation Level:	*Nature Sentinel (25% green)*	*Eco Watcher (50% green)*	*Earth Steward (100% green)*
Maximum subsidy:	$21.30/ton	$42.60/ton	$85.20/ton

These payments are substantial. It is important, however, to remember that these payments are going to the power plant and not the switchgrass producer. The green tag payment is an indirect subsidy. It is an incentive for the power plant to purchase green power in general and not switchgrass specifically. The degree to which switchgrass producers would benefit would depend on how many consumers were participating in the voluntary program. It would also depend on how much of the power plant's total green power was coming from switchgrass relative to other green sources. In addition, not all the incentive income from the green tag would go directly to the feedstock producers. The power plant could put part of it to other uses—for example, they could put it towards acquiring the needed capital (new equipment, etc.) to burn switchgrass. The relative influence of these additional factors would need to be determined before it could be known how large an impact a green tag payment would have on switchgrass producers themselves.

In spite of these uncertain influences, the significant impact of a green tag payment can still be shown. Assuming that a producer could be paid a green payment on a per-ton basis (see Table 22) for all the switchgrass they would produce, the potential of the payment can begin to be seen.

For example, suppose a scenario where the power plant pays switchgrass producers \$16/ton for their switchgrass (\$16/ton being the average price of coal given in Chapter 5). Assuming production on grassland, subtracting \$16/ton from the total delivered grassland production costs per ton in Table 19 leaves the remaining cost difference left to be addressed. For example, at a two ton/acre yield, switchgrass production costs are \$100.40/ton, so after being paid \$16 by the power plant for a ton of switchgrass, the producer would be left with \$84.40 in production costs not covered.

If the producer received some part of the green tag payment consumers pay to the power plant, could the payment make up part of the uncovered production cost? According to Table 22, if producers were to receive the full green tag payment at the 100% green power level (where consumers are paying a 2.0 cent/kWh premium) from the power plant, it would almost perfectly cover their remaining costs. A 2.0 cent/kWh premium, translated to \$85.20/ton, would be just slightly more than the \$84.40/ton the switchgrass producer would need.

Table 23 expands the above comparison at all yield levels and at each green tag premium level. Using grassland per-ton production costs from Table 19 and the per-ton green tag payment values found in Table 22, the table shows what percentage of each green tag premium paid to the power plant that the power plant would than have to transfer to switchgrass producers for producers to cover their remaining production costs. The table assumes that producers are already being paid $16/ton, the average coal price estimate, by the power plant for their switchgrass. Some of the table entries are blank, indicating that even if producers were to receive the full amount of the specified green tag payment, it would still not equal their remaining production costs.

Table 23. Percent of Green Tag Payment Necessary to Equate Switchgrass Cost of Production Less a Coal Equivalent Price Given a Green Payment Premium Level

Green payment level	2 tons/acre	4 tons/acre	6 tons/acre	8 tons/acre	10 tons/acre
0.05 cents/kWh *(25% green)*	---	---	---	---	---
1.0 cents/kWh *(50% green)*	---	---	89%	75%	67%
2.0 cents/kWh *(100% green)*	99%	58%	45%	38%	34%

For example, if a producer's switchgrass yields are at 4 tons/acre, receiving a full green tag payment of $21.30/ton (representing the per-ton value of the 25% green power premium level of 0.05 cents/kWh) from the power plant will not cover the production costs remaining after receiving a $16/ton payment for the switchgrass itself. The full payment of $42.60/ton from the 50% green power premium level also falls short. But if the producer were to be given 58% of the green tag payment from the 100% green power premium level of $85.20/ton, that payment would make up the remaining production cost difference.

Table 23 shows that a green tag payment has the potential to be a significant incentive payment for switchgrass producers. A full payment at the 25% green energy level does not completely offset remaining production costs at any yield level, but the 50% green power level is able to do so starting at 6 tons/acre yields. The 100% green power level payment could be effective at every yield level.

In addition, Table 23 not only shows the potential effectiveness of a green tag payment as a stand-alone switchgrass incentive, but also its effectiveness at being a significant part of an overall incentive package. Even if producers were not able to receive enough of a green tag payment from the power plant to make up the whole production cost difference, it could still make up a large part. If the green tag payment was not a producer's only incentive, partial payments at the 25% and 50% green power levels would become even more significant.

A green tag payment could serve as a significant incentive source to switchgrass producers. Table 23 represents one scenario that shows this. In order to make precise conclusions, a much more complex analysis would need to be done to account for the variability of green tag income to the power plant and the proportion of green energy generation that switchgrass represents to the power plant (since the green tag payment is made to the power plant for green energy generation, not just green energy generated by switchgrass). In addition, the analysis would also need to take into account that the power plant would not necessarily be able to pass along the full green tag payment to producers. They may need to utilize a portion of it for capital expenditures related to burning switchgrass in their plant.

Accounting for these additional considerations may adjust the relative effectiveness of the green payment as a producer incentive. Even so, the substantial impact the payment could have in a basic scenario like the one represented in Table 23 suggests that even after the adjustments, the green payment could prove to be very valuable to switchgrass producers.

Potential of a Green Tag Payment

The green tag payment, as a consumption-based payment, creates a more economically efficient incentive. This payment is also complementary to the modified CRP and carbon market payment options by being a way for consumers to play a role in a green energy incentive. A green tag can better effect the back-side of the energy production process—i.e., the consumption side—and indirectly create a bioenergy producer incentive by allowing the power plant to recover some of the added cost of using a green energy by passing part of it along to energy consumers. Table 23 also showed how a green tag payment could even be directly passed on if the power plant transfers some part of the payment to switchgrass producers. Acting either as a direct or indirect producer incentive, a green tag payment represents an incentive that shows a great deal of promise.

CHAPTER 9. IMPLICATIONS AND VARIATIONS BETWEEN INCENTIVE USES

The three previous chapters presented three different switchgrass incentive options that could be used to equate the costs at which switchgrass producers can deliver switchgrass to the power plant and the price the power plant is willing to pay. The three incentive options differ on a fundamental level. The CRP payment represents a standard type of government support program, the carbon payment represents the use of a market-based payment incentive, and the green tag payment represents an indirect consumer-based payment. The three payment types have advantages and disadvantages outside of the actual nominal value of the payment itself.

Modified CRP Payment: Advantages and Disadvantages

The modified CRP government payment could provide a significant subsidy for switchgrass production. The varying modified CRP payment level could produce a significant impact on the needed breakeven market price. Table 20 showed that even at only a fifty percent modified payment, the impact on the breakeven price is still evident. Also, a modification to the already-existing CRP program would be an easily perceived transition by farmers within a familiar program. The security of knowing that their incentive support was coming from a known government program could help allay worry regarding any perceived risks of transitioning to a potentially variable income source.

In an economic sense, the modified CRP payment would represent a way of internalizing the environmental benefits to society brought about by switchgrass production with its associated soil and water benefits. Farmers with land in CRP are paid to keep their land idle and protect it with vegetative cover, an action that subsequently protects against soil erosion and serious chemical runoff that could be generated from using the land for continual row crop production. Planting switchgrass for use as a bioenergy crop would retain the environmental benefits of the CRP land, while the modified CRP payment paid to producers would represent a uniform, simplified way to attach a value those benefits. A more exact valuation would be impractical, as it would involve complex modeling and require constant and precise measurements of a wide variety of continually changing agronomic variables from each switchgrass acre. The partial CRP payment could thus be a practical way for the government to subsidize the desired environmental qualities.

A perceived disadvantage, at least from the government's perspective, is that the payment is still essentially a government subsidy payment. It would still come with the attached social costs of utilizing a subsidy as an economic tool by creating market distortion and inefficient supply levels. As such, the government will need to answer for themselves whether or not they want to take on a substantive part of either the fiscal or social responsibility of making switchgrass into a commercially profitable bioenergy crop. From an economic and political vantage point, they certainly have a vested interest in wanting to encourage green energy commercial development. Economically, government continues to seek diversified energy sources and reduce dependence on foreign energy inputs. Socially, there is increased emphasis improving the condition of the natural environment for both aesthetic value as well as the practical issue of sustainability. Finally, from a practical standpoint, the government themselves would benefit. The overall existing cost of the CRP program would go down, and with little to no net environmental quality tradeoffs.

Government payments are in place for other agricultural commodities, and certainly even other existing energy sources—fossil fuels themselves being a major one—and they serve a similar purpose. In the case of agricultural commodities, the existence of subsidies signifies that the government feels the social benefits of a strong agricultural program and supporting U.S. farmers justify the financial cost. In the case of fossil fuels, subsidies represent the government's decision that the social benefits of having a more inexpensive energy source available justify the financial cost. Following this reasoning, it falls to policymakers to determine if bioenergy crop development is a priority to the diversification of energy sources, to society and to the environment in general, and whether it warrants financial support from a government program.

Carbon Payments: Advantages and Disadvantages

The current direct financial impact of a carbon payment on switchgrass production is minimal. The potential of receiving less than $1 per acre is not of significant financial value to producers. The continued voluntary nature of U.S. carbon trading will persist in keeping payment levels for permits low. However, the idea of representing the potential of the market to create an independent and efficient incentive is a valuable one.

The U.S. sulfur market illustrates how successful an emissions market can be when it is well-designed, managed soundly, and is closely monitored and regulated. The market has made a substantial impact on both sulfur dioxide abatement and the associated abatement costs. Within ten years of the establishment of trading, sulfur dioxide emissions from coal-fired power plants were reduced by more than 50%, at costs of less than one-third of even the most generous initial estimates (Ellerman et al. 2000, 2003).

Carbon trading presents different, more significant economic challenges were it to move to some form of mandatory trading status, but the effective impact of such a move should not be discounted, even when started on a smaller, more regional scale. If a pilot program or regional carbon market were launched with mandatory participation for power plants or other industry players and carbon sequestration was planned for as an acceptable method of abatement, it is important for switchgrass producers to know the value it could hold for them. Table 21 of Chapter 7 shows the impact a more substantial carbon payment would have on needed switchgrass market prices. At these higher carbon prices, the effects of a carbon payment can match and in some cases surpass the effects of a modified CRP payment.

Regional Push for Carbon Mitigation

If a carbon payment were clearing at a market level that was financially significant to bioenergy producers, it could allow the government to modify the level of its support in response. Table 21 shows the theoretical potential for success is there. In order for it to be a realistic consideration, however, the purpose and the design of the carbon markets as they stand today would have to change. In the U.S., although ratification of the Kyoto Protocol is no longer being considered, there have been some state-level government movements that are looking towards CO_2 mitigation. New Hampshire, Wisconsin, California, Oregon and New Jersey have set up greenhouse gas registries. In August of 2003, nine Northeastern governors committed to work towards developing a regional cap-and-trade program for greenhouse gases. If these development overtures were to continue, carbon payments could become a more significant incentive source in time (DOE EIA, *Climate Change Policy Developments* 2004).

Green Payments: Advantages and Disadvantages

The final consideration, the consumer-based green tag payment, represents a third incentive possibility. While the carbon market incentives are supplied through "upstream" energy users—production and other industrial sources—the green tag payment would be attached to the "downstream" users, i.e. all energy consumers themselves. The green tag payment would also be usage-proportional, since the payment would be a per-kWh set nominal fee (essentially a per-unit green energy "tax"). Consumers using more energy would pay more.

The effects of a green payment would be indirectly felt by switchgrass producers, in contrast to the first two direct incentive options. The nature of a green tag payment indicates that it will be paid to the power plants and not the farmers (although Chapter 8 discusses a scenario where the power plant could transfer a part of that payment to producers). The effects of adding this type of consumer incentive into an overall incentive "package" could be varied.

A green payment has the potential to involve a group of energy users—everyday individual energy consumers—that were not necessarily being directly reached with the first two incentive options. On the other hand, there is the chance that indirect effects from either of the first two incentives could be felt by this group. This could be as a result of natural income re-distribution resulting from a government subsidy. Indirect effects could also be felt through higher consumer good prices (energy or otherwise) from industries involved in abatement investments to reduce their carbon emissions as they participate in carbon market trading. Such scenarios could force consumers to bear a portion of the bioenergy incentive that is larger than intended. In a situation where a green tag payment became a prominent incentive tool, these potential possibilities would need to be evaluated and addressed to determine exactly how a more comprehensive green tag program should be designed.

Another important consideration is that in the current case of green tag payments, the decision as to whether or not to participate is still voluntary. Though this could reduce the relative weight of some of the concerns mentioned above, it would also mean that the income the power plant receives from green tag payments could be inconsistent and potentially unsubstantial. Consumers may think the idea of subsidizing green energy is a great one and be in full ideological support. When it comes time for them to make the decision to participate and actually pay the premiums, however, they may decide even though they are in support of the idea, they don't want to spend the additional money. They could choose to leave it to other consumers to foot the bill. Or they may elect to participate for a short time, and then decide they no longer want to pay the premiums.

Table 22 in Chapter 8 showed a starting baseline as to what the different green tag program levels would be able to contribute, showing that the payment holds significant potential in being a very successful incentive. Table 23 enforced that potential by showing its effectiveness in a scenario when the power plant is able to transfer the payment to switchgrass producers. Overall, the green tag payment's success as an incentive would depend on the number of consumers participating in the voluntary program at any given time and the level of financial support they generated for the plant (i.e., which premium program level they subscribed to). It would also depend on what portion of their premium payments would be dedicated to switchgrass use at the plant itself. Power plants can create green energy portfolios that are diversified between several different clean energy sources. How much of the consumer consumer-paid green payment incentive would be available to switchgrass producers would depend on how much the power plant would use switchgrass as a green energy source relative to its other green energy options.

Conclusions

Each of the three incentive options has different advantages and disadvantages. The modified CRP payment holds good potential. Its effectiveness will depend on producer yields, the level of the modified CRP payment allowed, and on the market price of switchgrass itself. It will also depend on the federal government's willingness to adapt an existing government program and allow it to work as a bioenergy subsidy.

Due to its voluntary nature, the carbon payment is at a developmental stage and would not offer significant help at this time. However, the fundamental idea of using such a market-based payment in conjunction with other incentives is important. If more expansive carbon market participation developed and carbon prices increased, it could serve as a much more significant subsidy.

The green tag payment seems to be the incentive with the most promise. It also provides a viable subsidy option that does not depend on a government payment but one that comes from energy consumers themselves. The effects of outside variables on the incentive level it could offer switchgrass producers would still need to be determined to know exactly how much assistance it could provide, but even so, the green tag payment seems to be an option that deserves serious consideration.

All three incentive sources will continue to evolve as continued emphasis is placed on green energy development. As they develop, each incentive will be able to make a more significant individual financial impact on switchgrass producers. When looked at collectively, they have the potential to play a significant role in a very balanced incentive program to create a successful and profitable switchgrass feedstock supply.

CHAPTER 10. CONCLUSIONS

Utilizing switchgrass as a bioenergy feedstock has been shown to be one of the most promising and viable sources of biofuel production. The agronomic and environmental attributes are favorable to consistent large-scale production, and the energy potential as a fuel is desirable. In order to be a potential fuel feedstock, however, switchgrass' production costs must be low enough to be competitive with other forms of energy.

Production costs reported in Chapter 4 show that switchgrass costs of production vary depending on a few key variables. Yield is the major determining factor that influences costs. To be commercially competitive, switchgrass producers will need to consistently produce at higher yield levels. Chariton Valley producers currently yield on average two to three tons/acre. They would benefit from adopting methods of increasing yields through production management. Agronomic research must continue to improve management techniques and plant genetics.

In addition, land charges play a very significant role. Strictly from a cost perspective, any changes in producer land charges create a significant change in total production costs. However, as the potential productivity of farmland increases, its land charge also increases. Switchgrass producers must balance yield potential with associated land charge in deciding what land to devote to switchgrass production.

Switchgrass' total deliverable costs in general were shown to be too high for producers to be profitable as well as competitive with coal. As a result, various incentive payments were discussed. The three chosen here represented payments from three different payment types. A government incentive in the form of a modified CRP payment, a market-based incentive in the form of a carbon market payment, and a consumer-based incentive in the form of a green-tag payment were all examined. All three have relative policy and societal advantages and disadvantages, as discussed in Chapter 9, but they represent diverse options in addressing the existing gap between the deliverable cost of switchgrass vs. what the power plant will/is able to pay.

A modified CRP payment represented a government incentive that could create a significant financial benefit to switchgrass producers. A CRP payment option could also be seen as a more secure incentive option by switchgrass producers already familiar with the existing government program. In addition, modifying the program would potentially allow for a net reduction of overall CRP payments made by the government (cutting the program's cost) while serving as a valuable bioenergy incentive.

The carbon payment was shown to have little impact as an incentive to switchgrass producers, given current carbon prices. The value of the payment was shown to be more substantial if carbon prices were to rise in the future. If prices increase, the market-based carbon payment would be an excellent incentive source, as it would represent an excellent way for switchgrass producers to benefit from essentially a non-governmental bioenergy subsidy.

The green tag payment was shown to have great potential to producers. It appeared to be the incentive that could have the largest impact on covering the cost difference between switchgrass production and coal. The payment's relative effectiveness at doing so would greatly depend on other variables, such as energy consumer participation and how much of the payment could be transferred, directly or indirectly, back to switchgrass producers. But the fact that it represents a potentially significant incentive source that would be usage-based and independent of a government subsidy indicates that it should be an important consideration in any switchgrass incentive plan.

Having a plentiful and affordable energy supply is of incredible importance to society. The regulation and subsidization of the fossil fuel industry testifies to this importance. In recent years, as concern for the environmental implications of heavy fossil fuel usage has grown, the importance of the development of greener energy sources has also increased. As government and society begins to look to bioenergy and other green energy sources with increasing regularity, maintaining that same standard of commercial availability and affordability is a primary objective. To that end, transferring the same type of economic support received by fossil fuels to switchgrass and other green energy sources is key. In the case of switchgrass, it would establish a more level playing field in terms of energy production and it would help to equate the existing cost differences between the achievable total deliverable costs of switchgrass and the cheap cost of coal. This would ultimately create a very promising opportunity for switchgrass to become a commercially competitive green energy source.

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APPENDIX A. COST BREAKDOWN FOR SWITCHGRASS PRODUCTION ON CROPLAND

Table 24: Establishment Costs for Switchgrass Production on Cropland

PREHARVEST MACHINERY OPERATIONS	Fixed Costs ($)	Variable Costs ($)	Labor Hrs/Acre (Hrs)	Total Machinery Cost/Acre ($)
Disc (Tandem)	3.07	1.35	0.07	5.15
Harrow	1.68	0.57	0.05	2.71
Airflow Spreader (seed & fertilizers)	1.94	0.91	0.12	4.03
Spraying chemical	1.16	0.76	0.05	2.39
TOTAL MACHINERY COST	7.85	3.59	0.29	**14.28**
OPERATING EXPENSES	Unit	Price/unit	Amount	Cost/Acre
Seed	lb. PLS	7.00	10.00	70.00
Fertilizer (0-30-40)	lb. N,P,K			
P	lb.	0.28	30.00	8.40
K	lb.	0.15	40.00	6.00
Lime (including application)	Ton	12.00	3.00	36.00
Herbicide				
atrazine	lb.	2.31	1.60	3.70
2,4 D	Pt	1.68	1.50	2.52
TOTAL OPERATING COSTS				**126.62**
TOTAL MACHINERY COSTS				14.28
TOTAL OPERATING COSTS				126.62
LAND CHARGE (Cash rent equivalent)				98.00
TOTAL ESTABLISHMENT COSTS				238.90
AMORTIZATION FACTOR	11 years	@ 6%:	0.12679	
PRORATED ESTABLISHMENT COST/ACRE				**30.29**

Table 25: Reseeding Costs for Switchgrass Production on Cropland

PREHARVEST MACHINERY OPERATIONS	Fixed Costs ($)	Variable Costs ($)	Labor Hrs/Acre	Total Machinery Cost/Acre ($)
Airflow Spreader (seed & fertilizers)	1.94	0.91	0.12	4.03
Spraying chemical	1.16	0.76	0.05	2.39
TOTAL MACHINERY COST	3.10	1.67	0.16	**6.42**
OPERATING EXPENSES	Unit	Price/unit	Amount	Cost/Acre
Seed	lb. PLS	7.00	7.00	49.00
Fertilizer (0-30-40)	lb. N,P,K			
P	lb.	0.28	30.00	8.40
K	lb.	0.15	40.00	6.00
Herbicide				
Atrazine	lb.	2.31	1.60	3.70
2,4 D	Pt	1.68	1.50	2.52
TOTAL OPERATING COSTS				**69.62**
TOTAL MACHINERY COSTS				6.42
TOTAL OPERATING COSTS				69.62
LAND CHARGE (Cash rent equivalent)				98.00
TOTAL RESEEDING COSTS				174.03
TOTAL EXPECTED RESEED COSTS	Reseed Prob:	25%		43.51
AMORTIZATION FACTOR	10 years	@ 6%:	0.13587	
PRORATED RESEEDING COST/ACRE				**5.91**

Table 26: Annual Costs for Switchgrass Production on Cropland

PREHARVEST MACHINERY OPERATIONS	Fixed Costs ($)	Variable Costs ($)	Labor Hrs/Acre	Total Machinery Cost/Acre ($)
Spread liquid nitrogen	1.16	0.76	0.05	2.39
Application of P and K	1.60	0.79	0.05	2.88
Spraying chemical	1.16	0.76	0.05	2.39
TOTAL MACHINERY COST	3.92	2.31	0.14	**7.66**
OPERATING EXPENSES	Unit	Price/unit	Amount	Cost/Acre
Nitrogen	lb.	0.25	100.00	25.00
P (removal rate for fall harvest)	lb.	0.28	11.65	3.26
K (removal rate for fall harvest)	lb.	0.15	136.80	20.52
Herbicide				
Atrazine	lb.	2.31	1.60	3.70
2,4 D	pt.	1.68	1.50	2.52
TOTAL OPERATING EXPENSES				**55.00**
Interest on Operating Expenses		7.0%		1.92
HARVESTING EXPENSES	Fixed Costs	Variable Costs	Labor Hrs/Acre	Total Cost/Acre
Mowing/conditioning	3.16	1.71	0.12	6.07
Raking	1.93	1.24	0.15	4.65
Baling (large square bales)	28.86	26.04	0.50	59.90
Staging and loading	0.80	0.54	0.57	7.02
TOTAL HARVESTING COSTS	34.75	28.53	1.34	**77.65**
TOTAL MACHINERY COSTS				7.66
TOTAL OPERATING COSTS				55.00
INTEREST ON OPERATING EXPENSES (7%)				1.92
HARVEST COSTS				77.65
LAND CHARGE (Cash rent equivalent)				98.00
YEARLY PRODUCTION COSTS/ACRE				**240.23**

APPENDIX B. COST BREAKDOWN FOR SWITCHGRASS PRODUCTION ON GRASSLAND

Table 27: Establishment Costs for Switchgrass Production on Grassland

PREHARVEST MACHINERY OPERATIONS	Fixed Costs ($)	Variable Costs ($)	Labor Hrs/Acre	Total Machinery Cost/Acre ($)
Mow (Rotary)	2.61	1.76	0.11	5.44
Airflow Spreader (seed & fertilizers)	1.94	0.91	0.12	4.03
Spraying Roundup®	1.16	0.76	0.05	2.39
Spraying atrazine and 2,4 D	1.16	0.76	0.05	2.39
TOTAL MACHINERY COST	6.87	4.19	0.33	**14.24**
OPERATING EXPENSES	Unit	Price/unit	Amount	Cost/Acre
Seed	lb. PLS	7.00	10.00	70.00
Fertilizer (0-30-40)	lb. N,P,K			
P	lb.	0.28	30.00	8.40
K	lb.	0.15	40.00	6.00
Lime (including application)	Ton	12.00	3.00	36.00
Herbicide				
Atrazine	lb.	2.31	1.60	3.70
2,4 D	Pt	1.68	1.50	2.52
Roundup®	Qt	12.48	2.00	24.97
TOTAL OPERATING COSTS				**151.58**
TOTAL MACHINERY COSTS				14.24
TOTAL OPERATING COSTS				151.58
LAND CHARGE (Cash rent equivalent)				55.00
TOTAL ESTABLISHMENT COSTS				220.83
AMORTIZATION FACTOR	11 years	@ 6%:	0.12679	
PRORATED ESTABLISHMENT COST/ACRE				**28.00**

Table 28: Reseeding Costs for Switchgrass Production on Grassland

PREHARVEST MACHINERY OPERATIONS	Fixed Costs ($)	Variable Costs ($)	Labor Hrs/Acre	Total Machinery Cost/Acre ($)
Airflow Spreader (seed & fertilizers)	1.94	0.91	0.12	4.03
Spraying chemicals	1.16	0.76	0.05	2.39
TOTAL MACHINERY COST	3.10	1.67	0.16	**6.42**
OPERATING EXPENSES	Unit	Price/unit	Amount	Cost/Acre
Seed	lb. PLS	7.00	7.00	49.00
Fertilizer (0-30-40)	lb. N,P,K			
P	lb.	0.28	30.00	8.40
K	lb.	0.15	40.00	6.00
Herbicide				
Atrazine	lb.	2.31	1.60	3.70
2,4 D	Pt	1.68	1.50	2.52
TOTAL OPERATING COSTS				**69.62**
TOTAL MACHINERY COSTS				6.42
TOTAL OPERATING COSTS				69.62
LAND CHARGE (Cash rent equivalent)				55.00
TOTAL RESEEDING COSTS				131.03
TOTAL EXPECTED RESEEDING COSTS	Reseed prob:	25%		32.76
AMORTIZATION FACTOR	10 years	@ 6%:	0.13587	
PRORATED ESTABLISHMENT COST/ACRE				**4.45**

Table 29: Annual Costs for Switchgrass Production on Grassland

PREHARVEST MACHINERY OPERATIONS	Fixed Costs ($)	Variable Costs ($)	Labor Hrs/Acre	Total Machinery Cost/Acre ($)
Spread liquid nitrogen	1.16	0.76	0.05	2.39
Application of P and K	1.60	0.79	0.05	2.88
Spraying chemical	1.16	0.76	0.05	2.39
TOTAL MACHINERY COST	3.92	2.31	0.14	**7.66**
OPERATING EXPENSES	Unit	Price/unit	Amount	Cost/Acre
Nitrogen	lb.	0.25	100.00	25.00
P (removal rate for fall harvest)	lb.	0.28	7.76	2.17
K (removal rate for fall harvest)	lb.	0.15	91.20	13.68
Herbicide				
atrazine	lb.	2.31	1.60	3.70
2,4 D	pt.	1.68	1.50	2.52
TOTAL OPERATING EXPENSES				**47.07**
Interest on Operating Expenses		7.0%		1.65
HARVESTING EXPENSES	Fixed Costs	Variable Costs	Labor Hrs/Acre	Total Cost/Acre
Mowing/conditioning	3.16	1.71	0.12	6.07
Raking	1.93	1.24	0.15	4.65
Baling (large square bales)	19.24	17.36	0.33	39.93
Staging and loading	0.80	0.54	0.38	5.13
TOTAL HARVESTING COSTS	25.13	20.85	0.98	**55.78**
TOTAL MACHINERY COSTS				7.66
TOTAL OPERATING COSTS				47.07
INTEREST ON OPERATING EXPENSES (7%)				1.65
HARVEST COSTS				55.78
LAND CHARGE (Cash rent equivalent)				55.00
YEARLY PRODUCTION COSTS/ACRE				**167.16**