Estimating the Economic Impact of Substituting Switchgrass for Coal for Electric Generation in Iowa

Final Report

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DISCLAIMER

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EXECUTIVE SUMMARY

The structure of the U.S. economy plays a significant role in setting the private cost-benefit decisions that consumers make within the national economy. The economic system does not easily reveal the totality of true costs of our economic choices. In the case of the Chariton Valley Biomass Project (CVBP), there is an obvious private cost equation that strongly favors the continued use of coal from the Western United States over a mix of that coal and locally produced switchgrass. Because of societal economic structure, however, the cost of fuels apparent to the purchasing electric generating facility does not accurately reflect the total cost of each fuel to U.S. society as a whole. The private price is distorted by historical and existing tax policies, by subsidies from state and federal government programs, and from the lack of monetized recognition of the environmental costs or benefits associated with production and use of either fuel.

A framework for scalable economic net benefit analysis is presented which will review the private cost-benefit balance for the utility, and for societal cost-benefit balances. The private cost-benefit balance is determined by the fuel price, and also by those few environmental components which have been internalized into a price, such as payments for acid rain program emission allowances, or fees for releasing air pollutants under federal Title V Operating Permit regulations. There is a much larger body of subsidies and environmental impacts, however, which have not been internalized into a private price component. These may present significant costs to society, which therefore bears these costs without implicitly or explicitly tying them directly to the specific activity creating those costs; in this case, fuel consumption. Shedding light on these hidden costs or benefits may, or may not, illustrate the overall economic sense of making a switchgrass for coal substitution.

Given current economic structures, the conversion of the coal-fired plant to a facility that co-fires 5 percent switchgrass with coal leads to net private costs ranging from \$51 to \$141 million (25 year, net present value, 3% discount, 2002 dollars). However, our study also indicates that under low (\$40/ton) and medium (\$52/ton) price scenarios for switchgrass fuel the larger society could experience net social benefits ranging from \$22 to \$63 million. There are several key elements of our study that make these projections conservative:

- The continuing movement toward internalizing some of these environmental social costs will only improve the private cost-benefit balance over time
- The potentially significant contribution of mercury damage costs, or indeed internalization of mercury control costs has presently been excluded from our analysis, awaiting more numerical certainty. Inclusion of these benefits on either the private or social cost-benefit structure will enhance the project.
- We have assumed static values for internalized environmental costs and benefits. Thus a flat value is assumed for greenhouse gas emission benefits based upon values from a pilot emission trading program as of March 28, 2005. Those values are expected to dramatically rise if and when a national greenhouse gas emission management program develops, as has been proposed in both houses of the U.S. Congress.
- We have made no attempt to predict future policies that may appear, in the forms of renewable energy portfolio standards, renewable energy subsidies, or green power purchasing programs. Development of such policies would enhance the private cost-benefit balance of the switchgrass project.

All of these factors taken together point to our analysis as likely presenting a lowest-benefit scenario. Future development should only enhance the prospects of the project's private and social economic feasibility, perhaps dramatically.

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Introduction

The Center for Global and Regional Environmental Research is conducting a study on behalf of the Chariton Valley Biomass Project (CVBP) to determine the economic feasibility of burning switchgrass as a partial substitute for coal in the production of electricity. It is thought that such a substitution would be more environmentally friendly than a 100 percent reliance on coal fired electricity. A pilot project is underway utilizing the Alliant Energy, Inc. operated coal-fired power plant in Chillicothe, Iowa. Using retrofit technologies it is possible to reduce the amount of coal required by approximately 5 percent. The key question of economic viability is answered by determining how much more it would cost to achieve this higher level of environmental health.

This study will be conducted to compute costs and benefits at two levels of analysis; the private cost-benefit situation for the utility, and the net social cost-benefit structure faced by the larger community. The firm must see a positive contribution to profit when considering only its private costs and benefits, whereas society must see a positive contribution when considering the increments to social costs and benefits that accrue to taxpayers and citizens. Derivation of a net social benefit for the project may be the ultimate harbinger for the economic fate of this initiative. The switchgrass substitution is likely to be the more expensive alternative for the individual electricity generating firm(s), because although coal is abundant and inexpensive on a private cost basis, it is heavily subsidized at the national level through direct and indirect subsidies. The determination of a net social benefit may spur policy changes that reduce harmful subsidies and encourage the socially beneficial activity. The policy changes will, in turn, lead to an improved economic balance for the private decision-maker.

Study Objectives

The objective of our study is to develop a framework for cost benefit analysis of switchgrass substitution for coal in electric generation at the Ottumwa Generating Station. Our work builds upon previous studies conducted for the Chariton Valley Biomass Project and seeks to answer the question of how the project's documented environmental benefits will impact the private and social cost benefit analysis.

Summary of Potential Social Costs and Benefits

A range of potential social costs and benefits were explored in an effort to fully capture the true societal costs of using switchgrass to replace coal for electric generation. These potential costs and benefits include existing subsidies to coal and switchgrass production, and the environmental impacts that a coal-to-switchgrass fuel switch would create.

The Social Costs of Subsidies

Existing subsidies for the switchgrass production have been thoroughly explored by Duffy, by Antares Group, and through the Economic Peer Review which the project underwent in 2003. These subsidies, most notably in the form of Conservation Reserve Program (CRP) payments, are already factored into the price scenarios utilized in our study. Detailed development of these costs scenarios may be found in Brummer, et al, 2003. Subsidies in the form of renewable energy production credits are currently not available to the project. Our study has not speculated on their impact, however, such information is available in Antares Group, 2002.

Existing coal subsidies have not been previously considered in the economic analyses conducted on the Chariton Valley Biomass Project. We therefore examined the levels of direct subsidies that are awarded to coal producers in an effort to discern impacts on coal prices. Table 1 lists the subsidies which we were able to research.

Table 1. Existing Coal Subsidies (EIA, 1999)

Social Cost Component of Total Unit Price
Capital Gains Treatment of Royalties on Coal
Excess of Percentage Over Depletion: Coal
Clean Coal Technology Program
Coal Research and Development
Abandoned Mine Reclamation Fund
Black Lung Disability Fund

Capital Gains Treatment of Royalties on Coal

Owners of coal mining rights who lease their property can receive royalties on mined coal, which can be taxed at capital gains tax rates. These rates are lower than the top income tax rates, generating a tax subsidy for coal production by incentivizing leasing of the lands for mining. It is estimated that the tax breaks reduced federal revenue by $65 million in 2000 (EIA, 1999).

Excess of Percentage Over Depletion: Coal

Tax rules allow for percentage depletion deductions to assist in recovering capital investments. While primarily used for oil and gas development, the rules do allow for coal subsidization as well. Total outlays for this tax treatment in 2000 were estimated to be $325 million, with the majority going toward oil and gas production (EIA, 1999)

Clean Coal Technology Program

The Clean Coal Technology (CCT) program is a research and development program that assists the coal energy in discovering new technologies that will allow for cleaner combustion of coal. Congress has appropriated a total of $2.3 billion for the program, which is doled out in annual grants to qualifying projects. Though no outlays were expected in 2000, 1999 saw $183 million in outlays. According to EIA, "The CCT Program has demonstrated a portfolio of technologies that have improved the economic and environmental performance of coal technologies." (EIA, 1999)

Coal Research and Development

Research and development programs are funded by the federal government to achieve higher efficiency of coal-fired electric generation, to design improved emission control systems for coal-fired power plants, and to research creation of alternative fuels or uses from coal. Total funding for these subsidies were estimated at $220 million in 2000 (EIA, 1999).

Abandoned Mine Reclamation Fund

The abandoned mine reclamation fee is a trust fund arrangement supported by a per-ton fee on coal mine production. The funds are used to clean up acid mine drainage and other environmental problems at abandoned mine sites. For many years, outlays have fallen far short of collections, resulting in a trust fund balance of $1.6 billion in 1999 (EIA, 1999). Since the fund is derived from a fee applied to coal production, this cost has been internalized into the price paid for coal.

Black Lung Disability Fund

The black lung disability fund is also a trust fund arrangement which is funded through an excise tax on mined coal. The fund is used to pay medical expenses for miners suffering from black lung disease. Unlike the abandoned mine reclamation fund, however, the black lung disability fund is seriously in arrears; i.e. the collections are far below outlays, and have been for some time. The deficit was $6.2 billion in 1999. Since the deficit is covered by other taxpayer funds, the result is a significant subsidy to the coal industry. Thus, while a portion of the total costs of black lung disease have been internalized through the excise tax, the majority of costs related to the disease remain external to the price of coal.

Summary of Coal Subsidies

Of the subsidies investigated, it appears that the Black Lung Disability Fund is the only subsidy that has not been internalized into the private costs of coal, or may have a direct impact on the cost of coal to the Chariton Valley Biomass Project. There is a surtax on coal production that is designed to cover the societal costs of this fund, however, those receipts are far below what is required by the fund. This net federal outlay therefore is a direct subsidy to coal producers that is a cost born by the general public through taxation. Given the total tonnage of coal produced across the U.S., this subsidy corresponds to only fractions of a cent per ton. It is therefore not included in our analysis.

Costs and Benefits of Environmental Impacts

The second major component of the social cost-benefit equation is the social cost or benefit associated with changing impacts on the environment. A few of the environmental impacts have had private economic value placed on them due to regulatory activity, such as emission trading programs for control of sulfur dioxide (SO_2) emissions. However, most of the environmental changes remain without a defined market value and thus will fall in the social cost-benefit arena as the costs are borne by society as a whole, often without participants' knowledge that the costs are being borne. Table 2 provides a list of environmental change components that were evaluated in our study.

Table 2. Possible Components of the Environmental Change Vector, ΔE

Activity	Environmental Impact Component
Power Plant Combustion	Greenhouse gas emissions
Power Plant Combustion	Sulfur Dioxide (SO2) emissions
Power Plant Combustion	Nitrogen Oxides emissions
Power Plant Combustion	Carbon Dioxide emissions
Power Plant Combustion	Particulate emissions
Power Plant Combustion	Volatile Organic Compound (VOC) emissions
Power Plant Combustion	Mercury and heavy metals emissions
Power Plant Combustion	Non-metal toxic emissions
Coal Mining	Acid mine drainage from coal mining
Coal Mining	Coal mining habitat impacts
Coal Mining	Coal mining natural resource impacts
Switchgrass Farming	Water quality impacts from siltation
Switchgrass Farming	Water quality impacts from chemical runoff
Switchgrass Farming	Soil erosion impacts
Switchgrass Farming	Wildlife habitat impacts-non-game species
Switchgrass Farming	Wildlife habitat impacts-non-game species
Ash Disposal	Secondary use of ash in concrete

Greenhouse Gas Emissions

Greenhouse gas emissions have become the central focus among international parties attempting to address the prospect of global climate change. It is widely believed that human emissions of greenhouse gases, primarily carbon dioxide, are contributing significantly to a warming of the earth's global climate. The impact of switchgrass substitution for coal upon greenhouse gas emissions has been previously documented (Ney and Schnoor, 2002). This earlier study evaluated greenhouse gas emission impacts from the fuel cycles of switchgrass and coal, including emissions from fuel and other inputs to the growth and harvest of the switchgrass crop and the mining and preparation of coal. This study found that the substitution of switchgrass for coal presented a net greenhouse gas benefit of 360 lbs carbon dioxide-equivalent (CO_2-eq) for every million Btu (MMBtu) of switchgrass combusted. Private costs are calculated by conservatively assuming that the current CO_2-eq price on the Chicago Climate Exchange, $1.50 per metric ton (March 28, 2005), is maintained throughout the 25 year net present value calculation. Social costs are calculated using damage cost functions taken from the literature and are described in the results section of this report.

Sulfur Dioxide Emissions

Sulfur dioxide emissions are key precursors to the formation of acid rain which has plagued much of the eastern United States and Canada. The Clean Air Act Amendments addressed the need for sulfur dioxide controls with the creation of the Acid Rain Program for regulation and reduction of sulfur dioxide and nitrogen oxide emissions. Reduced sulfur content in switchgrass, 0.04% compared to the low sulfur coal combusted at the Alliant Energy Facility, 0.3% means that there will be slight reduction in emissions of sulfur dioxide. Stack testing completed during the second test burn at the Ottumwa Generating Station (OGS) indicated a reduction of SO_2 by 0.032 pounds per MMBtu for co-firing compared to 100 percent coal combustion. We have assumed that the SO_2 emission rate from coal remains constant during the co-firing, meaning that for each MMBtu of switchgrass burned, SO_2 is reduced by 0.64 pounds. For a 5% co-fire substitution of switchgrass for coal, the reduction in controlled SO_2 emissions would total 448 tons annually.

The reduction in SO_2 emission can reduce private expenditures for purchasing emission allowances under the Acid Rain Program administered by the U.S. Environmental Protection Agency. As of March 28, 2005, SO_2 allowances were trading at $707 per ton. The reduction in emissions may also reduce private expenditures in fees paid to administer the Iowa Title V Operating Permit Program. These fees are applied at the rate of $32.25 per ton (2003) on the first 4,000 tons of any individual pollutant, however we expect the marginal cost of this benefit to be zero since total facility SO_2 emissions may exceed the 4,000 ton threshold. Social costs are calculated using damage cost functions from the literature and are described in the results section of this report.

Nitrogen Oxide Emissions

Nitrogen oxide emissions are a key component contributing to smog formation (ground-level ozone) in much of the United States' larger urban areas. Control of these emissions has thus been deemed important for the reduction of smog and the deleterious health effects associated with this form of air pollution. Stack testing completed during the second test burn at the Ottumwa Generating Station (OGS) indicated an increase of NO_x by 0.001 pounds per MMBtu (midpoint of data) for co-firing compared to 100 percent coal combustion. We have assumed that the NO_x emission rate from coal remains constant during the co-firing, meaning that for each MMBtu of switchgrass burned, NO_x is increased by 0.015 pounds. For a 5% co-fire substitution of switchgrass for coal, the increase in NO_x emissions would total 10.5 tons annually.

The increase in NO_x emissions may increase private expenditures in fees paid to administer the Iowa Title V Operating Permit Program. These fees are applied at the rate of $32.25 per ton (2003) on the first 4,000 tons of any individual pollutant, however we expect the marginal cost of this benefit to be zero since total facility NO_x emissions are likely to exceed the 4,000 ton threshold. Social costs are calculated using damage cost functions from the literature and are described in the results section of this report.

Carbon Monoxide Emissions

Carbon monoxide emissions act alone, and in concert with ground level ozone, to create unhealthy living conditions in many of United States largest cities. While acute health problems are generally not associated with power plant emissions of carbon monoxide, those emissions do contribute to a higher ambient background condition. Stack testing completed during the second test burn at the Ottumwa Generating Station (OGS) indicated a slight decrease of CO emission by 0.00001 pounds per MMBtu (midpoint of data) for co-firing compared to 100 percent coal combustion. We have assumed that the CO emission rate from coal remains constant during the co-firing, meaning that for each MMBtu of switchgrass burned, CO is reduced by 0.0001 pounds.

For a 5% co-fire substitution of switchgrass for coal, the decrease in CO emissions would total 0.07 tons annually.

There are no fees assessed to internalize CO emissions, via the Iowa Title V Operating Permit Program, into the private cost-benefit equation. No damage cost function was discovered for inclusion of CO emissions into the social cost-benefit equation.

Particulate Emissions

Particulate emissions have recently received a great deal of attention, especially fine particles, for the adverse health effects brought about by high particulate concentrations. The U.S. Environmental Protection Agency has recently proposed rules for the regulation of particles less than 2.5 microns in aerodynamic diameter. This couples with existing regulations on large particles and on particles of less than 10 microns in diameter. Stack testing completed during the second test burn at the Ottumwa Generating Station (OGS) indicated a reduction of PM_{10} by 0.00175 pounds per MMBtu (midpoint of data) for co-firing compared to 100 percent coal combustion. We have assumed that the PM_{10} emission rate from coal remains constant during the co-firing, meaning that for each MMBtu of switchgrass burned, PM_{10} is reduced by 0.035 pounds. For a 5% co-fire substitution of switchgrass for coal, the reduction in controlled PM_{10} emissions would total 24.5 tons annually.

The reduction in PM_{10} emissions may reduce private expenditures in fees paid to administer the Iowa Title V Operating Permit Program. These fees are applied at the rate of $32.25 per ton (2003) on the first 4,000 tons of any individual pollutant. We expect the marginal cost of this benefit to be $32.35 per ton since total facility PM_{10} emissions should be lower than the 4,000 ton threshold. Social costs a calculated using damage cost functions from the literature and are described in the results section of this report.

Volatile Organic Compound (VOC) Emissions

Volatile organic compounds (VOC) are carbon-based compounds that arise as a byproduct of incomplete combustion. VOCs react in the presence of sunlight and nitrogen compounds to form ground level ozone, known more commonly as smog. In areas of the United States where smog is a problem dramatic emission control programs and emission trading systems have been put in place for reduction of VOCs. The south-central Iowa region where the power plant is located does not currently face problems in meeting the National Ambient Air Quality Standard for ozone and thus does not face control or emission trading requirements for emission of VOC at this time. We assessed changes in VOC emissions by comparing emissions predicted by the U.S. EPA document, “AP-42 Compilation of Air Pollutant Emission Factors”. We compared coal combustion emission factors with emission factors from wood combustion, the closest approximation for switchgrass combustion that we could find. Using this method, it would appear that VOC emissions may increase slightly, by 6.5 tons per year.

The increase in VOC emissions may increase private expenditures in fees paid to administer the Iowa Title V Operating Permit Program. These fees are applied at the rate of $32.25 per ton (2003) on the first 4,000 tons of any individual pollutant. We expect the marginal cost of this benefit to be $32.35 per ton since total facility VOC emissions should be lower than the 4,000 ton threshold. Social costs are calculated using damage cost functions from the literature and are described in the results section of this report.

Mercury and Heavy Metals Emissions

Mercury has recently received national attention as a biopersistent heavy metal that is endangering fish and wildlife in the great lakes region. Other toxic heavy metals, such as arsenic, barium, chromium, cadmium, lead, mercury, cobalt, beryllium, selenium, and manganese also occur in emissions from coal-fired power plants. Stack testing for mercury emissions was completed during the second test burn at the Ottumwa Generating Station (OGS) indicating a reduction of mercury emission 5.0E-07 pounds per MMBtu (midpoint of data) for co-firing compared to 100 percent coal combustion. For a 5% co-fire substitution of switchgrass for coal, the reduction in mercury emissions would total more than 13 pounds annually. Although the Iowa Title V Operating Permit fee of $32.35 per ton would apply to the emission of mercury, the private cost benefit gained from 13 pounds of annual reduction is too small for consideration. There are currently no other methods of internalizing mercury emissions into private cost-benefit decisions, although recently issued legislation is expected to lead to development of a mercury trading program that would value mercury emissions on a cost-of-control basis. EPA has projected the costs of compliance with the Clean Air Mercury Rule (CAMR) to approach $40,000 per pound by 2020 (EPA, 2005). This would lead to privatization of approximately $9.3 million, present value, in benefit from the mercury reduction presented by the CVBP. Despite the wide discussion of mercury impacts throughout the environment, we were unable to obtain damage cost estimates for inclusion of this mercury benefit into the social cost-benefit equation.

Testing of the OGS boilers has not been conducted for emission of the other metals. However, from an ultimate analysis of both fuels, switchgrass presents surprisingly higher concentrations of lead, but lower concentrations of arsenic, barium, chromium, cadmium, and selenium. Tests for the other metals listed were either not performed or less than detectable limits in the switchgrass (Amos, 2002).

Non-metal Toxic Emissions

In addition to the toxic metal emissions released during coal combustion, there are also over 60 different non-metal toxic pollutants emitted. The U.S. Environmental Protection Agency provides emission factors for the calculation of these emissions in "Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: *Stationary Point and Area Sources."* Hydrogen chloride (HCl) is the non-metal toxic air pollutant emitted in the most significant quantities. We assessed changes in HCl emissions by comparing emissions predicted by AP-42. We compared coal combustion emission factors with emission factors from wood combustion, the closest approximation for switchgrass combustion that we could find. Using this method, it is predicted that HCl emissions will decrease by 36.82 tons per year.

The decrease in HCl emissions will decrease private expenditures in fees paid to administer the Iowa Title V Operating Permit Program. These fees are applied at the rate of $32.25 per ton (2003) on the first 4,000 tons of any individual pollutant. We expect the marginal cost of this benefit to be $32.35 since total facility HCl emissions should be lower than the 4,000 ton threshold. We could not determine damage costs functions for HCl emissions.

Acid Mine Drainage from Coal Mining

A by-product of coal mining is the development of acid mine drainage. Slurries of highly acidic waters, often containing elevated levels of heavy metals, results from chemical reactions that occur within mine wastes. Expensive, complex treatment systems have to be installed in order to treat the drainage so that environmental degradation in minimized. We were unable to develop methods to assess the true social or privatized cost components of acid mine drainage.

Coal Mining Habitat Impacts

Coal mining is a destructive process. Surface mining of coal results in the removal of overburden (the land overlaying the shallow coal deposit). In this process, the surface is scraped away and stockpiled in another area. The process results in the destruction of the habitat over the mine deposit, as well as the area where the overburden is stored. Depending on the qualities of the overburden surface, there could be significant wildlife disruptions, or losses of trees and plant life. We were unable to develop methods to assess the true social or privatized cost components of coal mining-related habitat loss.

Coal Mining Natural Resource Impacts

The coal utilized at the Ottumwa Generating Station (OGS) is a western U.S. sub-bituminous coal typically surface mined in Utah and Wyoming in the Power River Basin Region. The mining process leads to destruction of lands above the coal seam (overburden). Additional lands are used to store the overburden and tailings once it is removed from the mine. The overburden possesses inherent value as a natural resource. It may consist of forest or grassland, wetland or range. We were unable to develop methods to assess the true social or privatized cost components of coal mining-related natural resource loss or degradation.

Switchgrass Farming Impacts on Soil Erosion, Siltation and Chemical Runoff

The effects of switchgrass production for the Chariton Valley Biomass Project upon soil erosion, nutrient loss and resulting water quality were analyzed using the Soil and Water Assessment Tool (SWAT) (Nepple, et al, 2002). The model indicated that production of switchgrass, in lieu of traditional row-crop agriculture, would reduce soil erosion over the Rathbun Lake watershed. In addition, nitrogen, phosphorus and atrazine loadings would be significantly reduced.

We have taken the results of the SWAT analysis and have attempted to marry the results to economic benefit analyses conducted to evaluate the conservation reserve program (CRP) administered by the US Department of Agriculture. The reduction of soil loss contributed to on-farm productivity retention (or improvement in some cases) and also creates positive off-farm benefits in the form of improved water quality and improved wildlife habitat, again relative to a baseline of traditional row-crop agriculture. Benefits of improved water quality include recreation benefits due to improved fishing habitat and reduced costs for Rathbun Fishery operations, but also help reduce water treatment costs for the Rathbun Regional Water Authority which treats Rathbun Lake water for drinking water across southern Iowa.

SWAT Results (Nepple, et al, 2002)

Modeling the impact of converting 50,000 acres of cropland to switchgrass production indicated that soil erosion would be reduced by 55% below the baseline profile by the conversion of 15.3 % of the watershed area to switchgrass. Table 3 summarizes the study findings.

Table 3. SWAT Predicted Reductions in Environmental Impacts

Element	Reduction relative to row-crop baselines
Sediment Yield	55%
Sediment-bound Phosphorus	36%
Soluble Phosphorus	26%
Sediment-bound Nitrogen	39%
Soluble Nitrogen	38%
Sediment-bound Atrazine	83%
Soluble Atrazine	86%

Economic Valuation

Estimates of the value of economic benefits received by the reductions in run-off were made using data presented by the USDA Economic Research Service (Ribaudo, et al, 1994). The methods and values of Ribaudo were derived for quantifying soil erosion benefits for Conservation Reserve Program lands. Utilization of these results for analysis of the benefits of the Chariton Valley Biomass Project is made possible by reducing the denominator to the common unit of tons of soil erosion avoided. The current study makes use of the Ribaudo category for soils for the Corn Belt, which includes the states of Iowa, Illinois, Indiana, Missouri and Ohio.

Average Erosion-Related Damage to Soil Productivity

Average erosion-related damage to soil productivity was estimated to total $0.66 per ton of soil lost. These losses include 100-year losses in yield at $0.4 per ton and $0.25 per ton in nutrient costs that would be needed to replace nutrients lost to erosion. A discount rate of 4% was assumed.

Off-Site Impacts

The economic burdens experienced off-site were also estimated by Ribaudo. Effects of improved water quality on recreational fishing were estimated using a fishing participation model based upon the National Survey of Hunting, Fishing and Wildlife-Associated Recreation. The model predicted changes in fishing activity decisions based upon water quality parameters. Costs of downstream water treatment were modeled, with calculations of cost based upon turbidity of the source water. Total annual offsite damage costs per ton of soil erosion were estimated at $1.78 per ton for all of the U.S., with the Corn Belt region assigned an impact value of $1.15 per ton.

Determining Chariton Valley Biomass Project Benefits

At full production capacity, the Chariton Valley Biomass Project is expected to utilize 100,000 tons of switchgrass, requiring 25,000 acres of production. Noting that this acreage is half of the acreage used in the SWAT modeling analysis, total soil erosion benefits predicted by the model will be cut in half. This assumption could under-predict benefits if the switchgrass production is ultimately placed on the more highly erodible lands of the region, or could over-predict erosion benefits if switchgrass production is ultimately placed on the least-erodible, more productive lands. Analysis of current utilization trends in the Chariton Valley indicates that more highly erodible lands have been placed into switchgrass production, thus we feel our assumption is conservative.

Switchgrass Farming Wildlife Habitat Impacts

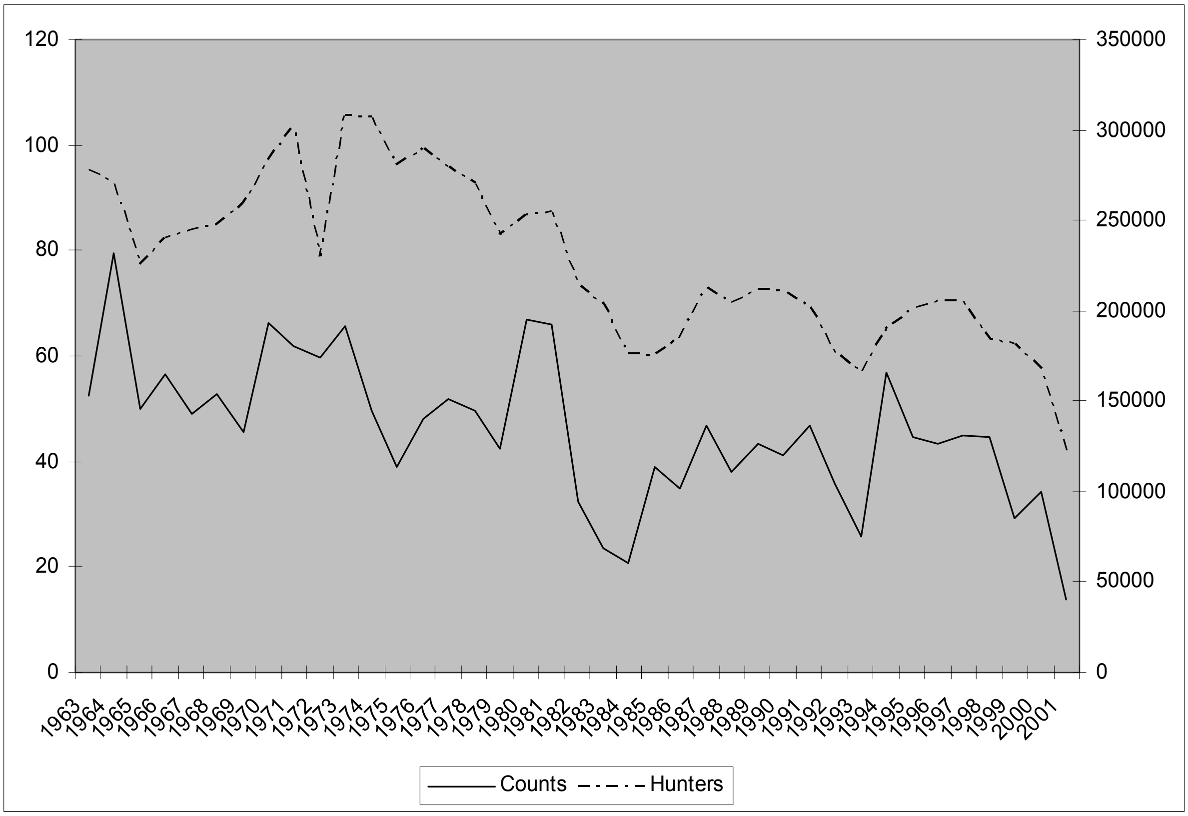
A recent study of the switchgrass field of the Chariton Valley Biomass Project found that switchgrass production offers a mixed result for creation habitat of non-game bird species. Depending on field construction and harvesting schemes employed each field of switchgrass will see some non-game bird species increase, while others will decrease (Murray, 2002).

Switchgrass Farming Wildlife Habitat Impacts - Game Species

Iowa is known nationally as one of the top hunting areas for the ring-necked pheasant. Each year, nearly one million male pheasants are harvested during the 10-11 week season. In addition to large numbers of Iowa residents, pheasant hunting draws hunters from across the United States, providing a boost to the Iowa economy. Expenditures include hunting license fees, guns and ammunition, clothing and equipment and travel expenses. According to the 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, pheasant hunting in Iowa during 2001 resulted in nearly $100 million in expenditures, despite the fact 2001 has the lowest pheasant counts and harvest recorded since record-keeping began in 1962. Pheasant harvest in 2001 was less than half, and in fact was nearly one-third of the average harvest of the period 1992-2001.

The number of pheasant hunters and hunting expenditures track in relation to the estimated pheasant population each year. The Iowa Department of Natural Resources conducts roadside surveys each year, traveling preset routes to count the number of pheasants that appear along each route. While the method does not guarantee a counting of each and every pheasant, throughout its use it has provided a good early indicator of hunting activity and harvest. Figure 1 shows the relationship between pheasant roadside counts and number of hunters.

Figure 1. Correlation Between Pheasant Counts and Pheasant Hunters, 1963-2001

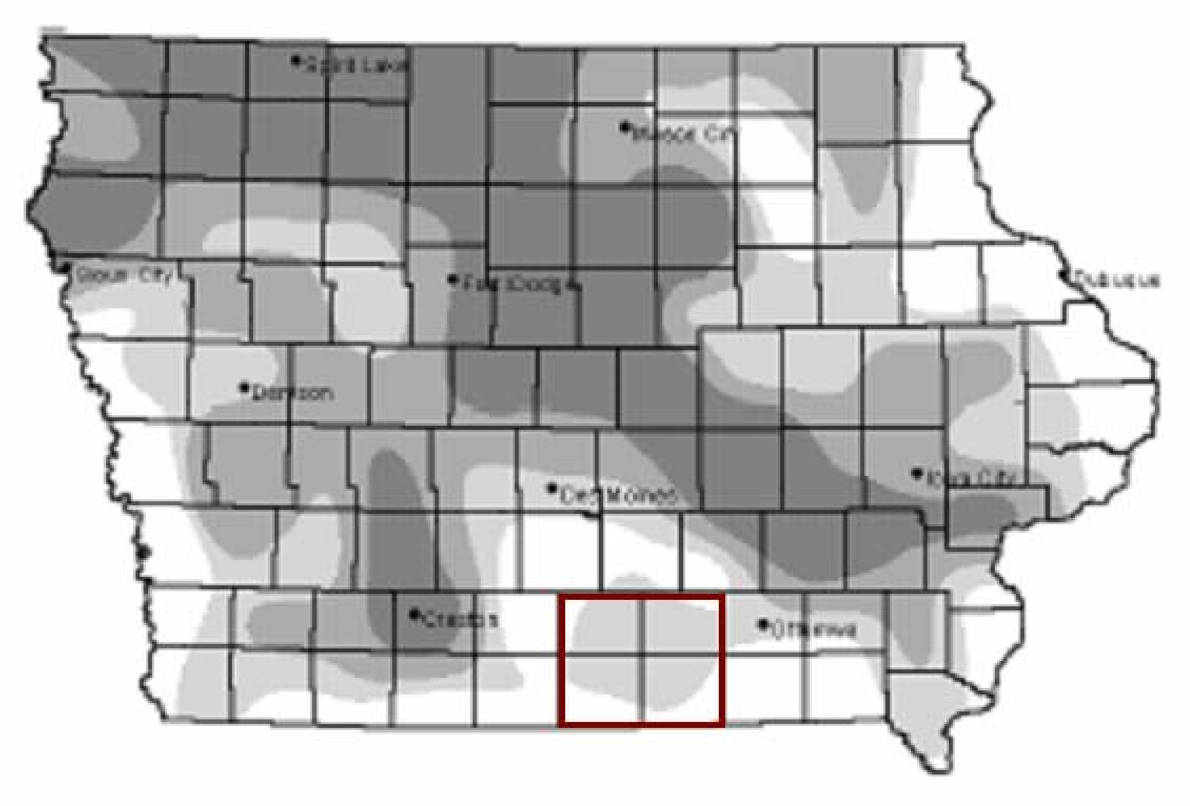


Statistical regression analysis shows a correlation between roadside counts and number of hunters with an r-squared value of 0.72. Certainly the number of hunters each year is not solely dependent upon the roadside counts, with economic conditions and weather likely to affect hunter numbers. However, there is statistical validity in the claim that higher counts to lead to higher numbers of hunters, and thus higher hunting expenditures. Data are not available to discern whether higher counts lead to a greater percentage of out-of-state hunters, whose per trip expenditures are likely to be larger than those for in-state hunters, however, publication of the pheasant counts can be expected to lead to an increased influx of hunters from outside of Iowa.

Pheasant Population Distributions in Iowa

Historically, the northwest portion of Iowa has provided the largest pheasant populations. However, the expansion of row-crop agriculture has led to a significant decrease in available habitat for nesting and hiding from predators. Over the last 25 years, there has been a shift in population southward and eastward (Figure 2). In addition to pheasant habitat that provides shelter from cold and predators and provides an available food supply, the severity of Iowa winters also plays a large role in determining fall pheasant populations. The fall hunting season following a harsh winter, or unusually cold and wet spring, is likely to see significant reductions in pheasant populations, as occurred in 2001.

Figure 2. 2003 Pheasant Population Densities in Iowa



Chariton Valley Biomass Project Impacts

Studies conducted by Iowa State University researchers quantified the numbers of pheasants found within traditional row-crop (corn) fields, strip-harvested and total-harvested switchgrass fields within the Chariton Valley Biomass Project area. The study found increased pheasant populations in the switchgrass relative to the row-crop fields (Murray, et al, 2003). The finding of 14-16% more pheasants in switchgrass fields versus row-crop fields points to an opportunity to achieve increased pheasant populations in the project area, and by extension, an increase in hunters and hunting expenditures in the local area. Pheasant populations were increased in both strip-harvested and total-harvested switchgrass plots relative to row-crop ground.

South central Iowa is already one of the more popular pheasant hunting destinations in Iowa, providing opportunities for turkey and quail hunting in addition to providing respectable pheasant populations (Red box, Figure 2). A recent increase in predators, notably coyotes in the southwestern part of the state, indicate that the sheltering role that switchgrass fields provide can aid in maintaining or improving pheasant populations in the project area. The current development of an outdoors-themed destination park in the project area could also serve as a focal point for attracting hunters to the region.

Project-specific economic impacts associated with increases in pheasant populations cannot be determined. There is a lack of baseline data regarding total pheasant populations within the project area, and a lack of information about hunting trips and expenditures within the project area. Qualitatively, the success of the Chariton Valley Biomass Project would appear to lead to increased pheasant populations in the project area, eventually leading to increased economic activity related to hunting

Statewide Impacts

As discussed previously, the hunting-related expenditures experienced within the state of Iowa are correlated to pheasant counts. A sizeable shift in production of switchgrass, away from row-crop agriculture, could boost overall pheasant numbers by providing shelter against winter weather, and cover from predators. Reductions in tillage and planting activity for perennial switchgrass production relative to annual row-crop production would lead to reduced disruption of nesting and lessen habitat destruction, providing cover prom predators and winter weather.

Ash Disposal – Utilization in Concrete

Current coal-only operations at the power plant allow for the re-use of collected ash in concrete products. This re-use of ash provides an additional income stream for the power plant. The use of boiler ash in concrete is expressly authorized by Department of Transportation rules governing the composition of the waste. If combustion of switchgrass significantly alters the composition of the ash, the facility may lose the ability to sell its ash for these purposes. This would result not only in lost income, but would also provide increased costs for landfill disposal of the ash. Recent reports from the Chariton Valley Biomass Project indicate that co-firing ash may still be utilized in production of concrete; therefore this impact is not evaluated further.

Results

The goal of the present analysis is to assess the economic net benefit (i.e., the difference between economic benefits and economic costs) over the lifetime of the switchgrass for coal substitution project. Because the costs and benefits of the project will accrue over many years, the overall net benefit is calculated as the present value of the annual net benefits over the lifetime of the project. That is, the present value of net benefits of the project is given by

$$PVNB = \sum_{t=0}^{T} \frac{NB_t}{(1+r)^t},$$

where *PVNB* is the present value of net benefits of the project, NB_t is the annual net benefit of the project in year *t*, *T* is the lifetime of the project in year, and *r* is the discount rate which reflects the opportunity cost of funds. For the purposes of this analysis, we assume *T* = 25 years and *r* = 0.03 (3 percent). While the quantitative results of the analysis are, of course, sensitive to these assumptions, the qualitative results (i.e., whether the present value of net benefits is positive or negative) is not sensitive over a range of reasonable variations in these parameters.

Annual net benefits can be separated into three components. These are (1) the costs of converting the plant for fuel substitution, including both the initial conversion cost and any recurring costs arising from the conversion; (2) the difference in fuel costs that results from the substitution and (2) the benefits from reduced emissions that result from the substitution. These can be described generally by the following equation:

$$NB_t = -C_t + (P_t^c \Delta Q_c - P_t^s \Delta Q_s) - \mathbf{D_t \Delta E_t}$$

where C is the conversion cost, P_t^c and P_t^s are the prices of coal and switchgrass respectively, ΔQ_c and ΔQ_s are the changes in the quantities of coal and switchgrass respectively involved in the substitution (assumed to be chosen so that electrical output is constant), $\mathbf{\Delta E}$ is a vector of changes in environmental impact levels, and $\mathbf{D}$ is a vector of prices or marginal damage costs associated with those impacts. The present value of net benefits can be separated into a present value of costs and a present value of benefits:

$$PVNB = \sum_{t=0}^{T} \frac{-C_t + (P_t^c \Delta Q_c - P_t^s \Delta Q_s)}{(1+r)^t} - \sum_{t=0}^{T} \frac{D_t \Delta E_t}{(1+r)^t}$$

Note that a decrease in an environmental impact is defined as a benefit, so that a negative element of $\mathbf{\Delta E}$ leads to a positive contribution to net benefit. We discuss these components in turn below.

Conversion Costs

The initial investment required to allow substitution of switchgrass for coal is assumed to be $1.75 million (CVBP). This is a one-time cost that occurs in the first year of the project. In addition, we assume the project leads to an additional $375,000 in annual labor costs, an additional $306,178 in annual operating and maintenance costs, and an annual cost of $25,000 resulting from reduced boiler performance due to increased sludge build-up from burning switchgrass (Antares Group, 2002).

Fuel Cost

The effect of the substitution of switchgrass for coal on fuel cost is based on alternative scenarios for the price of switchgrass. The analysis is based on an annual substitution of 100,000 tons of switchgrass for a BTU-equivalent amount of coal which, given the relative BTU contents of the two fuels, is 84,340 tons of coal per year. The price of coal used in this analysis is $14.09 per ton, which is based on an average U.S. delivered price (EIA, 2003). The prices of switchgrass under the low, medium and high cost scenarios are $40, $52 and $92 per ton respectively (Antares Group, 2002).

Total Costs

Based on these assumptions, the present value of additional costs from conversion and fuel under the three scenarios are given in Table 4.

Table 4. Present Value of Additional Costs (millions of 2002 $)

Cost Scenario	Low	Medium	High
Switchgrass Price ($/ton)	$40	$52	$92
PV of Additional Costs	63.00	83.90	153.55

Changes in Environmental Impacts

Changes in environmental impacts from substituting switchgrass for coal were obtained from the second test burn at Alliant Energy's Ottumwa Generating Plant in Chillicothe, IA, which took place during December 2003 (NO_x, SO_x and PM_{10}). Emission impacts for VOC, HCl and CO_2 are generated from standard EPA emission factors or mass balance. The predicted changes in emissions resulting from substituting 100,000 tons of coal for a BTU-equivalent amount of coal are given in Table 5.

Table 5. Changes in Emissions (tons/year)

Pollutant	Change
NO_x	+10.50
SO_x	-448.00
PM_{10}	-24.50
VOC	6.54
HCl	-36.82
CO_2	-252,175.00

Recall that a decrease (negative value) in emissions is a benefit.

Private Benefits

The private benefits of the project include any benefits that accrue to the utility as a result of changes in environmental impacts. They include changes in emissions fees, and changes in permit purchases and sales. In particular, we consider reductions in payments of Title V program fees for NO_x, SO_x, particulate matter (PM_{10}), Volatile organic compounds (VOC) and HCl emissions, reduced purchases of SO_2 emission permits, and increased sales of CO_2 permits. For the purposes of this analysis, we assume that there are no marginal private benefits from reduced NO_x and SO_x emissions for Title V program fee purposes (because facility emissions of more than

4,000 tons per pollutant are exempt from these fees), and that the marginal private benefits of reduced emissions of PM_{10}, VOC and HCl for Title V program fee purposes is $32.25 per ton of emissions. In addition, we assume that there is an additional marginal private benefit of reduced SO_x emissions of $707 per ton (Chicago Climate Exchange website, 2005) from reduced purchases of sulfur dioxide emission permits, and that reduced CO_2 emissions enables the sale of emission permits on the Chicago Climate Exchange at a price of $1.50/metric ton (Chicago Climate Exchange, 2004). The present values of the private benefits of environmental impacts based on these assumptions are given in Table 6.

Table 6. Present Value of Private Benefits (millions of 2002 $)

Pollutant	Present Value
SO_x	5.515
CO_2	6.587
PM_{10}	0.014
VOC	-0.004
HCl	0.021
Total	12.133

Net Private Benefits

Subtracting the present value of additional costs under the three alternative cost scenarios from present value of private benefits yields the present value of net private benefits, which are given in Table 7.

Table 7. Present Value of Net Private Benefits (millions of 2002 $)

Cost Scenario	Low	Medium	High
PV of Net Private Benefits	-50.87	-71.77	-141.42

In all cases, the present value of net private benefits is negative, implying that it is not in the private interest of a utility to undertake the project under these conditions.

Social Benefits

This analysis considers as social benefits of the project only the changes in environmental impacts that result from the substitution of switchgrass for coal. The effect of a pollutant reduction or increase is measured by the marginal damage cost of that pollutant, which is defined as the incremental cost to society of a small increase in emission of that pollutant from the current level. Hence, a large marginal damage cost corresponds to a high benefit of a given reduction in emissions, since more costly damage is avoided. The benefits from reduced emissions of NO_x, SO_x, CO_2, particulate matter (PM_{10}) and volatile organic compounds (VOC) are based on alternative damage cost scenarios. The marginal damage costs of NO_x, SO_x, PM_{10} and VOC are from Scheraga and Leary (1994), while the CO_2 benefits for the low, medium and high benefit scenarios are from Nordhaus (1993a, 1993b), Peck and Tiesberg (1992) and Fankhauser (1995) respectively. Benefits from reduced soil erosion and improved water quality are assumed constant across the damage cost scenarios, at $16,572 and

$28,876 per year respectively. CO_2 damage costs are assumed to increase over time, while all other damage costs are assumed to be time-invariant. The marginal damage costs used in this analysis are given in Table 8.

Table 8. Marginal Damage Costs (2002 $/ton)

	Benefit Scenario		
Pollutant	**Low**	**Medium**	**High**
NO_x	14	75	136
SO_x	408	1,428	2,448
PM	544	7,072	13,600
VOC	489	2,557	3,264
CO_2: 2005-10	9.25	17.68	23.26
CO_2: 2011-20	11.70	21.76	25.81
CO_2: 2021-30	13.60	27.20	28.36

The present value of the social benefits, based on the changes in emissions given in Table 5 and the marginal damage costs given in Table 8, are given in Table 9.

Table 9. Present Value of Social Benefits (millions of 2002 $)

	Benefit Scenario		
Pollutant	**Low**	**Medium**	**High**
NO_x	-0.003	-0.014	-0.025
SO_x	3.183	11.140	19.097
CO_2	51.93	99.81	116.27
PM_{10}	0.232	3.017	5.802
VOC	-0.056	-0.291	-0.371
Soil Erosion	0.289	0.289	0.289
Water Quality	0.503	0.503	0.503
Total	56.08	114.45	141.56

Net Social Benefits

Subtracting the present value of additional costs under the three alternative cost scenarios given in Table 4 from the present value of total social benefits under the three benefit scenarios given in Table 9 yields the present value of net social benefits, which are given in Table 10.

Table 10. Present Value of Net Social Benefits (millions of 2002 $)

	Cost Scenario		
Benefit Scenario	**Low**	**Medium**	**High**
Low	-8.91	-29.81	-99.46
Medium	42.90	22.00	-47.65
High	63.34	42.44	-27.21

The present value of net social benefits is positive if the social benefits of reduced environmental impacts are more than the net private cost for the given scenario. Thus, the low switchgrass cost scenario leads to a net social cost of $8.91 million when the low end of damage costs are applied, and benefits ranging from $42.9 million to $63.34 million in 2002 dollars on a net present value basis. The medium switchgrass cost scenario yields a net social benefit for the medium and high social benefit scenarios, but provides a net social cost when the low range of benefit values are considered. Evaluation of the high switchgrass price scenario shows that there is a net social cost regardless of the benefit scenario analyzed.

Caveats

It is clear from Table 9 that the net social benefit of co-firing switchgrass with coal depends critically on the benefit of reduced carbon dioxide emissions. The benefit of reduced CO_2 emissions represents the overwhelming majority of total social benefits, and is the only benefit that appears to be capable of offsetting the additional costs of the project. There are great uncertainties about the current and future environmental costs of CO_2 emissions. In addition, reduced emissions of other substances, in particular mercury, which have not been included in this analysis may also have social benefits large enough to affect the outcome of the analysis. At this point, the lack of a reliable estimate of the marginal damage cost from mercury emissions prevents the inclusion of social benefits from mercury reduction in the calculations.

Summary and Conclusions

A framework has been crafted to provide the ability to analyze the economic cost-benefit balance of switchgrass co-firing with coal for electric generation, on a multitude of scales. Internal and external costs have been identified and directions for future efforts to quantify environmental impacts and determine their economic value have been put into place. The list of impacts and valuation methods presented in this report is not intended to be all-inclusive and additional impacts and valuation methods will be employed as necessary to provide a true cost-benefit analysis.

On a private cost basis, the economics of switchgrass co-firing with coal appear to present a daunting challenge. Switchgrass costs of $40, $52, and $92 per ton lead to present value (PV) private costs (25 years) of $63 to $154 million (2002 dollars). These private costs are only partially offset by the limited internalization of environmental costs that has occurred to date, providing a net private cost ranging from $51 to $141 million. However, despite having only limited ability to document damage cost functions for pollutant reductions that would arise from the Chariton Valley Biomass Project, it appears that on a social cost/benefit basis, the project would have the potential to provide a net benefit to society. The net social benefit to society would range from $22 to $63 million (PV, 2002 dollars) if switchgrass costs were maintained at the low

($40/ton) to medium range ($52/ton) price. Switchgrass costs at $92/ton would not allow for attainment of a net social benefit, based upon the analysis presented herein.

It isimportant to note, however, that this analysis does not contemplate policy changes that may lead to improved private economic prospects for the project. Such changes could include tax credits for renewable energy production, green power surcharges, evolution of a national greenhouse gas emission reduction target, or producer incentives that might allow a lower switchgrass production cost. Add to these the potentially significant but presently unquantified damage cost function for mercury emissions and the prospects for a positive private cost-benefit balance look considerably brighter.

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