Preparing the Way for a Biofuels Industry in Virginia: Assessment of the Feasibility of the Agricultural, Energy, and Conservation Communities to Implement a Sustainable Energy Industry

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Executive Summary

High fossil fuel costs, global climate change, hurricane frequency and severity, impaired water quality in the Chesapeake Bay, loss of farmland and farmers, increasing food costs, and concerns over support for international terrorism through dependency on foreign oil imports are all intertwined problems of energy and agriculture. The complexity of these systems and our inability to affect one without consequences for the others has confounded and perplexed policy makers and the public. As a result, implementing biomass energy alternatives has gained a great deal of public support recently.

Biomass can be produced by any landowner in Virginia. Biomass that is feasible for use as an energy feedstock can only occur on lands that are workable, i.e., not too steep, too wet, or too infertile. Uses of the feedstock will initially focus on a replacement for fossil fuels in the production of steam and/or electricity. The economic impact for Virginia landowners is potentially quite large and could exceed the annual economic impact of traditional crops like tobacco, peanuts, and cotton.

Biomass as boiler fuel is by far the largest single use of biomass energy in the Commonwealth. Cofiring or 100% direct firing of wood chips is a well accepted practice and the demand for wood chips in Virginia is steadily increasing. Technologies for converting biomass to an energy product (e.g., steam, electricity, transportation fuel) are progressing rapidly in the laboratory, and there are demonstration plants other pilot projects under construction and that show great promise. At present the only mature commercial technology available for converting biomass to energy is direct firing (either 100% or cofiring with coal) or gasification; a process that extracts volatile gases from biomass for the burning process. Direct firing biomass either alone or with coal for steam, electricity or combined heat and power was identified as the least expensive and most rapid way to increase the use of renewable energy in Virginia.

This project focused on the idea that native warm season grasses (WSG), including switchgrass, big bluestem, and indiangrass can provide a cost effective biomass alternative to wood, crop residues, or other biomass systems. The knowledge required for establishing, managing, and harvesting WSG in Virginia is available and proven. The WSG stands will succeed in marginal soils and under water stressed conditions. The WSG stands have the potential to provide protection from erosion, habitat for wildlife, and mitigate nutrient runoff. The risks related to producing WSG are largely known. What is not well understood are the economic parameters under which a WSG would be considered viable. Issues related to productivity, transportation, processing, storage, and delivery are largely guesswork or available in piecemeal at this point. There are several scenarios that may result in successful systems that take material from the field to the refinery but each requires a different set of circumstances, players, and assumptions before any sort of success can be realized.

There are many unknowns that will further impact the success of this system. These include federal greenhouse gas policy and carbon sequestration, nutrient and habitat crediting, management issues (such as smoke from controlled burning), financing and federal incentive programs, and advanced technologies (such as gasification). Inclusion of all of these factors is important in the decision making process, but are beyond the scope of this study.

We were able to provide some realistic economic analyses using information from landowner meeting and from an ongoing WSG boiler fuel project conducted at the Piedmont Geriatric Hospital in Burkeville, Virginia (PGH). We were able to use information on the fuel requirements of this specific boiler to proceed through an analysis of the system needed to supply the boiler with fuel. We determined that the boiler would require approximately 11,730 tons of material a year. Using some existing information regarding costs for establishing, managing, harvesting, and delivering WSG feedstock from the surrounding area, we were able to analyze the economic feasibility and risk to producers for entering into such a market.

In summary, the profit potential to producers and brokers of WSG is related to the price per ton and the total yield from the acreage in the system. Under typical circumstances, producers would need to receive between $60-72 per ton in order to realize a profit over a 10 year contract period. Further comparisons between WSG, coal, and wood reveal that the present low market price of coal would keep interest in switching to WSG fairly low but that facilities presently employing wood systems may be close to a break-even point (assuming price was the sole determining factor). Further, we were unable to incorporate realistic estimates related to processing and/or densifying WSG before delivery. So our estimates would apply to the most simplistic direct-burning systems in practice today. Additional processing would require additional costs and decrease WSG competitiveness with other solid fuels.

Our conclusions were that WSG is an economically viable option in only the most narrow, specialized cases in Virginia at present. Broader adoption of WSG will be unlikely unless the costs of competing fuels like coal return to all time highs. However, new incentive programs such as the USDA Biomass Crop Assistance Program or cap-and-trade legislation have the potential to change the economic landscape for WSG options in the very near future.

Table of Contents

Philosophy

The philosophy of the team that has worked to develop this system bears mentioning since it is somewhat different than the traditional agricultural development initiative. The Conservation Management Institute is a multi-disciplinary research and service unit that naturally looks at complex problems in a multi-disciplinary way. We have included in our discussions energy companies, farmers, researchers, the business community, government officials, and the nonprofit community of stakeholders. We have included economics and environment equally because of the belief that neither can be sustainable without the other.

The perfect renewable energy crop does not exist, but our criteria for the perfect crop are as follows:

- economically and environmentally sustainable over long time periods (50+ years)
- improves profitability of farms thereby increases stability of farming communities
- low labor requirement or at a time of the year when labor is typically available
- minimal equipment costs
- viability on lands not suitable for food crops
- minimal to zero annual input/maintenance costs, resistant to weeds and insects
- improves soils and sequesters carbon
- protects water quality
- provides habitat for rare and declining species and/or pollinators
- easy and inexpensive to establish

The closest match based on these criteria is a native warm season grass system. The following report seeks to summarize the current state of knowledge regarding this system, the potential demand for native warm season grasses as an energy feedstock, and what this system potentially means for landowners in Virginia in various common scenarios.

Introduction

High fossil fuel costs, global climate change, hurricane frequency and severity, impaired water quality in the Chesapeake Bay, loss of farmland and farmers, increasing food costs, and concerns over support for international terrorism through dependency on foreign oil imports are all intertwined problems of energy and agriculture. The complexity of these systems and our inability to affect one without consequences for the others has confounded and perplexed policy makers and the public. New technologies are on the horizon and existing technologies available right now, will make possible a new system of agriculture-based energy production that will help address these problems. The system described in this report is insufficient to solve the energy requirements of the nation or even the Commonwealth of Virginia. However, the system can be an important component of a well-designed, low-carbon energy system that is certainly feasible and required if society is to have any hope of effectively addressing these major local, regional, and global problems.

Biomass can be produced by any landowner in Virginia. Biomass that is feasible for use as an energy feedstock can only occur on lands that are workable, i.e., not too steep, too wet, or too infertile. Biomass that is economically feasible for use as an energy feedstock must also be within a reasonable transportation distance, or be in a dense form, to reduce transportation costs. Uses of the feedstock will initially focus on a replacement for fossil fuels in the production of steam and/or electricity. As technologies become available for the commercial production of bio-oil, ethanol, butanol, or hydrogen from biomass, the demand for native warm season grasses will increase, resulting in higher prices and , potentially, making this strategy more competitive with commodity grains, hay, and pasture lands. It is more likely to make it feasible to recover the millions of acres of abandoned farmland that have been lost to production in Virginia since the 1940's. The economic impact for Virginia landowners is potentially quite large and could exceed the annual economic impact of traditional crops like tobacco, peanuts, and cotton.

This report describes a potential system that holds the promise of changing the agricultural and energy landscape in Virginia. It addresses the existing projects and technologies that can utilize biomass energy, the advantages and disadvantages of focusing on native warm season grasses (switchgrass and related grasses) as a strategy for producing biomass, and the challenges that must be overcome to both scale up existing technologies and bring new technologies/products to market. The report does not intend to duplicate the many existing books and articles on biomass energy, but rather to synthesize existing information and present the case for native warm season grasses as one feedstock for Virginia's energy future.

Technology Overview

Biomass energy applications are as old as the first campfire. Plants capture and store energy from the sun in a variety of carbon-based molecules. This energy can be densified over long time periods into oil, coal, natural gas, or similar substances. The value of the material can be expressed across multiple forms and grades into a cost/million British Thermal Unit equivalent or $/MBTU. Biomass standing on the landscape can be similarly measured, and it typically has a lower energy content per unit weight and a higher fuel moisture content. It is a distributed, low density fuel found throughout Virginia, and therefore has the great advantage of being relatively close to the places where it is needed. However the cost of concentrating the material, either physically through a densification process and transportation, or chemically by reducing it to flammable chemicals in liquid or gas form, adds significantly to the overall cost of using the material. Energy producers must factor in not only the cost and quality of the fuel, but also future price stability and availability. The capital costs for traditional energy production facilities are substantial, and the equipment is a very long term investment, so stability of the fuel supply is a major concern for energy producers.

Uses of Biomass Energy

Biomass as boiler fuel is by far the largest single use of biomass energy in the Commonwealth. Cofiring or 100% direct firing of wood chips is a well accepted practice and the demand for wood chips in Virginia is steadily increasing. Wood has historically been a very low cost fuel source because its availability (as a waste product resulting from landfills, timber cuts, right-of-way maintenance, etc.) has exceeded the demand. In recent years that has begun to change, and with the installation of modern pelletizing mills in Virginia, that demand is projected to rise well beyond the capacity of the state to produce chips from these traditional sources. Clearly there are numerous low-value timber stands that could be harvested to meet the demand (much of which is abandoned farmland from the 1940s and since). One of the largest initial demands projected for native warm season grasses is as a boiler fuel to dry wood chips for the production of wood pellets. These wood pellets are in great demand in Europe as a clean, zero-carbon boiler fuel. Wood chips have problems with high moisture content and an unstable supply when relying on the spot market. Transportation costs can be high depending on the distance to market. In recent years wood chip prices have increased dramatically due to a concern about carbon emissions and a spikes in the price of coal.

Technologies for converting biomass to an energy product (e.g., steam, electricity, transportation fuel) are progressing rapidly in the laboratory, and there are demonstration plants other pilot projects under construction and that show great promise. At present the only mature commercial technology available for converting biomass to energy is direct firing (either 100% or cofiring with coal) or gasification; a process that extracts volatile gases from biomass for the burning process. Efficiency rates for this technology vary widely. The added emissions control costs for CO_2 capture from coal use are unknown, but could be substantial. Many of the largest electricity and steam producers (of which we are aware) are investigating biomass applications because of the increased cost of fossil fuels and the unknown future cost of greenhouse gas reductions.

Bio-oil, ethanol, and hydrogen refinement technologies are all under intense scrutiny by the energy research community. Success is believed to be worth billions of dollars for the patent holder and will result in one key to addressing the global climate change problem. Similarly, electric automobile technology is poised to become commercial. Hybrid gas-electric technology is already commercially available. The day when American cars can run completely free of imported oil is fast approaching, but only at the cost of increasing electricity demand. The Commission on Energy and Environment has recommended a reduction of 10% in electricity demand in Virginia by 2022 and is focusing primarily on conservation strategies. Based on the recorded testimony[1] it is presumed that renewable energy development, including biomass energy, would count towards the 10% goal.

The most complete study of energy status and trends in Virginia was completed by Karmis (Karmis 2005). In this study, direct firing biomass either alone or with coal for steam, electricity or combined heat and power was identified as the least expensive and most rapid way to increase the use of renewable energy in Virginia. A recent report by the National Academy of Sciences (Fargione et al. 2007) indicates that low intensity, high diversity systems are as, or more, productive than any dedicated biomass energy system presently available.

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[1] Meeting minutes of the Virginia Commission on Energy and Environment, November 19, 2008. Accessed Oct 1, 2009. http://dls.state.va.us/pubs/legisrec/2008/energy3.htm

These systems have long term economic and ecological advantages with implications far beyond their value as energy. Additional genetics and selective breeding work will no doubt result in more productive individual plant species and cultivars. Very little work has been done on any species other than switchgrass (*Panicum virgatum*). Even switchgrass has only recently received much attention in this regard. Future needs for work to extend this system are described elsewhere in this report.

Native Warm Season Grasses (NWSG)

Native warm season grasses have been produced in Virginia since pre-Columbian times. They are adapted to our soils and climate, and long-term test plots indicate that they can be very productive, stable, and require little in the way of nutrient inputs. Historically, these grasses were maintained as forage, but the common knowledge for has been mostly lost. Recent generations of farmers have learned to manage for fescue and orchard grass and utilize these native warm season grasses for conservation plantings.

A superb monograph on switchgrass was produced by Parrish and Fike (2005)at Virginia Tech detailing techniques for establishment and management for forage. Much of that information is applicable to the other species of native warm season grasses. The selective breeding work described for switchgrass is fairly inclusive of the available information since almost nothing has been done with the other major species such as indiangrass (*Sargastrum nutans*), big bluestem (A*ndropogon girardii*), and little bluestem (*Schizachyriam scoparium)*.

Establishment and Management Practices

Establishment of native WSG can be done via several strategies. Rapid establishment of a dense stand of productive WSG requires attention to detail and significant management inputs. Industrial-scale establishment of a WSG industry will require a proven system for establishment, carried out over thousands of acres, followed by periodic management inputs and regular harvest.

The two main criteria for successful establishment are exposure of bare soil prior to planting, and suppression of the potentially competing vegetation in the developing WSG crop. Both of these criteria lead to increased soil temperatures and reduce non-WSG competition, which will speed seed germination and stand establishment (Parrish and Fike 2005). Several strategies can be used to accomplish this, and they may be best used in combination pre- and post-planting.

Appropriate pre-planting strategies include overgrazing, fire, tillage, and application of herbicide. Overgrazing may be most appropriate in existing pasture, while tillage may be more appropriate in previously cropped areas. Fire acts to blacken the existing vegetation and, thereby, warm the soil which speeds the germination of WSG seeds. Each of these strategies may promote germination of undesirable weeds, which can be reduced using applications of herbicides. Local Extension agents should be consulted for appropriate chemical and safety recommendations, and specific recommendations for herbicide use on switchgrass plantings are provided in Parrish and Fike (2005). In the event that organic certification is desired, however, WSG have been reportedly established without pesticide inputs (Fred Circle, FDC Grassland Enterprises. *Personal communication*).

WSG seeds can be planted using any number of strategies, and a stand suitable for wildlife can be established using a rotary spreader, or by manual broadcasting. Industrial-scale establishment of thousands of acres of moderate to densely planted WSG will likely require dedicated equipment and a planting crew.

After planting, mowing and application of herbicide can be used to control competing vegetation during the establishment period (1-2 years). Repeated mowing is suggested over the course of the first growing season, as this will prevent existing weeds from setting seed and increasing weed pressure in the stand. Mowing must be done at a height greater than that of the developing WSG seedlings to reduce damage to the emerging WSG crop. Herbicides may be used as an alternative to mowing. While local Extension agents should be consulted for appropriate chemical and safety recommendations, these grasses have been reported to be sensitive to herbicides such as 2-4,D, and reduced application rates (by as much as 50%) may be warranted (Fred Circle, FDC Grassland Enterprises. *Personal communication*).

Managed stands should fill in within 2-3 years of planting and begin to produce high yields (Parrish and Fike 2005). Continued high yield appears to require periodic exposure of mineral soil; this reduces matting of vegetation on the soil surface and appears to reduce weed establishment. Mineral soil exposure can be accomplished either with periodic burns (using stubble burns conducted during the dormant period after biomass harvest) or strip tillage. Controlled fire has traditionally been used as a strategy for maintaining and rejuvenating WSG stands. While there is limited relevant data to identify the management practice that will maximize yields, it is generally assumed that stands will need to either be burned every 2-3 years, or strip tilled in a way that results in tillage of 1/3 of the stand annually.

Fertilization and liming of managed stands are of uncertain economic benefit. Experts in the field may have strongly held opinions regarding the value of such inputs, even without apparent financial interest. Stands of WSG are capable of producing significant quantities of biomass over a period of several years without fertilizer or lime additions (T. Cole, WSG producer, *personal communication*). However, there is evidence for a positive influence of fertilizer inputs on switchgrass production when grown in monoculture(Parrish and Fike 2005), but no data for WSG polycultures. Given recent increases in fertilizer costs, yield increase may not justify the cost of inputs. Further research specific to Virginia sites are needed given the interest in biofuels production.

Harvesting of stands for biofuels production will be conducted once the WSG stems have senesced and died. This would occur in November or December within Virginia (Parrish and Fike 2005). This late cutting should allow for maximum retranslocation of aboveground nutrients from the grass stems to the crown and root system of the plant (Hargrave and Seastedt 1994). The remaining stems and leaves will be relatively dry (perhaps 12-15% moisture content). Care must be taken during harvest to protect the crown of the grass, and cutting heights should be no lower than 10” from the soil surface to protect the long-term productivity of the stand.

The low moisture content of standing, senescent WSG, stands will make them susceptible to wildfire. Fire breaks should be part of the management plan. Early harvest of fully senescent stands will reduce the risk of fire and reduce potential losses due to fragmentation and decomposition of leaf material. While harvesting stands in September may result in significant increases in yield (up to 19%, (Parrish and Wolf 1992, 1993) this may be a short-term benefit that reduces nutrient retranslocation and may have long-term negative effects on stand productivity (Parrish and Fike 2005). Stands have been successfully harvested as late as March for biofuel use.

Management Specific to Energy Applications

The most significant stand management difference in utilizing native warm season grasses as an energy crop is in the timing of harvest. These plants senesce in the fall storing much of the nutrients and water collected in the plant during the growing season in the root mass. The remaining stems and dried leaves are at a very low moisture content (typically 15% or less) making it ideally suited for combustion. As with harvesting for forage, the root mass (typically the part of the plant within 10” of the soil should be avoided, but anything above that level can be harvested with little or no impact to the productivity of the stand.

Using controlled fire after harvest as a management technique to reduce detritus build up and blacken the soil has been shown to increase productivity of stands. These plants are very sensitive to soil temperature and the earlier the soil warms in the spring, the longer the growing season. The blackened soil absorbs sunlight, increasing soil temperature in the spring. Conversely, senescent stands may be very susceptible to fire in the fall, and care will need to be taken to leave fire breaks. Stands should be harvested as soon as practicable to avoid the risk of fire. There is some indication that the stands lose biomass to weather events over the course of a winter as well, which is all the more reason to harvest as early as possible. We have experimented with harvesting in Virginia as late as March with no major problems.

Expected Productivity

Test plots in Virginia for switchgrass have produced in excess of 6 tons/acre annually. More significantly, these same test plots never produced less than 5 tons/acre regardless of weather conditions. Mixed stands produce similar or greater volumes and, based on preliminary analysis, produce similar or greater BTU values. Test plots have been planted on multiple soils in all regions of Virginia with similar results.

Environmental Concerns/Benefits

Native warm season grasses have been used in conservation plantings for decades primarily to reduce erosion and to provide wildlife habitat. Research indicates that these grasses also build soils and sequester carbon. A system that utilizes native warm season grasses as a buffer around waterways makes sense where water quality of runoff from fields is a concern. If the native warm season grasses are also an economic crop, the probability of adoption of this practice should increase.

Varieties of WSG

WSG (as we consider them in this treatment) consists of three species: *Sorghastrum nutans* (Indiangrass), *Andropogon gerardii (*big bluestem), and *Panicum virgatum* (switchgrass). These are among the tallest, and heaviest-yielding, of the warm season grasses native to the eastern U.S. Currently, there is limited published research that focuses on yield comparisons in Virginia's climate and soil combinations.

Research conducted on these species has focused almost exclusively on *Panicum virgatum*, or switchgrass. An excellent examination of the issues related to comparison of varieties, and the occasionally conflicting lines of evidence supporting yield comparisons, can be found in Parrish and Fike (2005), specifically in section III.A of that review.

In the spring of 2008, several research plantings comparing yield of monoculture switchgrass plantings to mixed-grass plantings were established in Virginia. Data from these plantings may be available as early as November of 2009, and if so will be included in the final report. In addition, collaborative plantings of mixed-species WSG stands (without a monoculture comparison) were established at several sites in the spring of 2008; data from these plantings may be available as early as November of 2009 [, and if so will be included in the final report]. Visual observation of stand development suggests that while yields have not yet reached that of older, more productive stands, they are very nearly there.

Recently, local genetic varieties of each of these three species, representing cultivars specific to the North Carolina, have become available in sufficient quantities that they may be appropriate for consideration in industrial plantings. These seeds were obtained in the spring of 2009 by the Conservation Management Institute from Ernst Conservation Seeds of Pennsylvania. We are currently planting small plots (5ft x 5ft) with each of these varieties, and comparing their yields in monoculture and mixed stands to that observed in monoculture plantings of high-yielding switchgrass varieties such as “Alamo”, “BoMaster” and “Performer”.

Economics and Competing Land Uses

Ultimately, the decision to move from any of these crops to WSG will be driven by a combination of factors. We assume that the foremost consideration will be net profit per acre, and thus the simplest answer to this question is that a net profit per acre of WSG in excess of the average profit per acre from either of these alternate crops will result in a producer switching from one crop to the other. Encouraging conversion to WSG, therefore, would simply require supporting the net profit per acre, either by price supports, government subsidies for renewable energy crops, or assistance with establishment or equipment costs, which represent the largest upfront expenses associated with conversion.

Alternate considerations that may influence a producer's decision to switch to WSG include family tradition, interest in wildlife, crop pest pressure, climate considerations (particularly vulnerability to drought), access to appropriate equipment for crop establishment, management, and harvest, and access to dedicated markets.

The Conservation Management Institute has gathered information relative to this issue from a dedicated WSG outreach program that has focused efforts in Southside Virginia, the Shenandoah Valley, and the rural counties surrounding the Richmond area. To date, no producers have converted to WSG with a standing contract to sell WSG for use in a dedicated biofuels industry. However, these efforts have led us to discussions with producers and/or landowners interested in making a conversion to WSG. Some of these landowners were interested in converting hay and pasture lands to WSG, while others were interested in converting crop lands. We will focus on a limited number of cases as examples that identify particular driving factors. We will not identify these landowners in this document, but can provide more detailed contact information on request.

Three of these landowners in particular are converting large stands (50-250 acres+) from fescue pasture to native, warm-season grasses. Based on our interviews and discussions, the two major factors that are driving this conversion are (1) improved wildlife habitat, and (2) greater economic yield driven by increased forage yield per acre. Each of these individuals are aware of the emerging biofuel market, and are close to a facility that may be eligible for conversion to WSG as a cellulosic boiler fuel. They appreciate being positioned for such an emerging market, to the extent that it would offer greater yield per acre *or* a long-term contract at an attractive price per ton. Importantly, however, this market was not necessary for the conversion to WSG to be a profitable endeavor.

As an alternate case, we will discuss two specific landowners that are either converting or considering conversion smaller acreages (15-30 acres) from row crop to WSG production. Both of these producers identified pest pressure, specifically from deer, as a key factor in their interest to convert to a pasture crop. In addition, one of the sites considered for conversion consists of deep, well-drained sands, and the drought tolerance of the native grasses was an attractive factor. In one of these cases, the producer had experience with WSG from either existing leased lands. Importantly, we believe, both of these landowners have equipment on hand that would allow them to harvest WSG without a significant equipment outlay. In both cases the producers spoke of additional acreages that could be converted if establishment and marketing were successful.

Based on these interactions, along with other interviews and interactions in our outreach and planting efforts, we contend that the primary concerns that need to be addressed to encourage producers to convert are (1) access to funds to defray planting costs, which are considerable when an early rate of return is desired, and (2) access to equipment. Based on our discussion with landowners at large-scale events such as farm shows and farm days, many row crop producers are attracted by the idea of moving towards a drought tolerant, high-production crop, but lack the equipment required to harvest WSG. This lack of equipment was more often reported as a concern than access to markets, which are generally well established in the case of forage crops.

In the specific case of a biofuels industry, the concerns about planting costs and equipment access will persist. However, a biofuels industry that provides long-term producer contracts will allow a producer to amortize the cost of planting and equipment. Actions by the Virginia Farm Bureau and others to reduce planting costs and subsidize equipment access will encourage producers to convert acreages to WSG. Biofuels industries that provide long-term producer contracts will similarly encourage conversion from any of these examples.

Densification and Transportation

The two primary hurdles to be faced in the development of a native warm season grass energy feedstock system is establishment (see section on establishment and management), and transportation. The concept of densification and transportation go hand in hand and most likely some combination of the two will win out as the strategy of choice. Densification is the process by which the air is pressed out of the material making it possible to load far more into a container. Densification can be accomplished in a variety of ways from baling to pelletizing, and portable machinery is now commercially available.

Pelletizing, briquetting, and cubing are all processes designed to compress materials, such as WSGs, into a denser form. Because of their uniform shape and higher weight to volume ratio, pellets, briquettes and cubes are often easier to handle and transport than the original raw materials. These finished products may also be more easily incorporated into boiler feed systems.

However, densifying WSGs using pellets or other forms is not without costs. The process adds yet another link within the supply chain that may or may not add value to final product. While technically simple, densifying WSG requires large capital outlays for equipment (i.e., pellet mills), maintenance, and usage. Energy consumption is typically high. Operation costs vary greatly depending on size (output) of mill, however (Jannasch et al. 2001) estimated the energy requirement for pelletizing switchgrass was approximately 0.416 gigajoule/ton.

To minimize densification costs, many producers may simply choose to bale WSG in the field, and skip the pelletizing process. This method, in fact, was used in the Cheriton Valley Biomass Project and will probably be the technique used in large scale operations where economic efficiencies are paramount. Dr. Cundiff and his colleagues at Virginia Tech have analyzed round bale systems extensively and found a system that is technically feasible (Ravula et al. 2008). No doubt future advances in densification and transportation systems will increase efficiencies.

One of the most important issues of using biomass is the question of where the refineries are located and how much material each refinery requires to operate at peak efficiency. Producing electricity at present is a very monolithic process. Large refineries accept immense amounts of fuel at a central location and convert that fuel to electricity which is then transported over an electric grid. This is made possible by the use of a highly concentrated fuel (coal primarily, but also natural gas, oil, and nuclear material), and the efficiencies of scale that come from larger and larger facilities. Transportation costs are a small part of the total cost structure and extraction/preprocessing is a relatively large part. Biomass is a far less dense material that is also less concentrated on the landscape. Transportation costs are high, but extraction/preprocessing costs are low. A recent study by Roghair and Klopfer at Virginia Tech indicates that the placement and size of facilities are very important to the cost structure of a biomass facility. Moreover, the landscape around the facility has a large impact since if the landscape is largely devoted to feedstock production, then transportation costs are low. If the landscape is mostly devoted to other land uses, transportation costs will be far higher. Use of light rail and barge transportation was not included in the study, but clearly these two methods are traditionally the lowest cost for bulk transportation and would have an impact on the model if available.

Biomass Brokers, Co-ops, and Other Supply-Entity Types

Perhaps the greatest challenges to a viable biomass industry exist in the mechanisms required to deliver, store, and market WSG biomass to energy consumers. Producers are able to adequately plan, plant, and produce WSG feedstock but without efficient mechanisms in place to deliver the material to consumers the entire enterprise is infeasible.

Energy consumers (e.g., boiler operators, ethanol plants, pelletizing mills, etc.) must operate under a system of continuous supply without interruption. This is particularly important for consumers that produce energy directly through solid-fuel combustion or co-firing. From the consumer perspective, the supply of WSG must be available year-round, must be available on site, and be assured of supply through a multiple-day “buffer” to account for unexpected delivery interruption such as weather, holidays, etc. Without these assurances, generating consumer interest in WSG biomass as fuel for larger applications (i.e., refineries requiring more than 3,000 tons/year) will be very difficult.

The basic producer-consumer relationship for WSG biomass involves several steps. It is reasonable to make several assumptions about this system based on existing crop market systems, and feedback from biomass producers and consumers. One assumption is that consumers are willing to make the necessary investments in conversion to/installation of biomass technologies if they can be assured of a continuous supply of favorably priced material. Another is that producers can be assured of a willing buyer if they bring a crop to market. These two assumptions are interconnected, and both must be met simultaneously if the biomass industry is going to proceed. However, for that to occur both producers and consumers must be willing to assume the risk that the other is going to “hold up their end of the bargain”.

Certainly there are several models that would accommodate the needs of WSG biomass consumers, each with advantages and disadvantages and varying levels of complexity and risk for both the consumers and producers. The issues to be addressed by each system are the same and include processes related to production, harvest, storage, transportation, processing, delivery, and on-site storage.

Producer to Consumer Direct

Most producers in Virginia do not have the available land base to support even the smallest WSG biomass facilities, so multiple producers will be required to grow and supply WSG. The most basic delivery model would be for producers to deliver WSG in a field-packaged form (i.e., round bales) to the consumer directly. In this model, the consumer would be responsible for working directly with the producers to provide and deliver specific amounts of material at specific times throughout the year. The infrastructure needed for delivering and storing the bulk of the material would be the responsibility of the producer. The processing of the material could reside either with the producer or with the consumer depending on the form required. The most likely scenario would place any processing actions with the consumer and be handled either on-site or at a facility dedicated to processing the material. The consumer would be required to maintain a storage facility (on-site or elsewhere) to house processed materials ready for use in the refinery.

The advantages of this model include a simplistic arrangement between the consumer and producer, with the consumer assuming the responsibility for fulfilling the annual feedstock demands of the refinery. The costs incurred by the consumer include those related of all the processing and storage of the WSG until it is used. Practically, the consumer would be able to store only enough materials on-site for a set period of need (e.g., 7 days), and additional material would have to be stored elsewhere; either by the consumer at a dedicated facility or by the producers.

The disadvantages of this model are that the consumer would be required to manage all contractual relationships with the producers. It also requires that the producers maintain the capacity to store and deliver the WSG nearly on-demand by the consumer. The producer assumes the risk of failing to provide a continuous and adequate supply of feedstock. Alternatively, this model would require that the consumer have sufficient ability to accumulate a year’s supply of material and store it for processing, thus transferring the supply chain risk to the consumer. This model would increase in logistical difficulty as the size of the facility increased, requiring more contract relationships, more materials handling issues, and more collective storage space.

Biomass Cooperatives

Producer cooperatives would be comprised of multiple individual producers who market and deliver their biomass crops collectively. Cooperative models of marketing have been used commonly for other commodities where individual producers cannot effectively interact with larger consumers. These groups provide economy of scale and a larger market presence for those involved compared to what can be accomplished as individual producers. Cooperatives are typically operated at-cost, and profits are distributed to the producers by arrangement.

This model would likely require a representative of the cooperative to interact with the consumer directly on behalf of the group. This would reduce the need for the consumer to track and manager multiple contracts to meet their feedstock needs. It would also allow the producers to more efficiently manage the transportation and/or processing of feedstock for delivery. The cooperative could also permit the sharing of otherwise cost-prohibitive equipment such as a delivery vehicle or harvesting equipment. The cooperative model also provides a means to ensure that producers do not compete with each other for pricing, resulting in higher and more even pricing to the consumer. The relative risks related to supplying the feedstock can be spread across multiple producers rather than resting on individuals.

The consumer would receive feedstock from the cooperatives either as raw material (if they had processing capability) or as processed material ready for utilization. This arrangement is an advantage to the consumer since they can purchase fuel/feedstock similarly to more traditional coal or oil systems.

Biomass Brokerages

Biomass brokerage models introduce another independent entity into the producer/consumer relationship. Biomass brokerages assume the responsibility for all processes between the farm and the refinery including transportation, processing, and delivery. Biomass brokerages may also assume other processes such as harvest of material.

The brokerage would work directly with producers to contract production of WSG based on estimated yields and fixed prices for supply. These relationships would likely be for extended contract periods (e.g., 8 years) whereby the producer agreed to supply the brokerage with a minimum amount of WSG for a defined price (either a fixed price or a derivative of some other variable metric). The brokerage would work with multiple producers in order to procure enough WSG feedstock to meet the needs of the consumer.

The consumer would contract with the brokerage to provide a steady stream of feedstock to support their needs. The broker would be responsible for any processing of the material (e.g, chopping, screening, pelletizing, etc.) necessary in order to render it usable to the consumer.

The advantages to this system are that each entity is able to focus on specific tasks within the supply chain resulting in greater performance and efficiency over time. The risk associated with supply and demand will be somewhat buffered by the brokerage who, in turn, has a great deal of incentive to plan accordingly.

The disadvantage to this system is the increased cost of including an additional entity. This will likely result in lower profits to the producer and higher costs to the consumer. However these costs may more than offset the relative costs related to the risks to the producer in growing a WSG crop without a buyer, and to the consumer in ensuring that their feedstock demands are met.

Potential Land Base for Growing Biomass

One consideration for any burgeoning biomass enterprise is the likelihood of having the requisite land base to support the production. Competing land uses like row crop agriculture, development, and managed forests are unlikely to convert to biomass at this time. However, there are several existing land management scenarios that would be likely candidates for implementing native warm season grass biomass systems. They include:

- absentee landowners
- retiring landowner or producers with off-farm employment
- traditional grain farmers

For each case, there are opportunities for landowners to allocate acreage to biomass production that could potentially surpass the per acre income they are presently realizing through existing practices.

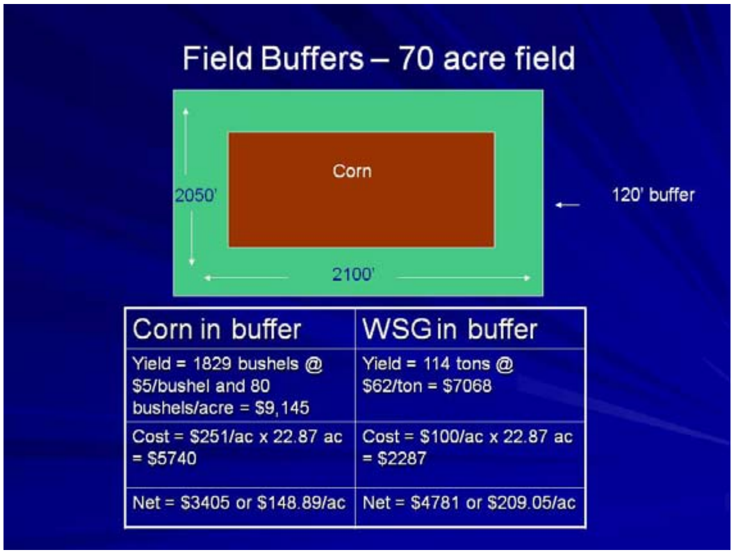
Scenario 1: Absentee Landowner with low value forest land or low value pasture land
There are thousands of acres in Virginia that are owned by "absentee" landowners and are either leased or left in a non-production state. Absentee landowners are typically not concerned with maximizing profits, but are holding the land for family/nostalgic, recreational or investment purposes. These lands are typically not prime farmlands, but were once farmed. Much of the land is forested with low value timber species or invasive species.

The competing land uses are often rentals for cattle production or hay production. Another option is planting pine. The average land rental rate in Virginia is $21 per acre (Virginia Cooperative Extension). Conversion to pine would require a longer period between establishment and harvest (typically 35 years) providing an annualized income in the $100/acre range[2].

Scenario 2: Retiring Landowner or Landowner with Outside Employment. Land under consideration is low value timber land or low value pasture land.
Landowners in this category are somewhat similar to scenario 1 although they still reside on the land and can provide some, but not all of the labor required to harvest biomass. Maximizing profitability is the primary strategy although recreation and aesthetics plays a major part.

Competing land uses are typically rented cattle production (since this landowner is unwilling/unable to provide the labor to manage cattle), hay production, or conversion to pine. Competing returns on land management would be similar to scenario 1 above.

Scenario 3: Traditional Grain Farmer
This scenario presumes that land is available that is suboptimal for grain production. This land could be steep, infertile, etc… One likely area would be buffers near streams or wood lines. These buffers are well documented problem areas for erosion in the case of stream buffers and low productivity in the case of wood lines. Machinery break downs in buffers are a concern. A simple analysis of buffers in corn fields making some assumptions about productivity and costs would indicate that native warm season grasses can be more competitive than grain in that area and could potentially provide value added income should nutrient or erosion credits ever come into play.



Field Buffers – 70 acre field

Corn in buffer	WSG in buffer
Yield = 1829 bushels @ $5/bushel and 80 bushels/acre = $9,145	Yield = 114 tons @ $62/ton = $7068
Cost = $251/ac x 22.87 ac = $5740	Cost = $100/ac x 22.87 ac = $2287
Net = $3405 or $148.89/ac	Net = $4781 or $209.05/ac

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[2] http://www.dof.virginia.gov/econ/data.shtml

Needs for Nurturing the System

As it stands, this system appears to be potentially feasible at least in some circumstances. A few questions remain to be answered that may speed up the adoption and mitigate the present risks. These needs are beyond the scope of this assessment but are presented here in the interest of understanding the complexity of the whole system.

1. Transportation issues are crucial to the success of the system. There is one major example of a similar system already in long use in Virginia at the electric plants utilizing wood chips. Utilizing trucks and tipping stations, these plants accept very large volumes very efficiently. Improving this system would seem to be the most likely area to improve efficiency of the overall system.
2. Depending on how the US decides to implement a greenhouse gas control policy, carbon sequestration and fuel switching could become much larger components of the analysis. If the value of removing a ton of carbon is set at $8 per ton, the value of this system will increase. The allocation of this increase between the farmer and the energy producer is unknown. One important unknown variable is the amount of soil carbon sequestration to be expected in Virginia soils. The 1 ton/acre is a rule of thumb from studies in the Midwest that probably has little applicability to our soils and climate.
3. Industrial scale stand establishment is still a work in progress. Much work has been done in the Midwest, but techniques are still being evaluated in Virginia. Traditional methods that require 2-4 years for stand establishment are clearly too slow and inconsistent for this system to be successful.
4. Offset payments for avoided nitrogen and phosphorous release in the Chesapeake Bay. Clearly removing land from the production of small grains in the Chesapeake Bay watershed would avoid the application of nitrogen and phosphorous. Removing buffers and planting them in native warm season grasses both removes nitrogen and phosphorous plus restricts runoff into waterways. The amounts are critical if a system of offset trading is to be successful. Ongoing research at the Conservation Management Institute and elsewhere seeks to answer this question.
5. Native warm season grass stands are noted as good early succession habitat for a variety of game and nongame animals. Small modifications in the seeding mix could yield large increases in habitat quality for game birds making possible hunting lease or other value-added financial opportunities
6. Burning stubble is a preferred management technique for native warm season grasses however we have little experience with the potential air quality impacts of potential burning on this scale. Data from pre-Columbian landscape studies indicate that wide-scale burning by native Americans was far more common than today, but the potential for problems with smoke and particulates remains to be evaluated.
7. Establishment costs are the biggest single hurdle to entry by producers. Providing low or no interest loans or grants for establishment would help producers enter the system. This is particularly true for smaller and low-income producers.

8. Establishment of a clearinghouse or broker for coordinating sales contracts and transportation would help immensely. Energy producers find the prospect of working with hundreds of agricultural producers daunting. Clearly this is a role for a private sector firm, but to date none have stepped forward, although at least two have begun organizing for such a move.
9. Opportunity exists for recovery of former farmland. Methods and costs for this recovery exist, but we feel that best management practices need to be developed. Testing the assumption that wood chips from the restoration effort can pay for the conversion should be tested.
10. Technology for combined heat and power production is changing rapidly. A pilot test of a gasification unit utilizing native warm season grasses would give facility managers more information about the costs and benefits of converting their equipment. Gasification promises to dramatically improve efficiency and reduce emissions of particulates especially. The added cost of the equipment compared to the reduction in fuel cost is, at present, unknown.
11. Transportation to a point on the landscape (the biorefinery) is a key component of the cost structure. Adoption rates by landowners is a key variable in determining the density of biomass on the landscape. Adoption rates are dependent on price, but also on many other factors that are not price related.

Case Study -- The Piedmont Geriatric Hospital Pilot Project

In an effort to provide a realistic illustration of a biomass energy project, we will use information from an ongoing case study at the Piedmont Geriatric Hospital in Burkeville, Virginia. This case study provides realistic parameters with respect to supply and demand that will allow us to estimate the economics of such an endeavor from the perspective of a potential producer cooperative established to supply the hospital with switchgrass boiler fuel.

Background

In 2006, the Conservation Management Institute approached the Piedmont Geriatric Hospital with a proposal to serve as a pilot project for the use of native warm season grasses in south-central Virginia. The Piedmont Geriatric Hospital is a state owned and operated facility near Burkesville, VA that is unique in that it produces its own steam for heating and hot water using a converted coal boiler. The primary fuel had been sawdust from nearby forest products processing facilities. There was some concern over the long term availability, cost, and quality of the material. They were also in the process of building a new wing to the hospital that would dramatically increase the demand for steam. They already had two fuel oil boilers that were used as peaking boilers and as a backup when the biomass boiler was taken off line for maintenance. The plan was to start using the fuel oil boilers to provide steam for the new wing, so comparisons are made against fuel oil for cost analysis.

This situation was fortuitous since it provided existing equipment and an existing application (direct firing for steam) for testing. We secured a donated supply of native warm season grasses from a producer near Deerfield, VA, and donated shipping from the VA Department of Game and Inland Fisheries. We used donated and rented equipment from Robertson Equipment Supply in Bedford, VA to process and blow material into the hopper system at the boiler. Utilizing small grants from several sources including the Virginia Department of Mines, Minerals, and Energy plus funding from the Conservation Management Institute overhead account, we conducted a pilot project to determine if native warm season grasses could serve as a boiler fuel utilizing existing farm equipment with minimal modifications (if any) to the feed system at Piedmont. After several tests, and one minor modification to the feed system, we successfully demonstrated the use of native warm season grasses at Piedmont Geriatric Hospital by completing a 150-hour test fire starting on July 7, 2008 and continuing through Sunday, July 13, 2008. Volume requirements of the material appear to be significantly lower to produce the target steam level due presumably to improved efficiency of the boiler as a result of lower fuel moisture content. Fuel moisture content of the native warm season grass material used was less than 15% whereas sawdust ranges widely from under 10% to over 50%.

For the purpose of this simulation, we made some critical assumptions in order to achieve realistic outcomes. Our assumptions include:

- the entity providing the feedstock to the hospital is comprised of one or more growers with sufficient acreage in pasture that can be converted to native warm season grasses

- we assume the supply contract will be for 10 years
- the entity is responsible for producing and delivering feedstock to the Hospital without special processing such as chopping, pelletizing, or densification (these issues will be addressed later in this document)

- the life of a native warm season biomass stand is 10 years. There is no harvest in the first year to allow stands to establish, and then harvests proceed for 10 years before stands require regeneration. Yields reach their peak in year 3 and begin to decline in year 7.

- annual costs are increased 3% per year to account for inflation

Analysis Parameters

In order to adequately represent the total process we must first establish the needs of the hospital in terms of the amount of feedstock necessary to meet the demand. For this purpose we assume that the entire capacity of the hospital need will be met with biomass boiler fuel without interruption and that the total (and typical) energy demand of the Hospital is 168,929 MBTUs per year.

This value can be used to estimate the total amount of biomass needed to meet that demand. We used assumed the MBTU content of dry switchgrass per ton to be 14.4[3]. Using this estimate of MBTU

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[3] Considered a minimum value. References place the MBTU of switchgrass per ton from 14.4-17.2 MBTU per ton.

content, the total feedstock needed to meet the minimum demand at PGH would require 11,731 tons of material.

Base Total Acres

The total base acreage required to meet the demand will depend on the total amount of material that can be produced. Most estimates of switchgrass production are 4-6 tons per acre without significant annual inputs of fertilizer, herbicide, etc.

It is also prudent to include extra acreage to ensure the base need is met. Potential losses to biomass during the production, transport, and processing stages are important to consider. We used potential losses of 30% to account for material lost due to weather damage, fire, storage, or transportation (Table 1).

Table 1. Estimated base and total acres needed under different yields to supply Piedmont Geriatric Hospital.

Tons per Acre	Total Base (acres)	Loss Mitigation (acres)	Total (acres)
4	2933	880	3813
5	2346	704	3050
6	1955	587	2542

Costs for Acreage, Establishment, and Harvest

The statewide mean cost per acre rental rate is \$21 for pasture land[4]. This is an appropriate rate because productive crop lands are unlikely to be used for biomass.

We assume that all the acreage will have to be converted to WSG. The costs for planting existing pasture to WSG are estimated to be \$196/acre (Virginia Cooperative Extension 2007 adjusted for inflation).

Warm season grass requires annual maintenance in the form of burning or disking. Burning is a preferred option since annual maintenance disking negatively impacts yield. We estimated the annual maintenance costs for stands to be \$49/acre[5]. We assume that all stands would be burned each year to provide a conservative estimate of costs.

Harvesting is done once per year from years 1-10. Harvesting costs were estimated to be \$110/ acre per year (Virginia Cooperative Extension 2007 adjusted for inflation). This includes costs related to cutting, conditioning, raking, and baling grass for storage on the farm site.

The annual yield is expected to change over the 10 year lifespan of the stand. Ideally, there should be no harvest in the fall following stand establishment (year 0). In year 1, the stand will provide

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[4] Virginia Cooperative Extension.

[5] Virginia Cooperative Extension.

harvestable material but typically the stand will not have reached full production potential until year 3. As the stand matures, the yield will typically stay constant (under appropriate conditions) until year 7 when yields will gradually decline. It is recommended that stands be completely regenerated after 10 years to maintain long-term viability.

Costs for Transportation

The costs for transportation are highly variable and are closely tied to costs for fuel. For this simulation, we used transportation estimates from a recent geospatial analysis completed for the Virginia Department of Mines, Minerals, and Energy (2008). The study evaluated the supplyshed necessary to support a biomass boiler at the PGH location for a range of sizes (from 10,000 tons to 100,000) tons and calculated the total number of miles of travel required to supply the location using common transport variables (truck capacity of 20 tons, loading costs of $3.54 per ton, and transport costs of $.30 per mile) to determine a mean cost for transport per ton. The resulting estimate was $3.62 per ton. We rounded this estimate up to $4 per ton. Additional searches turned up estimates of $0.25 - $0.67 per ton per mile estimates for transporting hay. So, at $4 we could transport each ton between 6-16 miles

We do not know the exact location (and therefore distances) of feedstock stands in relation to PGH. However we can estimate the likely distance feedstock would have to travel. If we assume the best case scenario for growing the required amount of feedstock is 100% of the landscape surrounding the hospital, then we know that area of that circle would be equal to the total amount of biomass needed or 11,731. The radius of a circle 11,731 acres in size is 2.4 miles (11,731 acres is 18.34 square miles, then solve for the radius using Area $= \pi r^2$). If we assume that only 1% of the area was planted in feedstock, then the total area of the circle surrounding the hospital would be 1,173,100 acres, or 1,833 square miles. The radius of that circle would be 24.15 miles. So, we feel our estimate of $4 per ton is a reasonable estimate for transport.

Net Present Value

To appraise whether planting warm season grasses would likely lead to positive financial outcomes, and to understand the influence of variables such as selling price, yield and discount rate, we used the net present value (NPV) project evaluation method. The NPV method is useful for evaluating long-term projects (such as planting warm season grasses) because cash inflows (sales) and outflows (i.e., establishment and stand maintenance costs) are discounted back to their present values. The sum of these present values indicates whether the project (i.e., planting WSG) provides wealth. Projects with a positive NPV add wealth; those with a negative NPV should be rejected.

NPV is the sum of :

$$\frac{R_t}{(1+i)^t}$$, where

t - the time of the cash flow

i - the discount rate or rate of return that could be earned on an investment (project) of similar risk.

We modeled NPV of a theoretical warm season grass project under various conditions. Variables were: yield (tons/acre), selling price of WSG, and the producers required rate of return or discount rate.

In summary, our parameters and assumptions were:

- Site prep and establishment $196.42, year zero, onetime cost
- Land rental: $21/year, escalated at 3% cost of inflation
- Stand maintenance: $49/year, beginning in year 1, escalated at 3% cost of inflation
- Transportation: $4/ton, escalated at 3% cost of inflation
- Harvesting: $109.96/year, beginning in year 1, escalated at 3% cost of inflation
- Productivity (% of peak yield): year 1: 0.5; year 2: 0.75; year 3-6: 1; year 7, 0.95; year 8: 0.9; year 9: 0.85; year 10: 0.8
- Discount rate: 0.04, 0.06, 0.08
- Peak yield: 3-8 tons/acre

Table 2 provides an example of annual cash flows for a WSG producer at 6 tons/acre and sales at $55/ton. Table 3 uses the net cash flows from Table 2 and illustrates the effect of a 6% annual discount rate. Table 3 illustrates that, given the parameters outlined above, a producer could earn a net present value of $183/acre by planting and selling warm season grasses. Amortized over 10 years at 6%, this would amount to $23.86/acre/year. Increasing yield or sales price would obviously increase NPV, annual income, and therefore make the endeavor more profitable. Table 3 also illustrates that, in this scenario, the financial breakeven point is not until year 5.

Selling price and stand productivity interact to influence NPV, cash flows, and therefore the decision whether or not to undertake an investment. To some degree, high productivity can mitigate a low selling price and vice versa. To better understand this relationship, we conducted a serious of simulations and allowed selling price and yield to vary while holding NPV=0. Figure 1 displays the results of these simulations and illustrates how productivity and revenue interact where NPV=0 and discount rate =0.6. For example, a 6 tons/acre yield and a selling price of $50/ton would result in a NPV of zero. That is, the endeavor would provide no real economic benefit. At any point above the line NPV>0 and a producer of WSG could expect some economic benefits.

Table 2. Example annual cash flows over the life of a 10 year warm season grass stand, using the parameter values described above. Number rounded. This example assumes 6 ton/acre peak productivity, sales at $55/ton and a discount rate of 0.06.

	Year										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Site prep ($/ac)	0	0	0	0	0	0	0	0	0	0	0
Establishment ($/ac)	196	0	0	0	0	0	0	0	0	0	0
Land Rental ($/ac)	21	22	22	23	24	24	25	26	27	27	28
Maintenance ($/ac)	0	49	50	52	54	55	57	59	60	62	64
Transportation ($/t)	0	24	25	25	26	27	28	29	30	30	31
Harvesting ($/ac)	0	110	113	117	120	124	127	131	135	139	143
Costs total (ac)	217	205	211	217	224	230	237	244	252	259	267
Productivity (%)	0.00	0.50	0.75	1.00	1.00	1.00	1.00	0.95	0.90	0.85	0.80
Revenue ($/ac)	0	165	248	330	330	330	330	314	297	281	264
Cash Flow ($/ac)	-217	-40	37	113	106	100	93	69	45	21	-3

Peak tonnage/acre	6
Revenue/Ton	55
Discount rate =	0.06

Table 3. Net present value (NPV) of cash flows over the life of a theoretical WSG planting. Numbers rounded. Non-discounted cash flows are presented in Table 1. The NPV in this example is $183/acre or an amortized return of $23.86/acre/year at 6%.

Year	NPV Cash Flow ($)	Cumulative Cost/Profit ($)
0	-217	-217
1	-37	-255
2	33	-222
3	95	-127
4	84	-43
5	75	32
6	65	97
7	46	143
8	28	172
9	13	184
10	-2	183

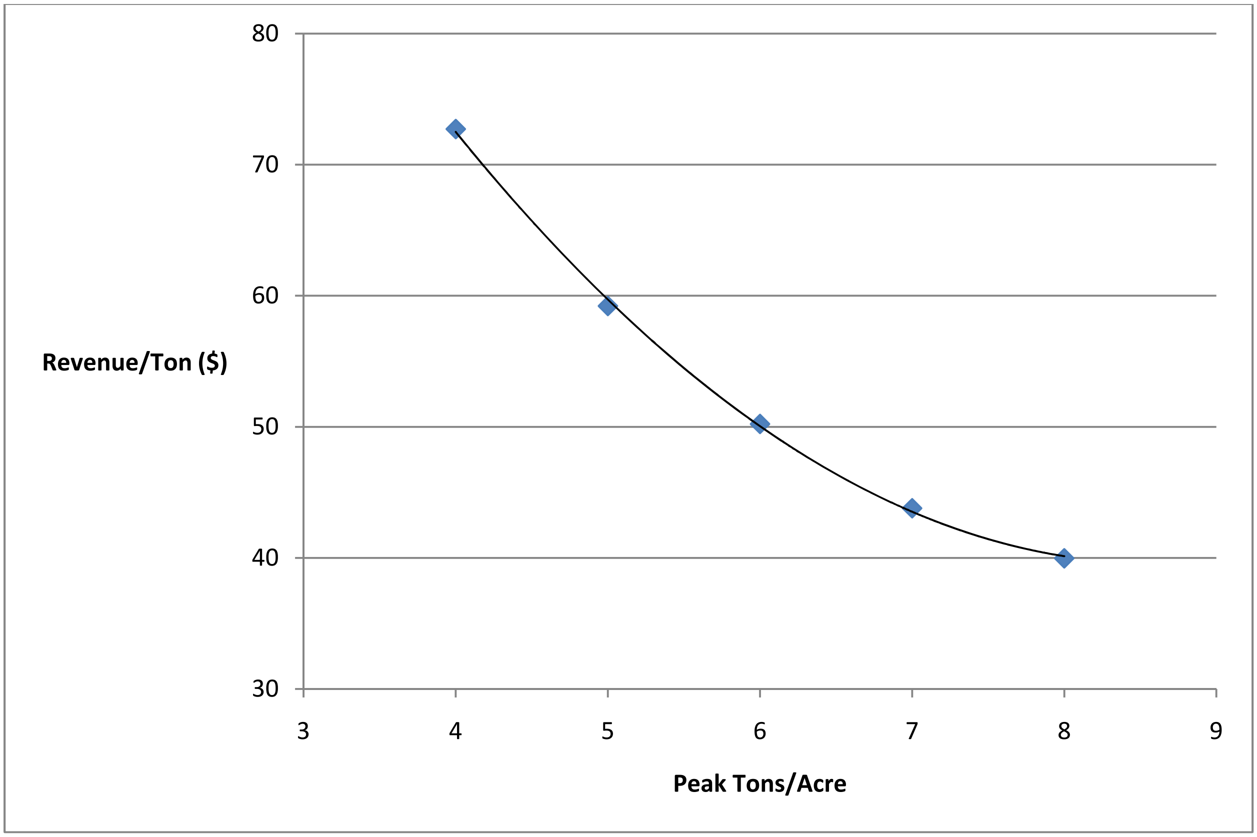

Figure 1. Relationship between revenue and yield where NPV=0 and the discount rate =0.06. Given the assumptions outlined above, any combination of yield and revenue on the line would result in NPV=0. Combinations that fall below the line represent NPV<0, while combinations of yield and revenue in the region above the line represent NPV>0. Discount rates of 0.04 and 0.08 do not significantly affect this curve.

<u>Comparisons between WSG to Coal and Wood</u>

We used the Fuel Value Calculator, an online[6] tool developed by the USDA Forest Service, to calculate and compare typical costs of using sawdust, coal, and warm season grasses as a boiler fuel. This tool allows the user enter their current energy source and cost per unit, and the tool determines the price at which competing fuels become economically competitive, based on their energy content and conversion efficiency. We evaluated the viability of warm season grasses relative to coal, a common source of energy in small to medium sized boiler operations in Virginia, and sawdust, the current source of energy at Piedmont Geriatric Hospital.

Gross heating values and energy conversion efficiencies were the default values provided by the tool. In conducting these analyses, we used the following assumptions:

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[6] http://www.fpl.fs.fed.us/documnts/techline/fuel-value-calculator.pdf

- Net heating value of sawdust is 5.74 MBTU/ton[7]
- Net heating value of WSG is identical to switchgrass and is 12.4 MBTU/ton
- Net heating value of coal is 26 MBTU/ton

Figure 2 illustrates the line of indifference and price region where a theoretical consumer of coal (i.e., boiler operator) would be willing to convert to warm season grasses as a fuel. At any point on the line a consumer would be indifferent to the source of BTUs assuming the prices paid per ton matched those on the corresponding X and Y axis, and assuming there were no other unaccounted external costs (i.e., social, political, environmental or operational). Prices below the diagonal would make warm season grass a better value on a BTU per dollar basis; consumers would be unwilling to pay prices above the line for warm season grasses, as this area represents a poor value on a BTU per dollar basis. For example, as illustrated in Figure 2, if a boiler operator were paying the current price of $45/ton for coal, to achieve the same cost per BTU, the maximum rate for warm season grasses would be $21/ton. This number can be derived by dividing the net heating value of warm season grasses (12.4 MBTU) by the net heating value of coal (26 MBTU) then multiplying this value by the price per ton of coal. Warm season grasses costing less than $21/ton would result in a net cost savings for the consumer of BTUs.

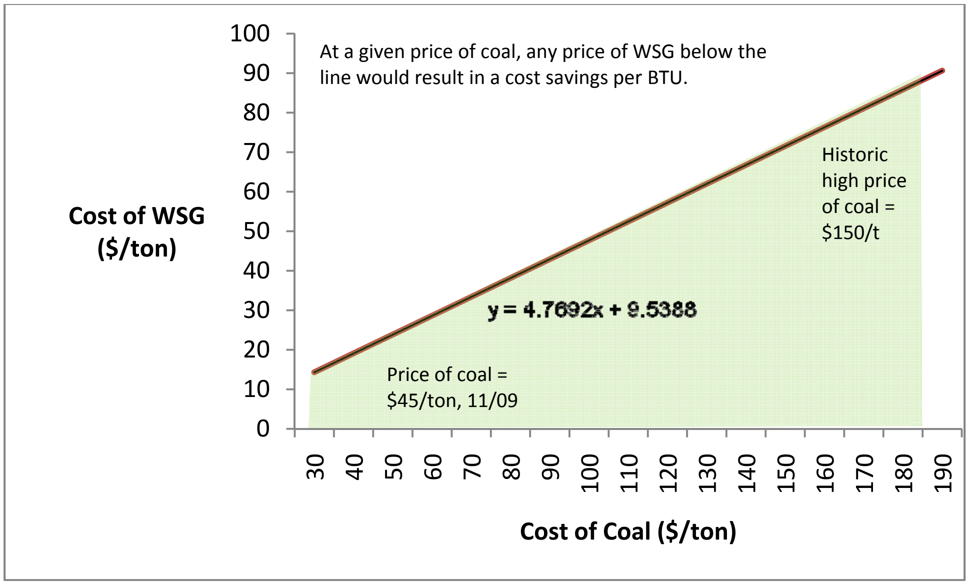

Figure 2. Cost comparison of coal vs. warm season grasses as a biofuel on cost per BTU basis. At a given price of coal, any price of WSG below the line would result in a cost savings per BTU. For example, if coal costs $45/ton, any value of WSG below $21 would result in a per BTU cost savings.

WSG vs Coal

These results indicate that warm season grasses are not a likely substitute for coal under current economic and political conditions. Coal is an exceptionally dense and energy rich fuel source. Producers

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[7] This value supported by empirical data collected at Piedmont Geriatric hospital

of warm season grass would be unwilling to sell their product at the low price required achieve similar per BTU costs. At current coal prices, producers of WSG would be unwilling to sell their product at $21/ton, the price needed to compete with coal on dollar per BTU basis.

If the price of coal were to rise due to market conditions or external factors, such as a carbon tax or government regulations, warm season grasses could become an economically viable substitute for coal. In the summer of 2008, for example, coal prices reached as high at $150/ton in Virginia. At this level, warm season grasses would be cost competitive at $72/ton (Figure 2), a price that could be attractive to farmers. There is currently significant pressure on the US Congress from European allies and environmental groups to enact new rules governing carbon emissions. A mandatory carbon cap-and-trade system could significantly affect (increase) the cost of burning coal, and therefore the economic viability of using warm season grasses.

Regardless of whether a cap-and-trade system is enacted, environmental concerns about the burning of coal are likely to escalate. Pressure will mount on consumers of coal. Rather than converting entirely to warm season grass as an energy source, it is likely that coal boiler operators will reduce their carbon footprint by co-firing warm season grass with coal. A well publicized and full scale test at the Chariton Valley Biomass Project established a proof of concept and generated 19,607,000 kilowatt-hours of electricity from the renewable switchgrass fuel. Even a few small scale operations in Virginia would require tens of thousands of acres of warm season grasses annually.

Comparison of WSG vs. Wood

The relatively high energy content of WSG compared to other biomass fuels, such as sawdust, make the conversion to WSG potentially cost-effective. Using the Fuel Value Calculator described above, we estimated the price at which warm season grasses would become economically competitive over sawdust, the current fuel at PGH. Prices for sawdust vary greatly but rarely fall below the current price of $23/ton. At a net heating value of 12.4 MBTU/ton, warm season grasses contain significantly more energy than the sawdust typically delivered to PGH (5.74 MBTU/ton). Using these values, Figure 3 illustrates that PGH could pay as much as $52/ton for warm season grasses without increasing their cost per BTU under present conditions. At $33/ton any value for WSG less than $71/ton would result in a cost savings on a per BTU basis.

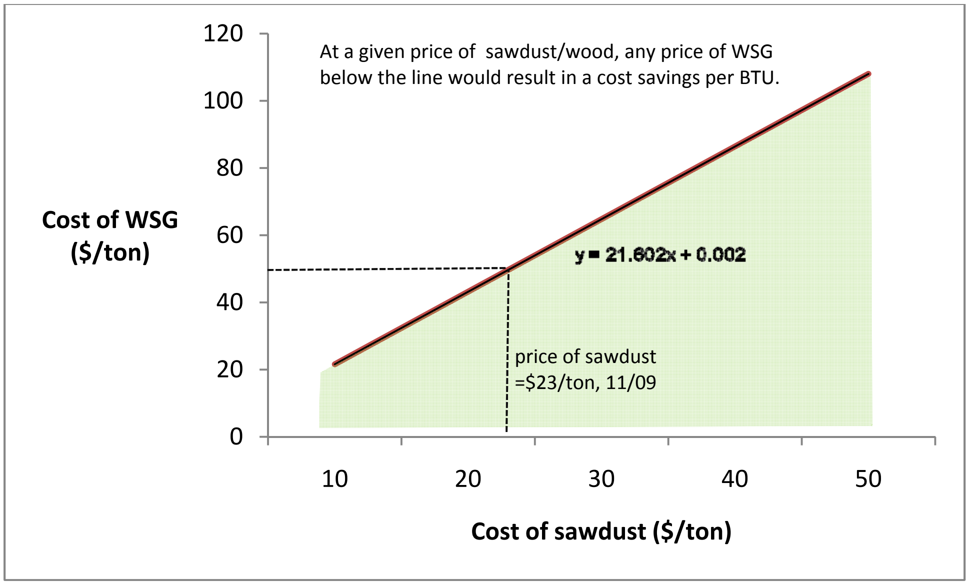

Figure 3. Cost comparison of sawdust vs. warm season grasses as a biofuel. At a given price of sawdust, any price of WSG below the line would result in a cost savings per BTU. For example, if sawdust costs $23/ton, any value of WSG below $52 would result in a per BTU cost savings.

Cost per BTU is not the only reason Piedmont Geriatric Hospital and other biomass operators may consider converting to warm season grasses as their primary energy source. The cost of sawdust has been steadily increasing as US furniture factories close and the European demand for wood pellets increases. Acquiring a consistent supply of sawdust has also become increasingly difficult, sometimes forcing shutdowns during the winter months. Quality of sawdust varies as well, both in term of moisture content and presence of foreign matter that must be removed prior to combustion. High moisture content can severely and negatively affect boiler operation, and debris can damage the boiler or feed transport systems.

The moisture content of WSG is significantly lower than sawdust and can be controlled through the timing of harvest. Unlike sawdust which may come from furniture factories and other sources where foreign objects are plentiful, harvested WSG tends to be largely free of potentially damaging objects.

It is for these reasons that cost per BTU is not the sole criteria choosing a fuel source, and WSG may be a suitable and cost effective substitute for sawdust under present market conditions.

Processing Costs

Our analysis did not address costs related to processing grass from the field harvested state to boiler-ready feedstock. Existing boilers are equipped with custom designed fuel delivery systems and each circumstance will likely require specific processing before WSG can be introduced to the firebox.

There is a fairly broad spectrum of possibilities for processing. The simplest case would involve direct firing of material in bale form (e.g., cigar burner systems) where entire bales can be placed into the system with no additional processing. More typically, material will require some sort of processing in the form of chopping to very specific size classes so that material can be handled with existing conveyor or auger type delivery systems (as is the case at PGH). The highest end of the processing spectrum may require WSG material to be densified into briquettes or pellets that would then be pulverized before being sent into the boiler (as with many existing coal burning boilers). Simply put, the more post-harvest processing is required before the material can be burned the higher the cost per ton that must be incorporated into the final estimates. We anticipate these costs will be mitigated somewhat by lower transportation costs (more BTUs per load than unprocessed material) but the result will be an increase in the break-even point for the entity that provides the material.

Risk Management

Clearly the most significant risk to boiler operators considering a fuel switch to WSG is the future price of their present primary boiler fuel. In the case of coal, our analyses indicate the likelihood of switching to long-term WSG contracts to supply feedstock would be unlikely given the historic and projected costs of coal. The price per ton of coal would have to return to all-time highs for WSG system to begin to compete even under the assumption of low or no processing costs (which will only add to the production costs and lower producer profits). That said, the potential for significant changes for coal systems that include costs related to new cap-and-trade systems is high at present and emissions costs certainly would make the switch to WSG more feasible. Entrepreneurial producer groups could have great advantages when and if these changes affect the coal market since they would be prepared to meet the demand with WSG systems that are already up and running.

However, if facilities are considering a switch to WSG from sawdust or other wood byproduct then the risks are reduced. WSG is already approaching competitiveness (again assuming processing costs required are at the lower end of the spectrum) for boilers presently using sawdust according to our analysis, and the likelihood that WSG will present a cost savings in these situations is increasing. Entities may be able to control some risk by entering into longer term supply contracts (i.e., 10 year) with boiler operators but then also add the risk that fuel costs will increase greatly over the term of the contract thus reducing long term profit potential for short term stability.

Some risk would also be mitigated through the existing hay market. Producers who choose to establish WSG stands presently would still be able to sell material as forage. We would expect the forage value of WSG to be comparable to fescue which is presently selling for around $30 per ton with similar requirements for management and harvest.

Further mitigation from risk would come in the form of Federal programs now coming online designed to assist producers in establishing biomass crops. For example, in 2009 the USDA has initiated a Biomass Crop Assistance Program (BCAP) that will assist farmers who endeavor to supply facilities that are switching to biomass feedstock. This would significantly reduce the financial risk for producers entering into long-term agreements to supply these facilities. This program is in its infancy and its impact should be closely monitored by interested producers in the landscapes surrounding these facilities as they are identified.

Case Study Conclusions

Producers interested in initiating a grass-based production system targeting the biomass energy market would be taking a moderate to high risk, particularly if their immediate market competition is for boilers presently using coal a fuel. Until coal costs rise significantly towards their all-time highs, warm season grasses cannot compete with coal on a BTU per dollar basis. However, existing biomass facilities, such as the Piedmont Geriatric Hospital, which burn sawdust, may see some economic and operational benefits by converting to warm season grasses. The net heating value of WSG is approximately double that of sawdust. Risks to producers are mitigated by the fact that secondary markets for warm season grasses exist in the cattle forage business. In the short term, The most viable opportunities for warm season grass biofuel will be limited to those landscapes surrounding facilities that are currently relying on sawdust or other low energy biofuels

There are several significant programs that could greatly increase the viability of WSG as a cash crop for producers that are expected to materialize in the near future. These include cap-and-trade legislation, incentive programs for biomass producers, and increases in traditional energy markets from their recent lows. Any or all of these would cause a significant shift towards increasing feasibility in Virginia.

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