Farm Scale Biomass Production for Electricity Generation and Community Development

Lee Carol Greenwell, Tom Keene, Dr. Ray Smith
University of Kentucky
College of Agriculture
Department of Plant and Soil Sciences

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Executive Summary

Renewable energy sources are of great interest across the globe. North America shares in this interest as can be seen through the amount of research being done in Canada and the United States. National, state-wide and local groups have and are exploring ways to put renewable energy to work for their areas. A simple Internet search will show the many places delving into the biomass field. Kentucky is no exception.

One of the many forms of biomass being researched and utilized is switchgrass (P*anicum virgatum* L.). Through various forms of processing, switchgrass can be used in liquid fuels and in heat and electricity generation through burning.

Kentucky is well-suited to switchgrass production. The state has approximately 14 million acres of farm land, and it has been estimated by the Governor's office that we would need over 1,000,000 acres of energy crops to help meet a 20 percent Renewable Portfolio Standard – about seven percent of the state's farmland. With an excellent highway and river barge system in place, biomass would be very accessible to customers such as East Kentucky Power Cooperative in Maysville, Kentucky.

Through the experience of the University of Kentucky College of Agriculture Department of Plant and Soil Sciences, the UK Cooperative Extension Service, producers in Northern Kentucky and East Kentucky Power Cooperative many aspects of switchgrass usage for biomass have been explored. From establishment to harvest, from processing to co-firing, lessons have been learned that will benefit future efforts in alternative energy.

The environmental benefits of switchgrass abound. Improved soil conditions, reduced erosion, carbon sequestration, wildlife habitat, aesthetic appeal, a resurrection of a native species are some of the many benefits of growing switchgrass. When using it for energy, one can note that it burns cleaner than coal – improving air quality, and would bring growth to many struggling rural communities.

Financial concerns are the greatest barrier standing between biomass and the current landscape. How can producers, energy providers and consumers find a balance to meet the essential farm-gate price? One example is a Missouri cooperative called ShowMeEnergy Cooperative. Private industry may also play a role. As in coal, government assistance in the form of subsidies would be helpful in laying the groundwork for a successful biomass industry.

In spite of the economic challenges, the future is bright for biomass because of the commitment to it on all levels. The Biomass Field Day on October 17, 2012, in Bracken County was well-attended by area farmers, government agency representatives, members of the staff and students from the University of Kentucky and Morehead State University, and a representative from EKPC. Renewable fuels are available to Kentuckians and can be supplied by Kentuckians. Through further research, private investment and government aid, costs of production will go down and a well-laid infrastructure will arise.

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Introduction

Renewable energy sources are being researched and explored heavily across the globe. In 2009, www.listserve.com listed the top ten renewable energy sources as nuclear power, compressed natural gas, biomass, geothermal power, radiant energy, hydroelectricity, wind power, solar power, wave power, and tidal power. For the purposes of their list, they defined *biomass* as "plant matter grown to generate electricity or produce for example trash such as dead trees and branches, yard clippings and wood chips biofuel, and it also includes plant or animal matter used for production of fibers, chemicals or heat. Biomass may also include biodegradable wastes that can be burnt as fuel. (1)" Using biomass in North America has been the topic of extensive investigation over the years. Renewable biomass sources such as switchgrass (P*anicum virgatum* L.), miscanthus (*Miscanthus giganteus)*, and other grasses have continually proven to be a good source of heat, electricity and biofuels; however, using these renewable resources for energy has been, and continues to be, an economic challenge.

Undoubtedly, the desire to utilize renewable resources for energy is present in North America. Research and feasibility studies have been performed across the United States and Canada. At a federal level, the US has the Biomass Research and Development Board (http://www.usbiomassboard.gov), which was established by the Food Conservation and Energy Act of 2008 to fund biomass initiatives; and the National Renewable Energy Laboratories (http://www.nrel.gov/biomass/), which works through research to convert biomass into fuels to offer us cleaner air, rural economic growth and reduced dependence of foreign oil. Numerous states have performed research on producing and utilizing various forms of biomass to meet their area's heat, electricity and fuel needs. Local groups have investigated how they could participate in the biomass market (2, 3, 4). In Canada, there are groups such as Resource Efficient Agricultural Production (REAP) (http://www.reap-canada.com/), the University of New Brunswick's Canadian BioEnergy Centre (http://www.unb.ca/fredericton/forestry/wstc/cbec/) and the University of British Columbia's Biomass and Bioenergy Research Group (http://biomass.ubc.ca/) which are dedicated to finding ways to make biomass a feasible and practical part of their energy landscape.

Switchgrass as a form of biomass

One of the common subjects of research performed on biomass is switchgrass production and utilization. Switchgrass is a native warm season tall prairie grass that was commonly occurring throughout North America before the continent was settled. Throughout years of study, switchgrass has been found to be an effective source of heat production in the form of pellets burned in pellet-burning stoves, fuel production and electricity generation, especially when co-fired with coal. There are many advantages to using switchgrass for energy – environmental and economical.

It grows well on marginal land that may otherwise be kept out of agricultural production. Landers, et al. believe that in their area of the mid-west, making the transition from annual row-crop production to a perennial grass system on marginal claypan soils will "improve soil conditions and water quality, reduce soil erosion, and sustain soil productivity (5)." Once established, it is easily maintained, requiring little input with regard to labor, fertilizer and pesticides. It can be harvested using standard hay equipment. Depending on the form it is baled in, it can be stored outside, covered or uncovered, or under shelter. It is an excellent cover and food source for wildlife such as deer, rabbits, song birds and game birds like wild turkey and pheasant. In a 2003 switchgrass study performed in the Chariton Valley area of Iowa, Iowa State University researchers quantified the numbers of pheasants found within traditional row-crop (corn) fields, stripharvested and total-harvested switchgrass fields and discovered increased pheasant populations in the switchgrass fields (6). Switchgrass is a warm season perennial that utilizes the C4 carbon sequestration cycle - producing two- to three- times more dry matter than plants that utilize the C3 carbon cycle (7). When fossil fuels are burned they only add carbon dioxide to the atmosphere. However, utilizing switchgrass for energy production is a carbon dioxide – neutral (or even carbon dioxide – negative) process where burning the grass returns the carbon dioxide to the atmosphere from where it will once again be obtained by the plant (8).

The economic advantages of switchgrass as a source of fuel and electricity aren't as straightforward as the environmental benefits. There are still many aspects of production and application to be improved upon before we will reap all the rewards biomass has to offer. In the form of biomass, switchgrass will bring jobs and economic growth to struggling rural areas while saving farmland (8, 9, 10) and land permanently altered by the harvesting of coal. For areas that rely on seasonal hunting as a source of income, financial benefits may be seen sooner as in the Chariton Valley area of Iowa mentioned above. Economic advantages will come to producers through lower input costs and in improved soil conditions on their farmland. For example, less trips across a field reduces input costs as well as reducing the impact equipment emissions have on the environment.

Governmental appeal for biomass

There are also governmental influences that make switchgrass an attractive energy source. The Energy Policy Act of 2005, also called the "Set American Free Act of 2005" calls for North American energy self-sufficiency by 2025 (11). The Energy and Security Act of 2007, covers many aspects of using biomass for energy, such as reducing sulfur dioxide emissions significantly when burning coal (12). In 2011, two actions were instated by the U.S. Environmental Protection Agency. The Cross-State Air Pollution Rule (CSAPR), which was to replace the 2005 Clean Air Interstate Rule (CAIR), was completed on July 6, 2011 (13). In December, 2011, the EPA signed a rule called the Mercury and Air Toxics Standards for Power Plants (MATS), which calls for reductions in toxic air pollutants by 2016 (14). The EPA also has established the Renewable Fuel Standard (RFS) which started in 2005 with a call for 7.5 billion gallons of renewable fuel to be mixed with gasoline by 2012; the amount was increased to 36 billion gallons by 2022 (15). The EPA also created the Renewable Portfolio Standard (RPS) which "requires electric utilities and other retail electric providers to supply a specified minimum amount of customer load with electricity from eligible renewable energy sources. The goal of an RPS is to stimulate market and technology development so that, ultimately, renewable energy will be economically competitive with conventional forms of electric (16)."

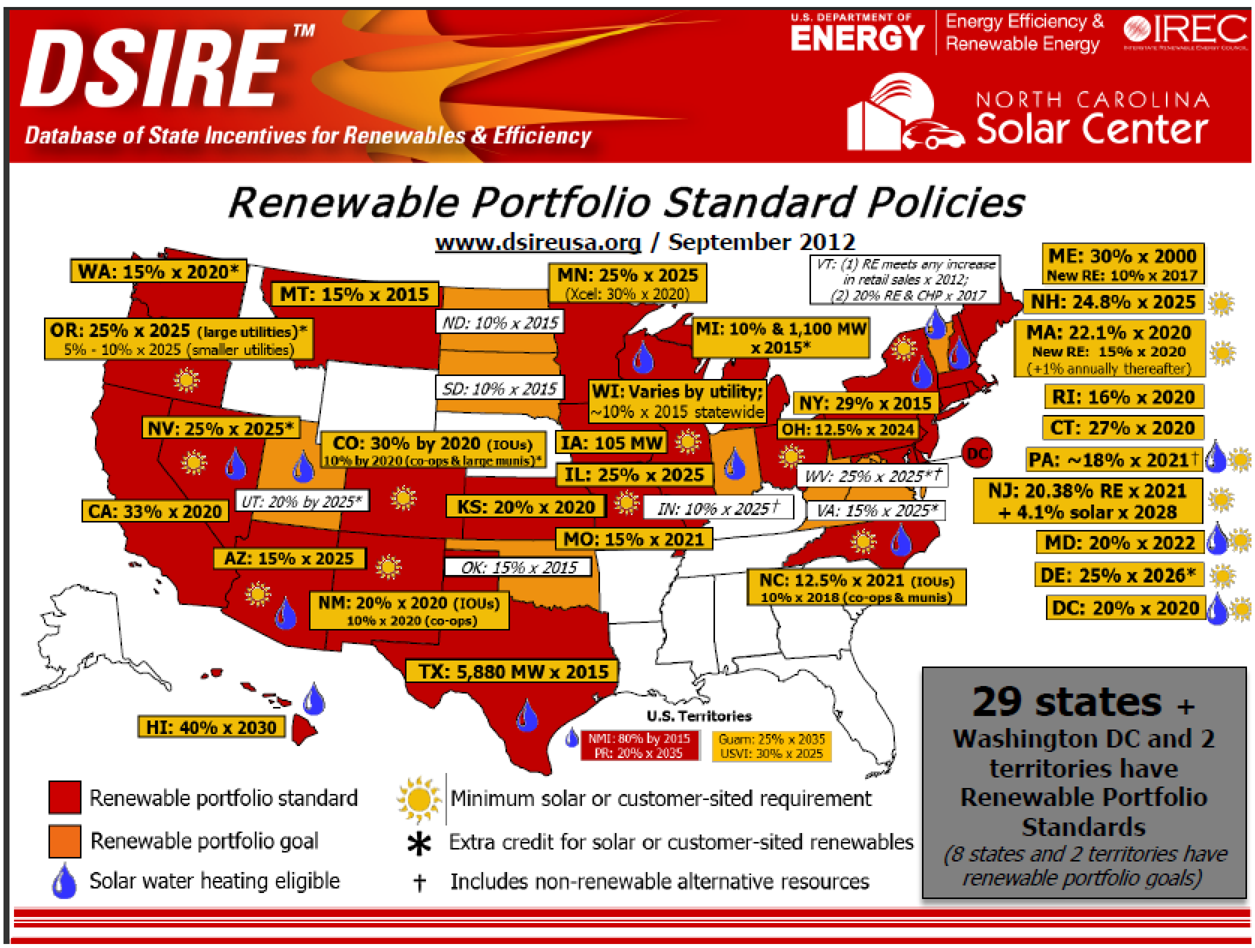


Figure 1. Renewable Portfolio Standards across the United States. September, 2012. www.dsireuse.org

State governments are on board for biomass utilization as well. From Washington (17) to Texas (18) to Maine (19), biomass is a part of the legislative landscape. In 2009, Kentucky Governor Steve Beshear appointed a *Task Force on Biomass/Biofuels in Kentucky*. The Governor pointed out that if Kentucky fails to increase its biofuels production, it will import 90% of its renewable fuel to meet RFS standards by 2022. He also cited an eminent RPS for electricity for the state. In a White Paper for the task force, Governor Beshear mentioned that if Kentucky is required to take on a 20 percent RPS, and decides to meet that demand through in-state renewable energy resources, almost 16 million tons of biomass would be used for combustion. "Assuming half of the requirement is met by forestry; over 1,000,000 acres of energy crops will need to be planted, representing about 7 percent of Kentucky's total farm acreage." (20)

Currently, these mandates are encouraging the development and use of biomass and biofuels across the United States, however, enforcement varies. As alternative fuels become more economically feasible to produce and utilize, states will be able to meet their goals readily.

University of Kentucky biomass research

The University of Kentucky has shared in this global interest in biomass research and potential usage. In particular, Dr. Ray Smith and members of his laboratory in the Department of Plant and Soil Sciences in the UK College of Agriculture, have spent significant time and effort exploring the nuances of producing and utilizing switchgrass as a form of bio-energy in the Commonwealth of Kentucky. From 2007 – 2011, Dr. Smith, Mr. Tom Keene and other members of the University of Kentucky College of Agriculture Department of Plant and Soil Sciences conducted a study: *Expanding Opportunities for Biomass and Hay Production in Northern Kentucky.* In this study, 20 farmers in twelve counties in Northern Kentucky near the East Kentucky Power Cooperative Spurlock Station in Maysville, Kentucky grew five acres of switchgrass each with the sole purpose of co-firing it with the coal already used by the power station.

Expanding Opportunities for Biomass and Hay Production in Northern Kentucky 2007-2011

Study Purpose

Tobacco production has been an important income source for farmers in Kentucky for many years. The tobacco buyout program and the resulting decrease in income, rising production costs and labor sourcing difficulties has made tobacco a less viable income source. Producers in the Northeast Kentucky region are eager to find alternative production options on their farms. A number of alternatives have been suggested, but many of these require high capital investments and have limited market opportunities. Biomass production with switchgrass and similar crops provide a renewable fuel alternative that works well with existing hay production systems and equipment. In other words, producers in Northeastern Kentucky can produce biomass using their existing machinery. There are numerous emerging options for biomass including electrical generation in co-fired units (like the one at East Kentucky Power in Maysville, Kentucky), pellet production for pellet fueled home heaters, and cellulosic ethanol production. Therefore, the objectives of this project were to (1) show the electrical generating utilities and the cellulosic ethanol industry that Northeast Kentucky producers can grow biomass crops sustainably and economically and (2) develop viable markets for biomass. (21)

During that study, many lessons were learned about the production of switchgrass as well as the process of co-firing it. Switchgrass is well-suited to the land and climate of Kentucky. Even marginal land produces acceptable yields. Below are tables of the five-acre plots, the soil conditions and yields of each:

Switchgrass Biomass Trial
Soil Test Results for Fall 2008, 2009, 2010

	P			K			pH		
	2008	**2009**	**2010**	**2008**	**2009**	**2010**	**2008**	**2009**	**2010**
Boyd-B	30	21	65	385	299	363	5.2	5.2	6.5
Boyd - H	50	62	57	188	330	207	6.6	6.1	6.3
Boyd - Y	22	108	70	198	313	328	5.8	7.1	7.1
Bracken - M	40	40	46	253	195	174	6.1	5.9	5.9
Bracken - P	27	21	21	200	121	111	6.4	6.5	6.6
Campbell - H	28	31	38	267	258	268	6.0	6.0	5.8
Fleming - C	87	20	30	329	183	216	6.9	7.0	6.9
Fleming - L	52	48	44	378	286	240	6.0	6.2	5.7
Grant - S	69	109	85	255	320	342	6.5	6.5	6.3
Harrison - D	475	374	-	438	675	-	7.2	7.3	-
Harrison - S	23	31	42	218	274	363	5.4	5.5	6.3
Lewis - M	43	68	50	317	270	279	6.8	6.9	6.5
Lewis - W	100	72	59	642	352	330	5.5	5.7	5.7

Mason - Co	31	26	52	147	205	202	6.3	6.1	5.8
Mason - Cr	107	121	-	326	288	-	5.9	5.6	-
Montgomery - S	164	164	-	366	310	-	6.0	5.9	-
Nicholas - H	59	38	20	373	260	252	6.0	4.6	4.9
Robertson - C	20	8	-	351	285	-	7.0	6.7	-
Robertson - D	84	20	-	320	259	-	7.0	6.2	-
Rowan - E	348	397	270	540	569	358	5.8	5.6	5.4

Table 1. Soil Test Results from 2007-2011 University of Kentucky study "Expanding Opportunities for Biomass and Hay Production in Northern Kentucky" (21)

Switchgrass Biomass Trial Soil Test Results for Fall 2008, 2009, 2010												
	B pH			**Ca**			**Mg**			**Zn**		
	2008	**2009**	**2010**	**2008**	**2009**	**2010**	**2008**	**2009**	**2010**	**2008**	**2009**	**2010**
Boyd-B	6.2	6.3	7.1	2184	2352	4893	374	352	331	3.7	2.8	3.3
Boyd - H	6.9	6.8	7.1	3761	3413	3504	195	197	189	2.5	2.4	2.3
Boyd - Y	6.6	7.2	7.3	3227	5202	5238	416	357	349	6.1	6.5	7.1
Bracken - M	6.5	6.8	6.8	3440	3652	3296	316	250	231	3.8	2.7	3.2
Bracken - P	6.8	7.0	7.1	3273	3273	3815	153	147	149	1.9	3.0	1.8
Campbell - H	6.5	6.9	6.8	6170	5946	5562	360	313	341	2.6	41.7	2.6
Fleming - C	7.1	7.2	7.2	4077	4681	4662	456	414	433	2.5	2.3	2.4
Fleming - L	6.5	6.8	6.6	3183	3587	2556	211	244	194	1.9	1.9	1.6
Grant - S	6.8	6.8	6.9	4646	3735	3629	228	235	238	2.8	2.2	2.2
Harrison - D	7.2	7.2	-	6103	5909	-	139	185	-	8.3	12.2	-
Harrison - S	6.1	6.4	6.9	4315	4378	5976	168	244	306	1.4	1.7	15.3
Lewis - M	7.1	7.2	7.0	4285	4441	3807	249	208	177	4.3	2.8	2.7
Lewis - W	6.5	6.7	6.6	3074	3029	3010	318	278	267	7.3	5.9	4.5
Mason - C	6.7	6.7	6.8	3628	3639	2858	175	220	122	1.4	1.6	0.8
Mason - C	6.7	6.6	-	3552	3133	-	243	223	-	3.7	2.6	-
Montgomery - S	6.5	6.6	-	3595	3279	-	250	239	-	4.0	3.6	-
Nicholas - H	6.7	5.6	5.9	6535	5592	4448	331	306	299	6.2	11.0	2.3
Robertson - C	7.1	6.9	-	12287	10211	-	377	341	-	3.2	1.9	-
Robertson - D	7.1	6.7	-	8794	5663	-	358	367	-	2.1	1.9	-
Rowan - E	6.5	6.7	6.8	1468	1280	1101	81	96	83	1.4	2.0	1.5

Table 1 *cont*. Soil Test Results from 2007-2011 University of Kentucky study "Expanding Opportunities for Biomass and Hay Production in Northern Kentucky" (21)

Table 2. Harvest yield data for Switchgrass for Biomass project. Plots have been named by the county in which the plot was located, followed by the first initial of the producer's last name. (21)

	County & Producer	Year Established	Tons/Acre 2008	Tons/Acre 2009	Tons/Acre 2010
1	Boyd-Y	2008	-	2.92	4.97
2	Boyd-H	2008	-	2.65	5.31
3	Boyd-B	2008	-	1.48	3.45
4	Bracken-M	2007	3.2	4.2	5.48
5	Bracken-P	2008	-	0.79	1.71
6	Campbell-H	2008	0.67	3.17	5.36
7	Fleming-C	2007	1.06	1.17	3.97
8	Fleming-L	2008	-	1.95	1.41
9	Grant-S	2008	-	2.49	3.66
10	Harrison-S	2007	-	1.02	2.36
11	Harrison-D	2008	-	2.5	-
12	Lewis-W	2007	1.7	4.92	6.18
13	Lewis-M	2008	0.53	1.99	3.91
14	Mason-Co	2007	1.57	3.25	4.77
15	Mason-Cr	2007	-	1.76	3.23
16	Montgomery-S	2008	-	2.03	3.14
17	Nicholas-H	2008	-	2.38	2.37
18	Robertson-D (Totals combined with Robertson-C)	2007	-	-	-
19	Robertson-C	2008	-	0.9	2.64
20	Rowan-E	2008	-	3	4.74

It takes careful management to establish because the switchgrass seed is slower to germinate than many weed species found in local pastures, therefore weed management is key to success. Once established, it takes three years for the switchgrass to reach maximum production. For biomass, the grass is harvested once per year and standard hay equipment can be used to cut it and bale it. Some modifications may need to be made to standard equipment depending on which variety of switchgrass one grows because of the height and bulk of the grass. After harvest, the switchgrass can be successfully co-fired with coal in either a chopped or pelleted form. A total of 684.75 tons of switchgrass (including material from 20 producers and two UK farms) was sold to East Kentucky Power Cooperative. The power company believed that the crop could be a viable source of energy for their plant as long as the supply can meet the demand, and they see progress toward a more economically beneficial process.

Expanding Opportunities for Biomass and Hay Production in Northern Kentucky 2007-2011 (21)

Additional Outcomes

Switchgrass vs Hay Comparative Budgets. Halich, G and Smith, R. University of Kentucky College of Agriculture, Department of Agriculture Economics http://www.ca.uky.edu/agecon/ March 31, 2010. This is an interactive spreadsheet developed by Dr. Ray Smith, University of Kentucky Department of Plant and Soil Sciences and Dr. Greg Halich, University of Kentucky Department of Agriculture Economics. It is a decision tool to help those considering switchgrass production to budget for biomass production and compare the profitability to hay production.

Switchgrass for Biomass Production in Kentucky. Smith, SR, Schwer, L, Keene, T, Sena, K. University of Kentucky College of Agriculture, Department of Plant and Soil Sciences. University of Kentucky Cooperative Extension Publication #AGR-201. http://www.ca.uky.edu/agc/pubs/agr/agr201/agr201.pdf. March, 2011.

Laura Schwer published **"Small mammal populations in switchgrass stands managed for biomass production compared to hay and cornfields in Kentucky"** *(2011).* Master's Thesis. *Paper 138, http://uknowledge.uky.edu/gradschool_theses/138*

Christie Otto, a student from Asbury College, Wimore, Kentucky, published **"Optimizing Cellulosic Ethanol Production by Evaluation of grasses for Ethanol Yield"** *Proceeding of the National Conference on Undergraduate Research (NCUR) 2009 University of Wisconsin La-Crosse, La-Crosse, Wisconsin, April 16-18, 2009.*

"Prechilling Switchgrass Seed on farm to Break Dormancy" was written by Dr. Ray Smith, Laura Schwer, Cindy Finneseth, Holly Boyd and Tom Keene. It was published in 2012 as University of Kentucky Extension Service publication # ID-199.

Expanding Opportunities for Biomass and Hay Production in Northern Kentucky 2007-2011 (21)

Additional Outcomes (continued)

Through the University of Kentucky's biomass work, three educational units were made available on **EcoLearnIt: Reusable Learning Object System** (http://ecolearnit.ifas.ufl.edu/)

A Decision Aid for Switchgrass for Biomass vs. Hay Production. Dr. Ray Smith, University of Kentucky. RLO ID# 89. July 2011.
http://ecolearnit.ifas.ufl.edu/viewer.asp?rlo_id=443&final_id=89

Switchgrass for Biomass Project: Highlights from the University of Kentucky. Dr. Ray Smith, University of Kentucky, Kenton Sena, Asbury University, Krista Cotten, University of Kentucky. RLO ID# 70. January, 2011.
http://ecolearnit.ifas.ufl.edu/viewer.asp?rlo_id=466&final_id=70

Switchgrass Stories: UK's Switchgrass Biomass Project. Dr. Ray Smith, University of Kentucky. RLO ID# 71. January, 2011.
http://ecolearnit.ifas.ufl.edu/viewer.asp?rlo_id=467&final_id=71

A separate research trial took place to determine the biomass potential of switchgrass and other perennial warm season grasses. The varieties of switchgrass, Indiangrass, and Big Bluestem were planted in 2008, then harvested in 2009, 2010, and 2011. Results ranged from 0.27 tons of dry matter/acre to 6.75 tons of dry matter/acre, with an average of 2.83 tons/acre.

Students in Dr. Smith's lab also share his interest in switchgrass application in Kentucky:
David Davis began his Master's thesis project: **Evaluation of Switchgrass Hay for Feeding Beef Cattle - a feed study beginning in 2010 in partnership between the University of Kentucky and Eastern Kentucky University's Center for Renewable and Alternative Fuel Technology (CRAFT) to evaluate the effect of maturity of the digestibility and intake of switchgrass hay used for feeding beef steers.** Using two varieties, Cave-in-Rock and Alamo, preliminary data suggests the stage of maturity in which the switchgrass is harvested effects dry matter intake (DMI) and dry matter digestibility (DMD). In the fall of 2011, beef steers were fed switchgrass hay harvested in the summer of that year at the vegetative, late boot, and flowering stages. Based on early information gathered from the study, hay harvested in the vegetative stage could offer higher DMI, DMD, and crude protein (CP).

Tom Keene is working toward his Master's degree with this thesis project: **Evaluating Kanlow Switchgrass Yields with Multiple Fertilizer Applications and Varied Harvest Dates.**

The success of this project led to other questions. Can Kentucky producers supply enough switchgrass to meet the demand of the power companies? Can switchgrass be grown and marketed in a way that is beneficial to both the producers and the end-users?

Kentucky energy

The United States Census Bureau states Kentucky's population is 4,369,356 (22). In 2010, Kentuckians utilized 455 million BTUs per capita. 93% of the state's electricity was generated from coal in 2011(23). In April, 2012 it was reported that 2415 thousand short tons of coal was used for electricity generation (23). Kentucky is the third highest coal-producing state (23). The average sales price for coal was $60.84 per short ton (23). The electrical power delivered to Kentuckians through coal cost $2.46/million BTU, $0.04 cents higher than the U.S. average of $2.42/million BTU (23).

In the Kentucky Energy and Environment Cabinet's 2011 Energy Profile the following information is given:

- In 2009, Kentucky consumed a total of 41 million tons of coal.
- In 2009, 92% the electricity generated was from the combustion of coal. 4% came from hydroelectric power, while the remaining 4% was generated by the combustion of petroleum products, natural gas, wood products and biomass.
- In 2009, Kentucky consumed 40,992,300 tons of coal
- In 2010, Kentucky consumed 40,148,000 tons of coal
- Western Kentucky supplied the majority (55%) of coal consumed in Kentucky in 2010, followed by imported coal (34%) from eight different states: IL, WV, OH, CO< WY, IN, UT, TN, and Eastern Kentucky coal (11%)
- 13,648,000 tons of coal imported in 2010, an increase of slightly less than 1% from 2009.
- Importation of coal focuses primarily on price, and the heat content and sulfur content of a particular coal.
- Since 1990, electric generation in Kentucky has increasingly utilized higher sulfur coal which can be attributed to the installation of sulfur dioxide scrubbers on coal-fired generators throughout the state.
- In 2010, Kentucky produced 105,007,300 tons coal compared with 2009 (over 107 million tons), production fell 3% and saw 4 fewer counties register production for the year.
- Sulfur dioxide – overall the electric power sector in Kentucky has decreased sulfur dioxide emissions by 72% since 1990. 2009 = 232,401 metric tons.
- Nitrogen oxides – overall the electric power sector of Kentucky has reduced the emission of nitrogen oxides by 75% since 1990. 2009 = 73,900 metric tons
- Carbon Dioxide – Overall the electric power sector of Kentucky has increased carbon dioxide emissions by 29% since 1990. 2009 = 86,155,120 metric tons

http://energy.ky.gov/Documents/Kentucky_Energy_Profile_2011.pdf (24)

East Kentucky Power Cooperative

In 2011, East Kentucky Power Cooperative (EKPC) met the peak demand of their consumers (2,481 MW of electricity to 1.1 million members) through its ability to supply 1,822 MW from coal, 1,032 MW from natural gas and 185.2 MW from renewable energy such as hydropower (25). EKPC is made up of ten plants including the Spurlock Station in Maysville, which generates 1,346 net MW of electricity. East Kentucky's power stations burned 5.44 million tons of coal in 2011(25). The cost of that coal was $2.59 per million BTU - $58.57 per ton. More information can be found in the 2011 East Kentucky Power Cooperative Annual Report - http://www.ekpc.coop/pdfs/EKPC_Annual_Report.pdf.

Based on knowledge gained from EKPC's Jeff Brandt (26), we learned that the Gilbert station burns approximately 930,750 tons coal per year. For their figures, EKPC calculates coal providing 10,000 BTU/lb and switchgrass providing 7,000 BTU/lb. Therefore, Kentucky producers would need to provide 13,296, 39,889, and 132,964 tons of switchgrass to replace 1%, 3%, and 10% of the coal they burn respectively. These substitution goals would mean between 1,662 and 26,593 acres of switchgrass, depending on yield, would need to be planted and harvested.

Tons of Coal Burned in Gilbert Unit 3 Annually	Tons of Coal to be Replaced with Switchgrass on a Heat Input Basis	Tons of Switchgrass Needed	Acres of Switchgrass Needed at 5 tons/acre yield	Acres of Switchgrass Needed at 8 tons/acre yield
930,750	(1%) 9,307.5	13,296	2,560	1,662
930,750	(3%) 27,922.5	39,889	7,978	4,987
930,750	(10%) 93,075.0	132,964	26,593	16,621

Table 3. Tons and acres of switchgrass required to substitute 1%, 3% and 10% of the coal burned in Gilbert Unit 3 of East Kentucky Power Cooperative power station in Maysville, Kentucky

Kentucky can meet the need

Where would this acreage come from? It is commonly suggested that the Conservation Reserve Program be modified to allow land set aside for CRP to be used for bioenergy production (5, 27). In 2011, 14 million acres of Kentucky were classified as farmland. In the area surrounding Maysville, there are 13 Kentucky counties within a 50 mile radius of East Kentucky Power Cooperative, representing a total of 2,154,947 acres. Of that, 3427 acres are in the Conservation Reserve Program and 442,650 acres are currently in hay production (28, 29, 30, 31, 32).

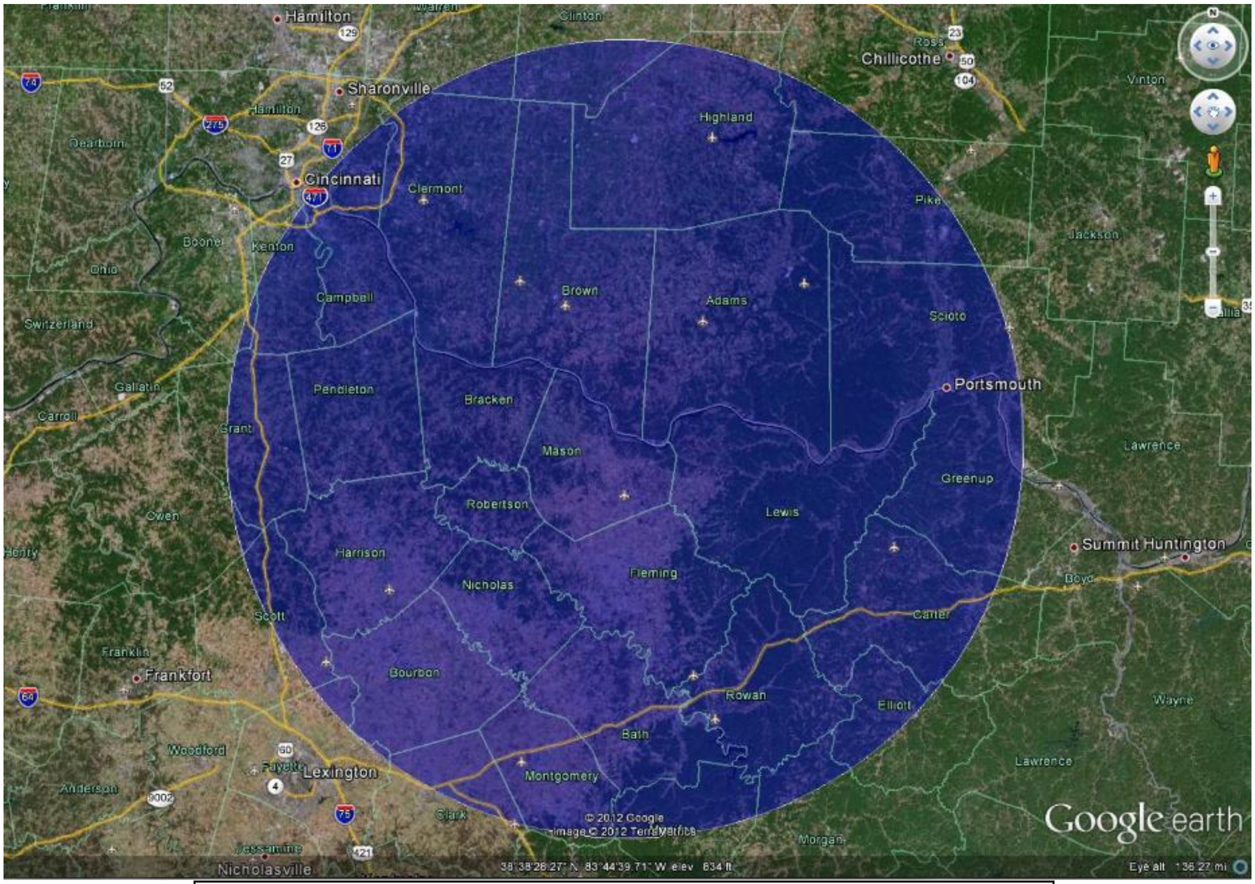


Figure 2. Google Earth image of counties included within a 50 mile radius of Maysville, Kentucky, location of East Kentucky Power Cooperative's Spurlock Station.

Portions of 11 other counties fall within the 50 mile radius of Maysville. Those counties represent a total of 1,967,149 acres and hold an additional 561 acres of CRP land and 126,150 acres of hay (28, 29, 30, 31, 32). Pasture acreage and abandoned land currently in scrub growth could be included as available land for switchgrass production. These numbers are difficult to assess: the Kentucky Agriculture Statistics Service currently does not offer a figure on the number of acres in pasture. One estimate found at www.statemaster.com states Kentucky held approximately 4.423 million acres of pasture in 2004 (33).

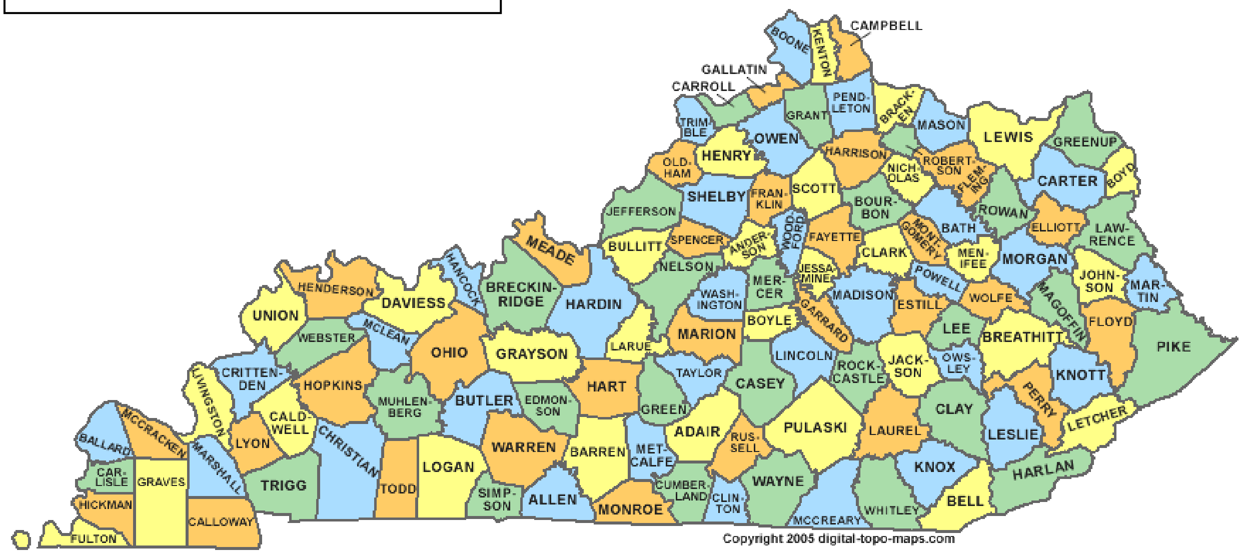
Counties within 50 mile radius of Spurlock Station, Maysville, KY *	Kentucky Total Land Acres - 2011 **	Acres in CRP***	Kentucky Alfalfa Hay County Estimates - 2011 "Acres Harvested" ****	Kentucky All Other Hay County Estimates - 2011 "Acres Harvested" *****
Bath	177,555	150	3,650	24,500
Bourbon	186,567	1,329	6,800	34,300
Bracken	129,856	37	2,520	
Campbell	97,012	30	880	
Fleming	224,493	365	8,500	37,000
Harrison	198,253	311		33,400
Lewis	309,620	49		20,000
Mason	154,227	494	8,400	26,500
Montgomery	127,168	346	2,200	23,100
Nicholas	125,837	162		187,000
Pendelton	179,572	153	2,600	
Robertson	64,231	1	1,000	8,500
Rowan	180,556	0	500	11,300
Total	2,154,947	3,427	37,050	405,600
Counties partially falling within 50 mile radius of Spurlock Station, Maysville, KY	**Kentucky Total Land Acres - 2011**	**Acres in CRP**	**Kentucky Alfalfa Hay County Estimates - 2011 "Acres Harvested"**	**Kentucky All Other Hay County Estimates - 2011 "Acres Harvested"**
Boone	157,280	33	2,200	
Carter	260,410	8		12,500
Clark	163,309	196	2,300	30,000
Elliott	149,895	0		7,650
Fayette	182,240	216	2,850	17,500
Grant	165,971	3	3,000	
Kenton	104,409	24		
Menifee	130,092	9		5,300
Morgan	244,544	0		12,200
Owen	226,272	37	3,600	
Scott	182,727	38	3,750	23,300
Total	1,967,149	564	17,700	108,450

Table 4. Land in CRP & Hay Production in Counties within a 50 Mile Radius of Maysville, Kentucky

* Google Earth (28)
** National Agriculture Statistics Service, Kentucky Land and Water Acres by County – 2011, Released: April 12, 2012 (29)
*** Source: USDA – The conservation Reserve Program – 41st sign-up Sept 2011 County by County Summary (30)
**** National Agricultural Statistics Service, Kentucky Alfalfa Hay County Estimates – 2011, Released: April 12, 2012 (31)
***** National Agricultural Statistics Service, Kentucky All Other Hay County Estimates – 2011, Released: April 12, 2012 (32)

For the sake of this discussion, Kentucky counties within a 50 mile radius around EKPC in Maysville, Kentucky were considered. Other Kentucky counties along the Ohio River corridor could provide biomass to the power plant very easily because of the well-established barge system. As you can see in this map, there are 29 counties that border the Ohio River, and many others that are very near it. Kentucky farmers could easily provide enough biomass to supply energy plants with a significant portion of their electricity output.

Figure 3. County Map for Kentucky. Copyright 2005. Digital-topo-maps.com



Switchgrass production costs and break-even prices

The University of Kentucky has addressed switchgrass production costs through the **Switchgrass vs Hay Comparative Budgets,** an interactive spreadsheet developed by Dr. Ray Smith and Dr. Greg Halich to aid producers considering growing switchgrass in lieu of, or in addition to hay (34).

> *Switchgrass vs. Hay Comparative Budgets (2010).* (MS Excel) April 2010.
>
> This decision tool has been created to help budget for switchgrass biofuel/bioenergy production and to compare the profitability to hay production (both with either large round or large square bales). This evaluation is analyzed over multiple years (10-30 years specified by the user) and includes establishment costs for the switchgrass stand.
>
> http://www.ca.uky.edu/agecon/index.php?p=150

Figure 4. View of "Main Page" of the interactive spreadsheet from Dr. Ray Smith and Dr. Greg Halich of the University of Kentucky College of Agriculture ***Switchgrass vs Hay Comparative Budgets 2010.***

Switchgrass vs. Hay Profitability Analysis - Main Parameters			Financial Analysis (per acre)			
Switchgrass:		**Instruction/Description:**	**Year**	**Stand Deterioration %**	**Revenue Switchgrass**	**Net Revenue Hay**
Bale Weight and Type	1200 lb (Round Bale)	Choose round or square bales at 15% Moisture	1	0%	-$246	$27
Price ($/ton delivered)	$64	Final price received for switchgrass (delivered)	2	0%	-$31	$27
Trucking Cost ($/ton)	$12	See "Machinery" worksheet	3	0%	$74	$27
Storage Cost ($/ton)	$0	See "Other Costs" worksheet	4	0%	$74	$27
Net Price after Trans and Storgage ($/ton)	$53	Net price received after deducting trucking and storag	5	0%	$74	$27
Yield Year 1 (tons/acre)	1.0	Yield expected with good establishment (15% moistur	6	0%	$74	$27
Yield Year 2 (tons/acre)	2.5	Yield expected with good establishment (15% moistur	7	3%	$70	$27
Yield Year 3 (tons/acre)	6.0	Average yield at peak production (15% moisture)	8	6%	$66	$27
Cutting Schedule	Once per Year	Choose once or twice per year	9	8%	$63	$27
Years Evaluated (stand age)	15	Choose 10, 15, 20, 25, or 30 years	10	11%	$59	$27
Stand Deterioration (Year this Starts)	7	Year yields begin to decline (5-10 or none)	11	14%	$56	$27
Stand Deterioration - % Full Prod in Final Yea	75%	% of full production in last year of analysis	12	17%	$52	$27
Probability Stand Re-plant 2nd Year	25%	Probability you will have to replant stand in Year 2	13	19%	$49	$27
Nitrogen (units applied at full production)	60	Enter "units" here and not lbs of product	14	22%	$45	$27
Nitrogen ($/unit)	$0.40	Enter price per "unit"	15	25%	$42	$27
Phosphorus (P_2O_5) ($/unit)	$0.30	Enter price per "unit"				
% Phosphorus Replaced vs. Removed	75%	Switchgrass and Hay - See "Other Costs" worksheet				
Potassium (K_2O) ($/unit)	$0.40	Enter price per "unit"				
% Potassium Replaced vs. Removed	75%	Switchgrass and Hay - See "Other Costs" worksheet				
Cost Share Establishment (Payment/acre)	$0	Enter any cost-share payments for establishment				
Gov't Payment for Switchgrass Production?	$/Acre	Enter only if paid directly to producer ($/Acre or $/Tor				
$/Acre	$0.00	Enter $/Acre or $/Ton as appropriate				
Discount Rate (see note below)[1]	5.0%	Should exclude inflation, see below note for details				
Hay:						
Hay Price ($/ton)	$80	Final price received for hay				
Trucking Cost ($/ton)	$7	Deduct trucking if this applies (see "Machinery Costs"				
Storage Cost ($/ton)	$0	Deduct storage cost if this applies (see "Other Costs"				
Net Price after Trans and Storgage ($/ton)	$73	Net price received after deducting trucking and storag				
Yield - Entire Year (tons/acre)	3.0	Average total yield with all cuttings (15% moisture)				
Cuttings (fractions allowed)	1.8	Average number of cuttings (e.g. 1.8 allowed)				
Phosphorus (P_2O_5) and Potassium (K_2O)		Same prices and % of removal as switchgrass				

This tool allows a producer to review the affordability and profitability of producing switchgrass by inputting costs and income figures to assess the ***NPV (Net Present Value) Advantage for Switchgrass.*** For example, at a third year yield of 6 tons per acre, the decision tool shows no advantage for growing switchgrass, but when the third year yield is changed to 8 tons/acre, the NPV Advantage equals $337.00, and a third year yield of 10 tons shows an even greater advantage at $673.00. These are just examples, however, and a producer would need to evaluate many aspects of the production of switchgrass to get a more accurate summary for his/her situation.

In the 2009 UK publication *Switchgrass for Biomass* this table shows a comparative budget for switchgrass and hay production:

COMPARATIVE BUDGET SUMMARY FOR SWITCHGRASS AND HAY (PER ACRE)

	Switchgrass Year 1 Production	**Switchgrass Full Production (Years 3 to 6)**	**Hay Production**
Yield	0.75 T per acre	6 T per acre	3 T per acre
Price per ton	$65	$65	$75
Total Returns	**$49**	**$392**	**$225**
Variable Costs			
Production	$234	$134	$119
Labor	$11	$34	$24
Trucking and Loading	$9	$69	$0
Total Variable Costs	**$254**	**$237**	**$143**
Returns Above Variable Costs	**($205)***	**$155**	**$82**
Total Fixed Costs	**$41**	**$75**	**$45**
Total Variable + Fixed Costs	**$295**	**$312**	**$188**
Returns Above Variable + Fixed	**($246)**	**$80**	**$37**

**Parentheses indicate a negative number, i.e. a net loss*

Figure 5. Table from 2009 UK publication “Switchgrass for Biomass” showing example of budget for switchgrass production.

For the purpose of this figure, transportation costs were calculated at $11.00/ton at a distance of 50 miles (35). Because the initial year is the establishment year, there is a negative return. In this scenario, it would take five years for switchgrass to become profitable and overcome the initial investment of establishment. As you can see from the “Summary Budgets” page of the **UK Switchgrass vs Hay Comparative Budgets** spreadsheet, estimated establishment costs are $294.00/acre:

Comparative Budgets, Per Acre Costs and Returns for Switchgrass and Hay

	Switchgrass Year 1 Production		Switchgrass Year 2 Production		Switchgrass Full Production (Years 3-6)		Hay Production	
	Quant.	Cost / Revenue	Quant.	Cost / Revenue	Quant.	Cost / Revenue	Quant.	Cost / Revenue
Gross Returns Per Acre								
Yield per Cutting (tons at 15% moisture)	0.75		2.13		6.00		1.67	
Cuttings	1.0		1.0		1.0		1.8	
Total Yield/acre (tons)	0.75		2.13		6.00		3.00	
Bale Weight (lbs)	1200		1200		1200		1200	
Price per Ton (15% Moisture)		$64		$64		$64		$80
Total Revenue - Crop		$48		$137		$386		$240
Government Payments		$0		$0		$0		
Total Revenue		$48		$137		$386		$240
Variable Costs Per Acre								
Seed (lbs)	7.0	$105	1.8	$26	0.0	$0	2.7	$8
Nitrogen (units)	0	$0	21	$9	60	$24	0	$0
Phosphorous (P_2O_5 units)	40	$12	0	$0	19	$6	41	$12
Potassium (K_2O units)	80	$32	0	$0	57	$23	113	$45
Lime - Delivered and Spread (tons)	0.5	$10	0	$0	0.2	$4	0.2	$4
Herbicides Applications (product only)	4.0	$40	1.0	$18	0.2	$2	0.2	$2
Fuel and Lube		$11		$15		$34		$22
Repairs and Supplies		$19		$18		$36		$22
Labor		$11		$15		$34		$24
Trucking and Loading Costs		$9		$25		$70		$21
Other Variable Costs		$2		$2		$2		$2
Operating Interest		$3		$2		$3		$3
Total Variable Costs Per Acre		$253		$129		$237		$165
Total Variable Costs Per Ton						*$46*		*$55*
Return Above Variable Costs Per Acre		-$205		$8		$149		$75
Fixed Costs Per Acre								
Machinery Depreciation/Overhead		$38		$36		$72		$45
Storage		$0		$0		$0		$0
Other Fixed (Taxes, Insurance, Etc.)		$3		$3		$3		$3
Total Costs Per Acre (variable + fixed)		$294		$168		*$312*		$213
Total Costs Per Ton						*$52*		*$71*
Return Above Variable and Fixed Costs		-$246		-$31		$74		$27

Note: Land value (opportunity cost of land) is not accounted for in this analysis. Yields for switchgrass and hay assuming 15% moisture level

Figure 6. Summary page from UK decision aid "Comparative Budgets for Switchgrass vs Hay" showing estimated cost per acre for establishing switchgrass.↑

Figure 7. Table from Iowa State University's publication "Estimated Costs for Production, Storage and Transportation of Switchgrass" showing estimated costs of establishing switchgrass. →

Table 1. The estimated costs of establishing the switchgrass, presented in dollars per acre.

Land charge			**$80.00**
Preharvest machinery operations custom charges			
Disk			$9.45
Harrow			6.25
Airflow spreader (seed and fertilizers)			7.70
Spraying chemicals			5.15
Total			**$28.55**
Operating Exp.	**Price/unit**	**Units**	
Seed	$7.50/lb	6	$45.00
Fertilizer			
P	$0.37/lb	30	11.10
K	$0.23/lb	40	9.20
Lime	$21/ton	3	63.00
Herbicides			
Pursuit +	$53/gal	3 oz	1.24
MSO	$1.75/pt	32 oz	3.50
2,4D	$16/gal	1.5 pts	3.00
Total operating costs			**$136.04**
Total establishment			**$244.59**
11 years at 8% amortization (.14008 factor)			
Prorated yearly establishment Cost per acre			**$34.26**

Similarly, Iowa State University found switchgrass establishment costs to be $244.59/acre (36).

What would be an acceptable yield and price per ton for switchgrass to become profitable for producers?

In *Assessment of Business Case for Purpose-Grown Biomass in Ontario* (March, 2012) the needed price for switchgrass bales is $135.7/tonne ($126.03 USD/ton). The establishment cost of switchgrass is $424.5/acre ($434.48 USD/acre), and the mature yield is estimated at 4.3 tonne/acre (4.7 tons/acre). (*Note the average yield in Kentucky is six tons/acre.) That would be equivalent to a payment to the producer of $592.34/acre - $202.34/acre more than the proposed budget from the University of Kentucky displayed above. The Western University Research Park, who wrote the report mentioned above, suggests a decrease in the establishment cost by $100/acre (CAD) to reduce the acceptable price of switchgrass at farm gate by approximately $5/tonne. Below is their budget sheet for switchgrass production (14):

Figure 8. "Economics of Switchgrass Production" from *Assessment of Business Case for Purpose-Grown Biomass in Ontario.* March, 2012

Table 1.3 Economics of Switchgrass

	Yr-1	Yr-2	Yr-3	Yr-4	Yr-5	Yr-6	Yr-7	Yr-8	Yr-9	Yr-10	Yr-11	
Yield (tonne/acre)	0.0	1.0	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	
Price of biomass ($/tonne)	135.7	135.7	135.7	135.7	135.7	135.7	135.7	135.7	135.7	135.7	135.7	
Revenue ($/acre)	0	135.7	583.51	583.51	583.51	583.51	583.51	583.51	583.51	583.51	583.51	
Net income from cover crop in Year-1 ($/acre)	95											
Variable cost items ($/acre)												
Seed	135.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Fertilizer	25.0	45.0	45.9	46.8	47.8	48.7	49.7	50.7	51.7	52.7	53.8	
Herbicides	48.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Crop insurance	9.0	9.2	9.4	9.6	9.7	9.9	10.1	10.3	10.5	10.8	11.0	
Custom work (seeding, applications, harvesting, bailing)	18.0	50.0	84.0	85.7	87.4	89.1	90.9	92.7	94.6	96.5	98.4	
Fuel and lubricants	11.0	11.2	14.0	14.3	14.6	14.9	15.2	15.5	15.8	16.1	16.4	
Equipment repair and maintenance	12.0	12.2	12.5	12.7	13.0	13.2	13.5	13.8	14.1	14.3	14.6	
Labour	13.0	13.3	15.0	15.3	15.6	15.9	16.2	16.6	16.9	17.2	17.6	
Interest on operating capital	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	
Storage and handling	0.0	20.0	35.0	35.7	36.4	37.1	37.9	38.6	39.4	40.2	41.0	
Other variable costs	3.0	4.0	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.9	
Sub-total variable costs	286.5	189.4	233.2	237.6	242.1	246.7	251.4	256.2	261.1	266.1	271.1	
Fixed cost items ($/acre)												
Depreciation	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	
Land cost	100.0	102.0	104.0	106.1	108.2	110.4	112.6	114.9	117.2	119.5	121.9	
Interest on term loan	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	
Other fixed costs	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.9	6.0	6.1	
Sub-total fixed costs	138.0	140.1	142.2	144.4	146.7	148.9	151.2	153.6	156.0	158.5	161.0	
Gross margin (Revenue - Variable costs) $/acre	-191.5	-53.7	350.3	345.9	341.4	336.8	332.1	327.3	322.4	317.5	312.4	
Net margin (Gross margin - Fixed costs) $/acre	-329.5	-193.8	208.0	201.4	194.7	187.8	180.8	173.7	166.4	159.0	151.4	
Average gross margin ($/acre/yr)												249.2
Average net margin ($/tonne)												27.7
Average net margin ($/acre/yr)												100.0

(Note: Indian grass, big blue stem, Canadian rye and other monoculture tall grasses have similar establishment costs and yields)

Landers, et al. (2012) found in their study that breakeven prices for two switchgrass cultivars in the midwest ranged from US$65 ($58.98/ton) on marginal, eroded soils to US$124/Mg ($112.52/ton) on soils with >27 cm of topsoil. Breakeven yields with a biomass price of US$40/Mg ($36.30/ton) would require yield increases of up to 450% for lower yielding cultivars (7). Landers, et al. (7) cited several studies regarding farm-gate prices for switchgrass:

(a) in 2008, researchers in Iowa found switchgrass production costs alone reach US$90/Mg ($81.67/ton) with a yield of 8.96 Mg/ha (4 tons/acre)

(b) in Tennessee in 2009, the breakeven prices for Alamo switchgrass under a 10-yr contract ranged from US$46 to US$69/Mg ($41.74 - $62.61/ton) with an average yield of 17.7 Mg/ha (7.89 ton/acre)

(c) in a study conducted on ten farm sites from southern Nebraska to North Dakota in 2008 estimated farm-gate breakeven prices for switchgrass to be approximately US$59/Mg ($53.54/ton) at an estimated yield of 7 Mg/ha (3.12 ton/acre)

(d) in the Great Lakes region in 2010 estimated the breakeven price required for switchgrass to compete with continuous corn (US$138/Mg = US$125.23/ton) to be US$115/Mg (US$104.36/ton) with an assumed yield of 9 Mg/ha (3.64 ton/acre)

(e) researchers in Illinois in 2008 determined the farm-gate breakeven price and yield for switchgrass to be US$98/Mg ($88.93/ton) and 9.4 Mg/ha (4.19 ton/acre), respectively, when including the opportunity costs associated with a corn-soybean rotation (7).

In 1996, Epplin found the estimated cost to produce, harvest, load and transport 1 dry megagram of switchgrass 64 km to a conversion facility was $37.08/Mg for an assumed yield of 9 dry Mg/ha (37). Of that cost, approximately 14% was for establishment, 22% for land, 32% for stand maintenance and harvesting, and 32% for loading and transportation (37).

Conversion Table

Mg (megagram) or Tonne (metric ton) to U.S. Ton

1 Mg = 1.102 U.S. Short Tons

Ha (hectare) to Acre

1 Ha = 2.471 Acres

Canadian dollar to US dollar

1 CAD = 1.0235 USD (9/22/12)

Iowa State University published an Extension Service article entitled "Estimated Costs for Production, Transportation and Storage of Switchgrass" in which they determined the cost of producing switchgrass to be $113.66 per ton (36).

Table 6 shows the total estimated costs for switchgrass. This includes production, storage and transportation.

Table 6. Total costs for switchgrass.

Production	$82.23
Storage	16.67
Transportation to storage	6.10
Transportation to plant	8.65
Total cost per ton	$113.66

Figure 9. *Total Costs for Switchgrass* from Iowa State University's publication "Estimated Costs for Production, Storage and Transportation of Switchgrass"

Through the University of Kentucky's Switchgrass vs. Hay Profitability Analysis tool, one can determine an estimated farm-gate price for switchgrass production   Table 5 displays several scenarios one might consider when determining the break-even cost for producing switchgrass in Kentucky:

Farm-gate Price for Switchgrass for Biomass Production in Kentucky			
Production Length	Farm-gate price when producer absorbs all the costs	Farm-gate price when producer receives assistance through EQIP for establishment price of $225.00/Acre	Farm-gate price when no P & K are added at establishment
5 years	$70 – 71/ton	$55 – 56	$65 – 66
10 years	$58 – 59/ton	$51 – 52	$56 - 57

Table 5. Estimated farm-gate price for switchgrass in Kentucky based on UK's Switchgrass vs. Hay Profitability Analysis Tool.   Fertilizer prices were adjusted to reflect February 18, 2013 prices: N = $0.608/unit, P = $0.795/unit, K = $0.45/unit (per conversation with local Southern States store 2/18/13)

Summary of Research Trials Listing Break-even Farm-gate prices and yields for Switchgrass for Biomass from Landers, et al. and Epplin			
Year of Study	**Location**	**Yield**	**Break-even Farm-gate price**
2012	Missouri	450% increase required	$65/Mg - $124/Mg or $58/98/ton - $112.52/ton
2010	Great Lakes region	9 Mg/ha or 3.64 ton/A	$115/Mg or $104.36/ton
2009	Tennessee	17.7 Mg/ha or 7.89 ton/A	$46/Mg - $69/Mg or $41.74/ton - $62.61/ton under 10 year contract
2008	Iowa	8.96 Mg/ha or 4 ton/A	$90/Mg or $81.67/ton
2008	Southern Nebraska to North Dakota	7 Mg/ha or 3.12 ton/A	$59/Mg or $53.54/ton
2008	Illinois	9.4 Mg/ha or 4.19 ton/A	$98/Mg or $88.93/ton
1996	Oklahoma	9 Mg/ha or 4.01 ton/A	$37.08/Mg or $33.65/ton

Table 6. Summary of Research Trials Listing Break-even Farm-gate prices and yields for switchgrass fro Biomass from Landers, et al, & Epplin.

One possible way to offset the cost and loss of income in the establishment year is to plant the switchgrass with corn. Landers, et al. mentions a 1998 study showing no negative effect on corn yield or switchgrass plant density (7). Another group in Canada noted that an Ontario farm had success co-seeding spring wheat with switchgrass at establishment (9). It is also anticipated that yield levels will increase significantly in the near future as more research is performed on switchgrass varieties and production methods (9, 38)

Incentives that may help

Perhaps subsidies will help those interested in producing switchgrass, or other forms of biomass, for energy. The feasibility study that was compiled for Bracken County, Kentucky producers pointed out three resources that may be useful (2):

1. ***Kentucky Agricultural Development Fund:*** *The Kentucky Agricultural Development Fund provides incentives for innovative proposals that increase net farm income, stimulates markets for Kentucky agricultural products, creates new opportunities for Kentucky farmer.*
2. ***Kentucky Agricultural Finance Corporation:*** *The Kentucky Agricultural Finance Corporation provides capital access for agricultural diversification and infrastructure projects.*
3. ***Kentucky Investment Fund Act (KIFA):*** *KIFA provides tax credits to individuals and companies that invest in approved venture capital funds. Investors in KIFA approved funds are entitled to a 40% credit against Kentucky individual or corporate income tax or Kentucky corporate license tax. KEDFA approves investment funds and fund managers.*

On a national level, there is the Biomass Crop Assistance Program (BCAP). *BCAP provides incentives to farmers, ranchers and forest landowners to establish, cultivate and harvest biomass for heat, power, bio-based products and biofuels* (10). The United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS) offers several programs including the Environmental Quality Incentives Program (EQIP) which pays for the establishment of native grasses (39).

The process of processing

HARVESTING Once a stand of switchgrass has been established a producer can begin to harvest, sometimes during the first year, though not at maximum yield, but certainly in the second year. Typically, switchgrass for biomass is harvested once each year. It can be cut after a killing frost and can be baled once the moisture is low enough 8 – 15% (9, 40). Some favor letting the cut grass lay on the field over winter to allow nutrients to leach back into the soil and reduce the ash content of the biomass when burned with coal for electricity (8, 9). Over-wintering can result in yield losses up to 25% - 33% (8). Normally, a producer bales the grass once it reaches the desired moisture, however some have experimented with dry-chopping the grass directly from the windrow (38). Many studies have been done regarding the best type of bale to use: large square and round bales are the most common. The choice of round bales or large square bales is influenced by the hay equipment on-hand, cost of a new baler (the price for a new large square baler can range from $65,000 to $100,000) (2), storage available for the bales and the system available for processing the biomass.

Arguments for round bales include the fact that many farmers already own that type of equipment (2) and, if being stored outside, shed water better than square bales (38, 41). Arguments against large round bales are the difficulty in loading and hauling them because they tend to lose their shape, especially when stored outside, and they can have an inconsistent bulk density which may affect processing (38).

The advantages of large square bales are their ease of handling throughout the process – taking them off the field, putting them on the truck, and hauling them. Depending upon the biomass processing system, they may also fit onto a conveyer better and offer a more consistent bulk density for grinding. However, a large square baler is an expensive investment and because square bales don't shed water, they should be stored outside under tarps or inside – another expense for those who don't already have adequate storage.

Twine and netting also need to be considered. Some biomass grinders can grind bales bound in sisal twine without removing the string according to Randy Baerg of Warren and Baerg and Nate Eskeland of CBI. Nylon twine and netting must be removed – an added step in the biomass processing system.

STORAGE There are many storage options for switchgrass bales for biomass: outside with no cover, outside with cover, storing on a gravel or pallet base, storing directly on the ground, or under-roof. All come with a cost, be it a percentage of loss due to weather or the expense of a new structure in which to house the material. Sokhansanj, et al. mentions a study where round bales were stored in Wisconsin under different scenarios. "Dry bales stored outdoors for 9 and 11 months averaged 3.4, 7.7, 8.3 and 14.9% dry matter loss for bales wrapped with plastic film, net wrap, plastic twine, and sisal twine respectively. Bales stored indoors averaged 3% dry matter loss. Preservation by ensiling bales in a tube of plastic film produced average dry matter losses of 1.1% (38)."

Larson, et al. estimated dry matter loss for storing a rectangular bale of switchgrass outdoors and covered with a tarp to be 30% after 360 days in storage under Tennessee conditions. They compared this to the estimated dry matter losses for round bales wrapped with twine and stored outside with and without a tarp were 9% and 13% after 360 days in storage (41).

During the initial years of the UK switchgrass trial, it was discovered that damp to wet material did not feed well through EKPC's system, therefore, dry storage would be key for processed material. Kentucky Steel Buildings, Panel and Supply, LLC of Winchester, Kentucky offers a 75' (W) x 240' (L) x 20" (H) building with vapor lock for $100,000.00. Iowa State University estimates a building cost of $12/square foot or $16.67/ton (42).

Table 4. Storage.	
Building costs $12 per square foot	**$360,000**
Yearly costs:	
Land, 2 acres	$160
Building: yearly ownership cost at 12%	$43,200
Storage cost per ton	**$16.67**

Figure 10. Storage costs from Iowa State University's publication "Estimated Costs for Production, Storage and Transportation of Switchgrass" (36)

Other economical ways to store under-roof may be a metal pole structure or a hoop structure. Virginia Extension offers comprehensive information about pole barns and hoop structures in the publication *Hay Storage Alternatives – Barns*. Below is a table from that publication stating the annual costs of storing hay in a hoop barn to be $15.61/ton and in a pole barn to be $18.41/ton (43).

Table 2: Per ton costs	Hoop Barn
1. Total investment (Table 1, Line 8)	$16,997
2. Interest rate (i)	0.05
3. Number of periods (n) years	20
4. Capital recovery factor =	0.0802
5. Annual cost recovery = Line 1 * Line 4	$1,364
6. Ins, Taxes, & Repairs = Line 1 * 3%	$510
7. Annual costs = Line 5 + Line 6	$1,874
Costs per ton (Line 7 ÷ Table 1, Line 11)	$15.61

Figure 11. Comparison between cost of hoop st Virginia Extension publication *Hay Storage Alter*

TRANSPORTATION For this paper we are assuming $11.00/ton for trucking and approximately $1.00 per 50 river miles. Iowa State University offers these numbers for transportation and hauling →

Figure 12. Transportation and handling costs from Iowa State University's publication "Estimated Costs for Production, Storage and Transportation of Switchgrass" (36)

Table 5. Transportation and handling costs.	
Field to storage costs:	
5 miles to storage at 25 miles per hour:	
Truck costs	
Load .5 hour; unload .33 hour, travel .4 hour	
1.23 hours x $70	$86.33
Loader costs (labor, tractor and fuel)	
($12 + $20 + $10.78 = $42.78/hour)	
0.83 hours x 42.78	$35.65
Total hauling cost to storage	**$121.98**
Transportation to storage cost per ton	**$6.10**
Storage to plant costs:	
30 miles one-way to plant at 45 MPH	
Plant will do the unloading at their cost	
Truck Costs	
Load .5 hour, unload .33 hour, travel 1.33 hour	
2.16 hours x $70	$151.67
Loader costs (labor, tractor and fuel)	
($20 x $10.78 x $12 = $42.78/hour)	
0.5 hour x $42.78	$21.39
Total hauling cost to plant	**$173.06**
Transportation to plant cost per ton	**$8.65**

GRINDING & PELLETING There are several options to consider when planning this portion of the system. Grinding and pelleting equipment are the most costly investments in the process of providing biomass to an energy utility company for co-firing with coal. The University of Kentucky currently has a portable system using a tub grinder and two briquetters from Biomass Briquette Systems, LLC (http://www.biomassbriquettesystems.com/) which are mounted on a trailer. The tub grinder is PTO-operated. The briquette machines operate on electricity. At an output capacity of 800 lb/hour, this system is but a proto-type model of what would actually need to be in place for a large scale, more permanent situation.

Figure 13. Switchgrass round bales stored outside under tarps.Picture by Lee Carol Greenwell, 2012.

Figure 14. Tub grinder used by University of Kentucky to grind switchgrass for biomass. Picture by Lee Carol Greenwell, 2012.

Figure 15. Ground switchgrass ready to feed onto conveyors for densification. Picture by Lee Carol Greenwell, 2012.

Figure 16. University of Kentucky's switchgrass processing equipment includes a tub grinder, tractor with front-end loader, two conveyors, and two briquetters mounted to a trailer. Photo by Dr. Ray Smith, 2012.

Figure 17. Conveyors take ground switchgrass to briquetters mounted on a trailer. Photo by Dr. Ray Smith, 2012.

Figure 18. Briquetters from Biomass Briquette Systems, LLC. Photo by Lee Carol Greenwell, 2012.

Figure 19. PVC pipe offers a way to move switchgrass briquettes from densification to the trailer used to haul fuel pucks to East Kentucky Power Cooperative in Maysville, Kentucky. Photo by Dr. Ray Smith, 2012.

Briquette quality, which is a reflection of the size and moisture content of the ground material, has been a focus for the staff at UK during the operation of this set-up. Whether processing bales on the farm or at the plant, moisture content should be around 10 – 15% for the best outcome (40). Drying wet material, therefore, can be an added expense to the process.

Figure 20. Switchgrass briquettes exiting the densification process. Ready to make electricity! Picture by Lee Carol Greenwell, 2012.

Figures 20 & 21. Switchgrass briquettes, sometimes called fuel pucks, from UK's densification process. The briquettes are approximately 3 inches in diameter and are 2 – 3 inches long. Photos by Lee Carol Greenwell, 2012.

UK's model offers one alternative in the processing phase: a portable grinder and briquetter that could come to a place to service one or several farms in the area. One portable grinder is the 5800T Grinder from Continental Biomass Industries, Inc. located in Newton, New Hampshire. This model can be mounted onto a trailer for portability or can be stationary. It can operate on fuel or electricity. For briquette quality, it can produce a ground material down to 1 inch at a rate of 50 tons/hour according to CBI U.S. sales representative Nate Eskeland. The portable version of this grinder would cost $625,000.00 (44).

Figure 22. Continential Biomass Industries, Inc. 5800T Grinder – trailer mounted. Picture courtesy of CBI, Inc.

Perhaps a portable grinder would not need to be this large, which could reduce the cost somewhat. During the UK biomass project, it is estimated that it cost $25,000.00 to grind 392 tons of switchgrass over the five-year period. A briquetter such as the ones being used by UK would cost $71,000.00. Once ground and/or pelleted, material could be trucked directly to the power plant or to a central storage location. An advantage to this system is in transportation. Pellets are easier to haul than loose, ground biomass and one can haul nearly twice as much preprocessed switchgrass compared with traditional round bales (41).

A stationery system could be located either off-site from the power plant or at the plant itself. Land would need to be purchased in an off-site scenario. Grinding, briquetting, storing, hauling and labor would all need to be considered. Loading equipment as well as the installation of utilities would be additional expenses. The same CBI grinder mentioned above in a more stationery configuration would cost $570,875,000 (44).

Figure 23. Continental Biomass Industries, Inc. 5800T Grinder. Picture courtesy of CBI, Inc.

Warren and Baerg Manufacturing, Inc is a company located in Dinuba, California. They offer a complete grinding and briquetting system that could meet our goals of 1%, 3% and 10% coal substitution with biomass. As proposed by Randy Baerg, a single grinding and cubing system could operate at a capacity of 12,672 tons per year at 6 tons/hour, 8 hours/day, 22 days/month, 12 months/year. At these rates, a dual system could process 25,344 tons/year, and so on. A single grinding system would cost $358,354.00; a single cubing system would cost $600,379.00 and a dual cubing system would be $903,442.00 (45). (All Warren & Baerg figures are to California.)

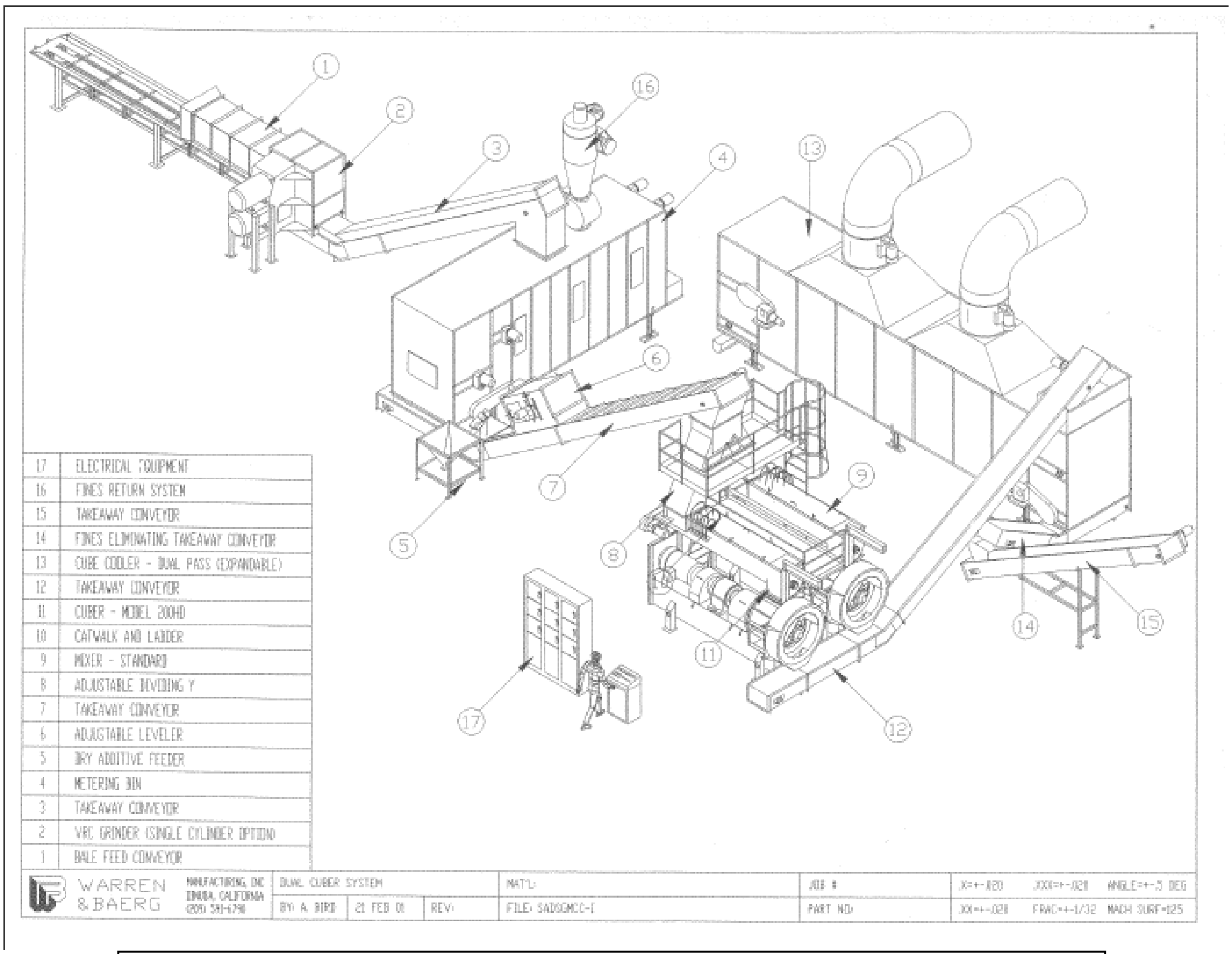


Figure 24. Configuration of a dual cubing system from Warren & Baerg Manufacturing, Inc.
Image courtesy of Warren & Baerg Manufacturing, Inc.

For a stationary system, a building would be required. Larson, et. Al. suggested the cost of a building large enough for the equipment and storage for two days of chopped material (For their situation a total of 329,000 tons of switchgrass was needed, therefore two-days' storage was 1802 tons.) was estimated to be $596,942.00 (41). For our purposes, two days' worth of material would be 73 tons at 1%, 219 tons at 3% and 729 tons at 10% substitution of coal burned at EKPC.

One way to reduce costs would be to locate the processing of the switchgrass at the plant. If pelleting were still to be part of the process, the cost and time of hauling the material to the plant would be eliminated here. Even more cost reductions could be seen by doing away with the pelleting/briquetting and feeding ground biomass directly into the units to be co-fired with coal. This would require

1. Material Unloading Facility
2. Processing Facility
3. Processed Material Storage
4. Pneumatic Feed System

Others have looked into the costs of processing switchgrass for biomass and found a wide range of figures covering all aspects of purchasing, building and processing. The Western University Research Park in Canada found that it would cost $15 million (CAD) to build at pellet mill at 150,00 tonne/year capacity. (9) Larson, et. al. estimated the cost in 2010 for an industrial compactor to be $1.4 million (41). The ShowMeEngery Cooperative in Centerview, Missouri invested approximately $7 million in their plant that processes nearly 100,000 tons of biomass per year (4). John Solow, et. al. at the University of Iowa Center for Global and Regional Environmental Research assumed for the Chariton Valley Biomass Project an initial investment of $1.75 million (6).

LABOR, MAINTENANCE, OTHER COSTS Labor, maintenance and other expenditures will need to be considered in the final analysis of the actual costs to establish an infrastructure for providing biomass to power-generating plants. Insurance, depreciation, wages, land purchase, taxes, etc. can add to the initial price tag. In addition to the $1.75 million investment, the Chariton Valley Biomass Project in Iowa reported labor costs of $375,000.00 and $306,178.00 operating costs annually (6).

Current value of switchgrass

What is the current value of switchgrass already established? This question could be answered in the form of added value in beef production. Several of the farmers who participated in the switchgrass trial from 2007 – 2011 are utilizing the crop in their cattle operations. Because switchgrass is a warm-season perennial, it typically begins to reach optimum forage output as cool-season grasses like fescue are dropping in production. With proper management, switchgrass can play a complimentary role in a rotational grazing system for cattle. A Nebraska study showed 2.2 lb/head/day average daily gains and 500 pounds of beef gained per acre when grazing “Trailblazer” switchgrass (47). The same Nebraska group stated that pastures stocked on a rotational schedule can provide 10 to 60 percent more animal days of grazing (depending upon certain factors) (47). Should a grower want to utilize switchgrass for hay, the same holds true – the timing of the plant’s growth allows a farm to harvest more hay during a period when production would be lower in cool-season fields. The University of Tennessee has found when switchgrass is grown for forage, it can produce up to two times that of a tall fescue field per acre (48). The quality of switchgrass as a forage for cattle is dependent upon growth stage and careful management practices. Switchgrass should be grazed before producing seedheads to maintain palatability and nutritive quality. It should not be grazed below 8 – 12 inches to sustain stand vigor (49). According to the International Plant Nutrition Institute (IPNI) Forage Crop Pocket Guide, switchgrass offers a quality feed (from IPNI Table 33b) (50):

Excerpt from IPNI Forage Crop Pocket Guide Table 33b. Total digestible nutrients (TDN) and relative feed value (RFV) for various forage crops			
		TDN	RFV
Tall fescue, orchardgrass	Vegetative – Boot	61-66	101-122
	Boot – Head	59-66	81 – 105
Switchgrass, Caucasian bluestem	Vegetative – Boot	58 – 62	90 – 104
	Boot – Head	50 – 58	62 - 90

Table 7. Excerprt from IPNI Forage Crop Pocket Guide describing TDN and RFV for common cool-season grasses in Kentucky and warm-season grasses well-adapted to Kentucky.

Producers are ready if and when a biomass market develops. In the meantime their cattle are gaining weight and making money for the producers that were proactive to establish switchgrass on their farms. Certainly, their neighbors are taking notice of this "new" low-input, drought-tolerant, quality feed.

Other potential uses for switchgrass

Switchgrass has branched into other markets besides the two discussed above: electricity for the public sector and forage for cattle. Roger Samson of REAP – Canada (Resource Efficient Agricultural Production) summarized many used for switchgrass in his presentation "Developing Market Opportunities for Warm Season Grasses in Ontario" (51):

1. Bedding for cattle – Switchgrass seems to absorb as well as wheat straw and hold up better as bedding for dairy cattle.
2. Straw Bale Housing – As a composite, Canadians have used switchgrass for housing materials. There are approximately 15 houses constructed of this material in Canada.
3. Heating fuel for commercial and industrial boilers – Grass briquettes and cubes are well-suited for this use.
4. Residential heating – There is a market for residential heaters that burn wood pellets and grain. Switchgrass pellets fit into this market as well, however, as discussed earlier in this paper, cost is a factor when compared to other home heating sources such as coal and natural gas. Currently wood pellets cost

approximately $250.00/ton (52). It has been estimated that switchgrass pellets can be marketed for $150.00 (CAD)/tonne (8).

5. Medium for growing mushrooms – In 2004, Royse, et al. had excellent success growing mushrooms in a substrate of switchgrass (53). In 2011, Pennsylvania mushroom farms were paying $150.00/ton for switchgrass mulch (54).
6. Mulch – Switchgrass has been used as mulch in vegetable production and proven to be a longer-lasting weed barrier than grain straws (55). It has also been used as mulch on highway construction (56).

These serve as opportunities for those who would like to establish a stand of switchgrass in preparation for the expanding biofuel market. Like other agricultural markets, a farmer's proactive approach can yield him/her a profitable endeavor with this crop. The figure below shows how productive and steady switchgrass can be once established compared with other forms of biomass(51).

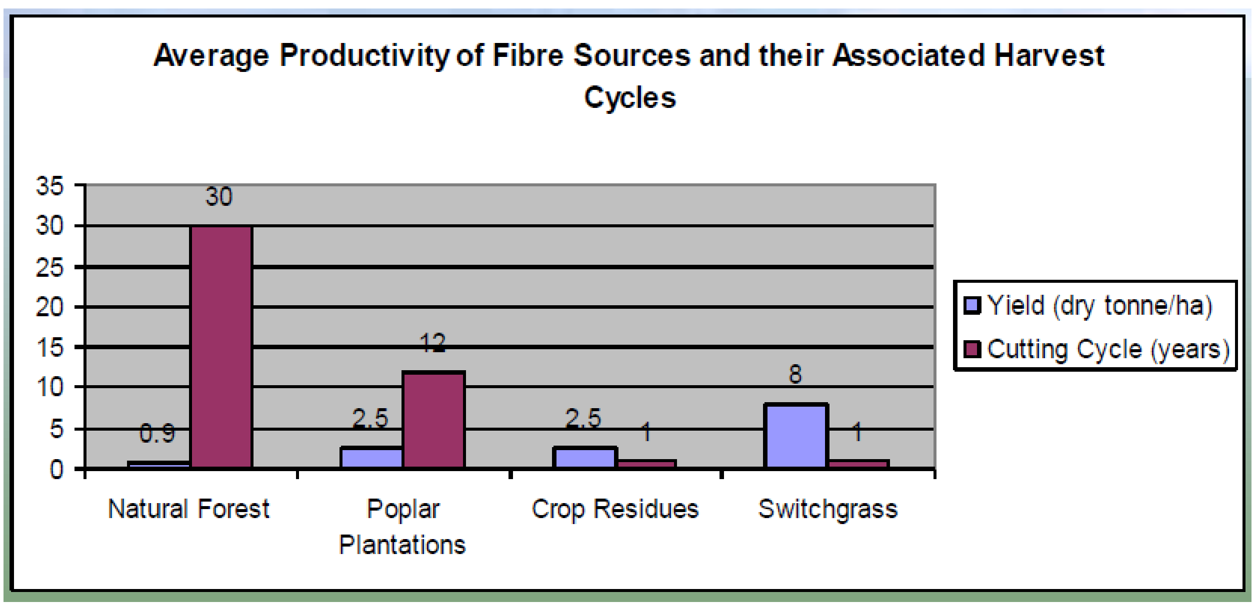


Figure 25. Average Productivity of Fibre Sources and their Associated Harvest Cycles from Samson R. (51).

What does all of this mean?

Interest in using switchgrass for biomass in Kentucky is present. Support for this endeavor has been seen across the board, from government entities like the Kentucky Agriculture Development Fund; private organizations such as the Kentucky Forage and Grassland Council; education facilities including the University of Kentucky College of Agriculture and Asbury University; producers like those in Bracken County and surrounding counties; and private industry – most importantly, East Kentucky Power Cooperative. Through the effort of these groups and others, it has been proven that Kentuckians can successfully grow, process and burn switchgrass for electricity generation. The next challenge is to make it affordable and profitable for all parties.

Establishing a stand of switchgrass can cost nearly $300.00 per acre. The EQIP program through the NRCS can offset some of that expense. We know other regions have successfully grown corn or wheat along with switchgrass to reduce the loss in production during the establishment year since switchgrass yields can range from zero to very low at that time. More experimentation with this could show exact benefits to Kentucky producers. It is also known that switchgrass can thrive on marginal ground that may otherwise be laying fallow, therefore offer extra income to farmers with such land available. Processing the biomass into a form that is easy to transport and handle once on site at a power company is sizeable expense to be considered. With prices ranging from $1.4 million to $15 million for a processing plant, depending on output goals and technical specifications, a question arises: Who is to absorb that expense? ShowMeEnergy Cooperative in Missouri funded their processing plant through local producers. Perhaps a processing company would open a facility in Kentucky. While money could be saved in the long-run by feeding ground material directly into a combustion unit at a power plant, upgrades must occur for that to happen. Is it worth the power company's time and money to make such alterations to their systems? As mentioned earlier in this paper, researchers have found breakeven prices, or farm-gate prices, to range from $33.65 in 1996, to $112.52 in 2012. East Kentucky Power Cooperative has paid $60.00 per ton of switchgrass in the form of large pellets/briquettes. When paying $58.57/ton for coal, which produces more BTU's per pound than switchgrass, one can see financial concerns for both producers and end-users.

Timing and commitments from growers, processors and end-users would be crucial to make a biomass system work in Kentucky, since it takes up to five years for a switchgrass stand to reach maximum potential. While coal is currently our most cost-effective source of electricity in the Commonwealth, there are many subsidies paid to the industry now and in years past (6, 46). Through government aid, the infrastructure for the coal industry has been laid in place, which makes it an affordable energy source. It has taken many years for that framework to evolve into the reliable system it is today. Likewise, it may take many years and government assistance for the biomass supply system to mature. While the cost of burning switchgrass and other biomass products for electricity may seem cost prohibitive initially, once an infrastructure is established, we will find it to be affordable, clean, renewable energy.

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