Reducing Bioenergy Cost by Monetizing Environmental Benefits of Reservoir Water Quality Improvements from Switchgrass Production

Task 2 Final Report

Pelletized Switchgrass for Space and Water Heating

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G = See separate Map Gazateer

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0.0 Executive Summary

Recent efforts to increase the use of biomass for renewable energy production have focused on plantation grown mono-crops, both trees and grasses, for electric power generation, primarily by co-firing with coal. The investigators recently participated in a detailed evaluation of the potential for using biomass as a fuel for electric utility boilers in Kansas[1] and concluded that under the most positive scenario co-firing switchgrass with coal would result in a "green electricity" premium of $0.010 – 0.150 per kiloWatt-hour above the cost of Wyoming coal. While this is significantly less than the cost premium for wind generated electricity there is no consensus that the Kansas green electricity market is large enough to support the minimum scale development of biomass co-firing, barring a regulatory or legislative mandate, state or federal. Electric power generation may offer an enormous market but it also means competing against the cheapest energy.

Development of renewable biomass energy in Kansas will require parallel efforts to reduce edge of field cost and to identify and penetrate higher value energy markets. This task focuses on the potential for pelletized herbaceous energy crops (HEC) like switchgrass or big bluestem to provide residential space and water heating energy within 50 miles of the Perry Reservoir basin in Northeast Kansas.

0.1 Cost Reduction Opportunities

Harvest Land Enrolled in the Federal Conservation Reserve Program (CRP)

The Federal Conservation Reserve Program normally prohibits harvesting for any purpose. Waivers have been granted in Iowa and elsewhere for harvesting for energy purposes. Access to CRP enrolled land is probably essential for two reasons: 1) it would provide reasonable assurance that access to the HEC would continue for enough years to justify the investment in processing equipment, and 2) it might permit harvesting of the HEC for a payment to the landowner for less than hay market rates against which biomass energy can not compete.

Many farmers in this region do not consider current CRP rents adequate to justify continued enrollment. In addition to the base CRP rent, a combination of incentives may prove adequate to increase enrollment, including: 1) the CRP 20% incentive for qualified buffer strips, 2) in eligible counties the 30% incentive payment from the Kansas Water Quality Buffer Strip Initiative described below, and 3) the potential for payment for harvested biomass energy.

Monetize Environmental Benefits

Native warm season prairie grasses offer a wide range of environmental benefits when planted as part of a carefully designed program, including reduced soil erosion, mitigation of agricultural chemicals, improved wildlife habitat, carbon sequestration, and greater visual diversity in the landscape. Environmental benefits, regardless of how real and documentable they are, are often difficult to internalize economically. Kansas reservoirs represent major public investments and serve as the principal water supplies for many communities, as well as major recreational assets. Reducing reservoir sediment loading and improving reservoir water quality are real benefits of

[1] King, J., Nelson, R., Hannifan, M., ***An Assessment of the Feasibility of Electric Power Derived from Biomass and Waste Feedstocks***, Kansas Electric Utilities Research Program and Kansas Corporation Commission, 1998.

planting HEC. Tasks 1 and 3 activities will evaluate the magnitude of environmental benefits that could be achieved and estimate their dollar value. They will be reported on separately.

Perry Reservoir has been classified as a category I watershed in the *Kansas Unified Watershed Assessment*, meaning it currently does not meet state water quality standards due to sediment and nutrient loading, and therefore has been assigned the highest priority with respect to restoration, including participation in the Governor's Water Quality Buffer Initiative described below.

> *"The Kansas Water Quality Buffer Initiative provides funds to supplement federal CRP rental payments by either 30% (for grass filter strips) or 50% (for riparian forest buffers). Incentives are calculated using established CRP soil rental rates. The supplemental payment provided through this initiative is in addition to the 20% federal supplement for continuous CRP sign-up.*
>
> *Cost-sharing for the establishment of grass filter strips or riparian forest buffers is available through the CRP program, and may be supplemented with additional cost-share funds from conservation districts or private organizations. Landowners throughout the state who install filter strips and riparian forest buffers can also apply for a reduction in the assessed value of their land for tax purposes.*
>
> *Currently, four drainage areas are eligible for the Buffer Initiative. They are the Little Delaware-Mission, Upper Delaware and tributaries, Upper Black Vermillion, and Horseshoe Creek Watershed. Currently, Atchison, Brown, Jackson, Nemaha, Marshall, and Washington counties are eligible for enrollment in the initiative."*[2]

The Upper Delaware drains portions of Nemaha, Brown, Atchison, and Jackson counties into Perry Reservoir.

<u>Minimize Transportation and Processing Cost and Energy</u>

Transportation cost and embodied energy can be the Achilles heel of biomass, particularly for the higher value pellet market. NEOS reported that, in Colorado, pellets selling for $160/ton had a transportation cost of $30 – 60/ton.[3] Most of these pellets were trucked in from other states. Unless high volume markets justifying rail shipment can be developed, the best strategy for minimizing transportation cost is to minimize transport distance by developing local markets. Small local markets do not translate into limited impact if the strategy can be readily replicated in many other locations.

<u>Market Directly to End Users</u>

Pellet manufacturers typically market most of their production in 40-50 pound plastic bags through retail outlets such as wood stove stores and farm and home centers. Retailer mark-up typically ranges from 20% to 40% of the retail price. Bagging, essential for this marketing path, may represent 10% of the retail cost. Bagged pellets, while perhaps more convenient than cord wood, still represent a significant inconvenience for most users who must visit the store, purchase the pellets, load the bags, unload them at home, and regularly load them into a pellet stove. Marketing directly to end users and providing delivery in bulk can eliminate bagging cost, avoid retail mark-up, and substantially increase customer convenience.

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[2] Kansas State Conservation Commission web page: http://www.ink.org/public/kscc/wqbi.html.

[3] Haase, S., et. al., ***Wood Pellet Manufacturing in Colorado: An Opportunity Analysis***, NEOS Corporation for State of Colorado and Western Regional Biomass Program, 1993.

0.2 Higher Value Market Opportunities

As a generating fuel biomass must compete with coal. Coal is extremely cheap, costing $0.77 to $1.12 per million Btus for two of Kansas's larger coal plants, equivalent to gasoline at $0.10 - $0.14 per gallon.[4] Biomass has its lowest potential value when competing in large industrial scale processes (power generation, ethanol production) and its highest potential value when competing with other forms of energy at retail for small volume consumers who tend to pay higher rates. Biomass pellets made primarily from sawmill waste but also from wood manufacturing waste, waste paper, and even peat are being used in the U.S. and elsewhere as a heating fuel.

The U.S. biomass pellet market, nonexistent in the early 1980s, had grown to 680,000 tons/year by the 1998-99 heating season.[5] Essentially all of these pellets are consumed in space heating stoves, not central heating systems. The market has developed because pellets can be more convenient than cordwood and because pellet burning stoves can meet emission restrictions that have essentially stopped wood burning in some communities. Wood is not a common primary or even secondary space heating fuel in Kansas. If biomass pellets are to achieve a significant market in Kansas they must compete not only in price, but also convenience, for the non-natural gas heating market shared by electricity and propane. A strategy to do this could be implemented based on the following points:

- Acquire HEC (switchgrass or big bluestem) at a low edge of field cost from land enrolled in the CRP program (requires U.S. Department of Agriculture waiver).
- Construct a pellet mill facility of the smallest size economy of scale permits (2-3 tons per hour) to minimize transportation distance from field to mill and delivery distance from mill to end use customer.
- Market a residential scale biomass pellet boiler capable of high efficiency with high ash content pellets for water heating.
- Use the hot water for domestic hot water year around, and for space heating with a heat exchanger in the supply-air duct or in a radiant system. Such a system would allow pellets to totally displace a propane furnace/water heating system, or a heat pump and electric water heater. Gas fired systems following this concept have been commercially available for a number of years.
- Provide bulk delivery directly to the customer using a truck similar to a medium size grain truck with a pneumatic pellet pump. Such systems are already in use in Northern Europe. Blow the pellets into a storage bin near the boiler and suck out the accumulated ash. Depending on bin size and use, two to four deliveries per year would be typical. Bulk delivery eliminates bagging cost, increases convenience (just like propane), and eliminates the high cost retailer middleman.

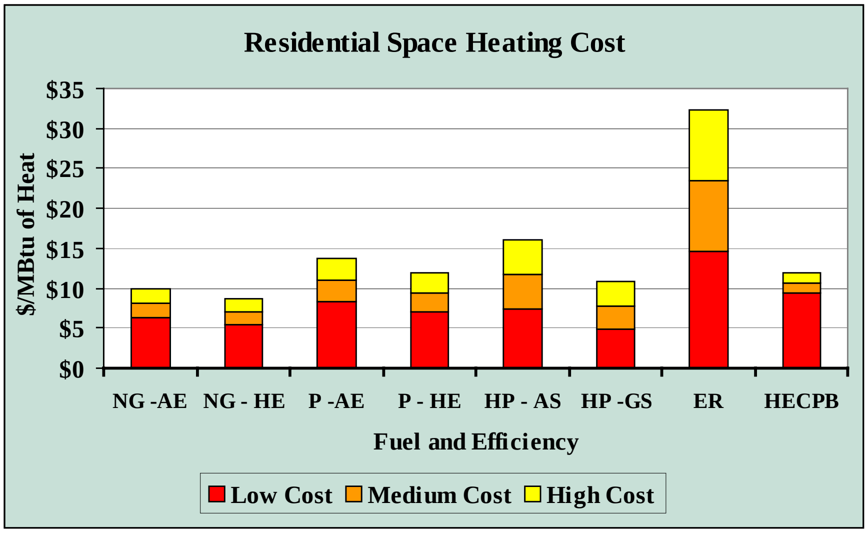
Figure 0.1 Pellet Boiler
Source: Eco-Tec

[4] King, J., Nelson, R., Hannifan, M., ***An Assessment of the Feasibility of Electric Power Derived from Biomass and Waste Feedstocks***, Kansas Electric Utilities Research Program and Kansas Corporation Commission, 1998.
[5] Pellet Fuels Institute.

0.2.1 Cost of Competing Fuels

Figure 0.2 shows the cost of space heating energy in dollars per million Btu delivered for three cost levels (low, medium, and high)[6] for the most common space heating systems and fuels. A HEC pellet boiler is much cheaper than electric resistance, somewhat cheaper than an air-source heat pump, and about the same as propane. It is generally more expensive than a ground-source heat pump, but the installed cost of ground–source heat pumps is much higher. A pellet boiler would rarely be competitive with natural gas given today's prices.

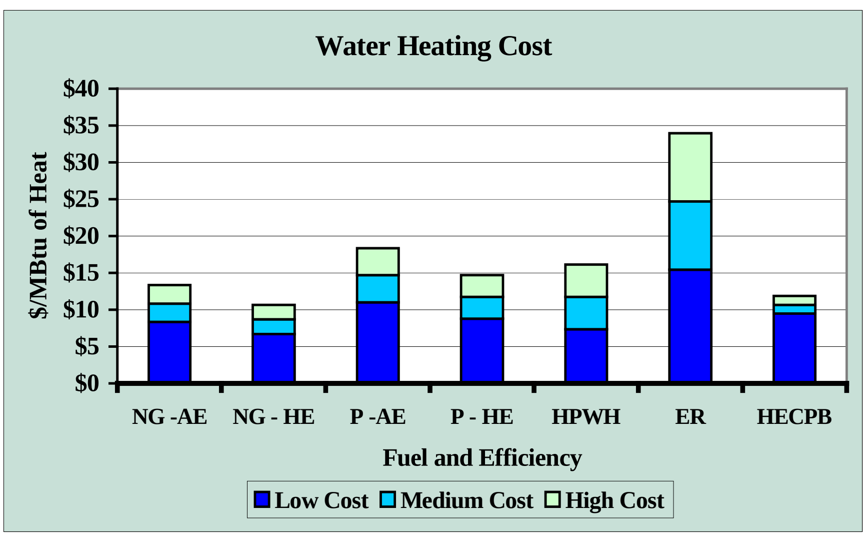
Figure 0.2 Space Heating $/MBtu: Competing Fuels -Systems



NG-AE = natural gas average efficiency, NG-HE = natural gas high efficiency, P-AE = propane average efficiency, P-HE = propane high efficiency, HP-AS = electric heat pump air source, HP-GS = electric heat pump ground source, ER = electric resistance, HECPB = herbaceous energy crop pellet boiler.

Figure 0.3 shows the cost of water heating energy in dollars per million Btu delivered for three cost levels (low, medium, and high) for the most common water heating systems and fuels. A HEC pellet boiler is significantly less expensive than electric resistance and competitive with all other systems with the exception of conventional natural gas water heaters. Detailed data for figures 0.2 and 0.3 can be found in the report.

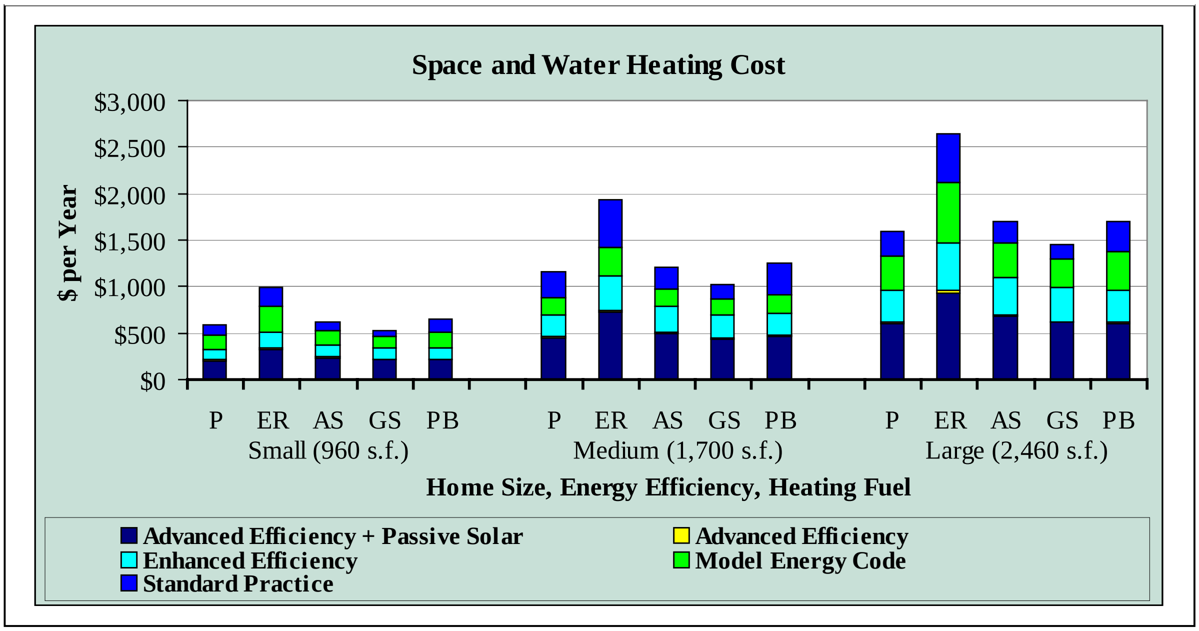
Figure 0.3 Space Heating $/MBtu: Competing Fuels -Systems



NG-AE = natural gas average efficiency, NG-HE = natural gas high efficiency, P-AE = propane average efficiency, P-HE = propane high efficiency, HPWH = electric heat water heater, ER = electric resistance, HECPB = herbaceous energy crop pellet boiler.

[6]Low/Medium/High energy costs assumed were: Natural Gas $/MCF= $5.00/$6.50/$8.00. Propane $/gallon = $.60/$.80/$1.00. Electricity $/kWh = $.05/$.08/$.11. HEC Pellets $/dry ton= $125/$150/$175.

Figure 0.4 Space and Water Heating $/Yr: Three Houses, Competing Fuels -Systems



P = propane, ER = electric resistance, AS = electric air-source heat pump, GS = electric ground source heat pump, PB = HEC pellet boiler.

0.2.2 Combined Space and Water Heating Cost

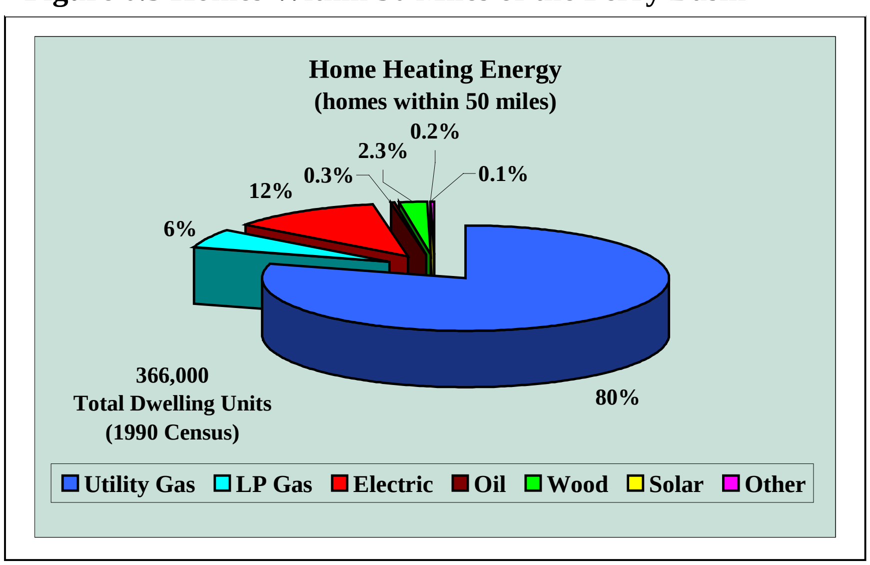
There are any number of combinations of energy costs, system efficiency, home size, and home efficiency. Figure 0.4 shows the total annual space and water heating costs for three different home sizes (960 ft^2, 1,700 ft^2, 2,460 ft^2.), five levels of building envelope energy efficiency (advanced efficiency + passive solar, advanced efficiency, enhanced efficiency, Model Energy Code, and Standard Practice) and five different heating fuels (propane, electric resistance, air-source heat pump, ground-source heat pump, and pellet boiler). The pellet boiler has approximately the same space and water heating energy cost as all heating systems except for the high energy cost resistance electric system and the high first cost ground-source heat pump.

0.2.3 Potential Residential Market

Counties that lie at least 50% within 50 miles of the Perry Basin had a total of 366,000 homes in 1990. An estimated 7,500 new homes are being constructed each year in this region. Figure 0.5 shows a breakdown of heating fuels used by these homes.

The target market of homes heating with LP (propane),

Figure 0.5 Homes Within 50 Miles of the Perry Basin

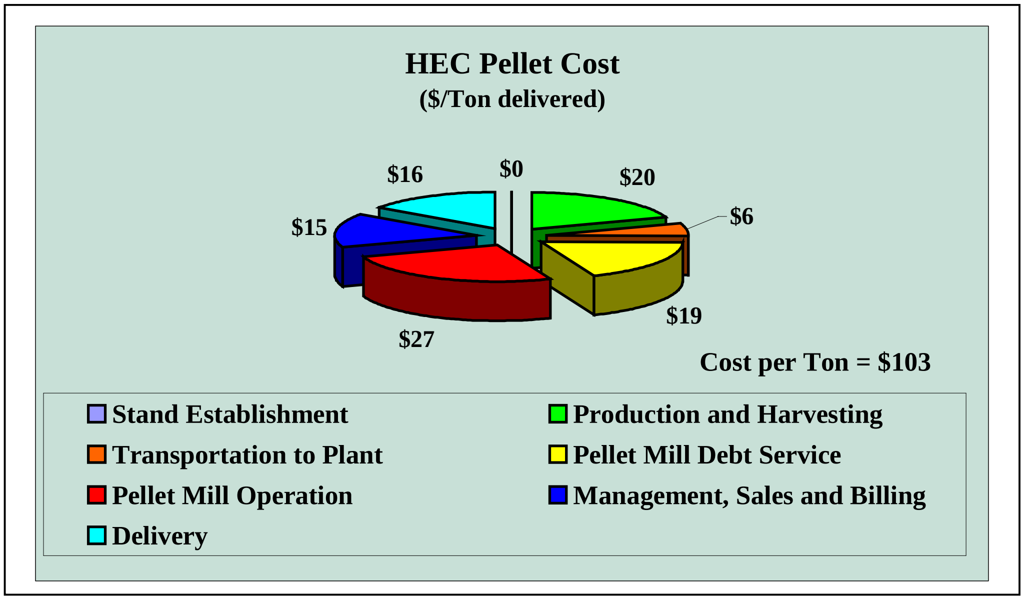


fuel oil, wood, solar, plus 10% of electrically heated homes in urban counties and 25% of electrically heated homes in rural counties, totals approximately 37,000 (1990). Somewhat more than 13,000 of these homes are in the high priority counties that comprise the basin (Atchison, Brown, Jackson, Jefferson, and Nemaha). A market of some 2,400 homes would be required to consume the 14,500 tons of pellets produced annually by a fully operational 3 ton/ hour pellet mill processing the average switchgrass harvest from 3,000 acres.

0.2.4 Pellet Cost

Pellet production cost is estimated at $103/ton for a fully operational 3 ton/day plant. Figure 0.6 shows the cost breakdown by major category. HEC pellets could sell for $30 – 40/ton above cost and be competitive with most non-natural gas space and water heating systems. This represents an encouraging scenario, but it is also the most optimistic with all steps in the process meeting expectations.

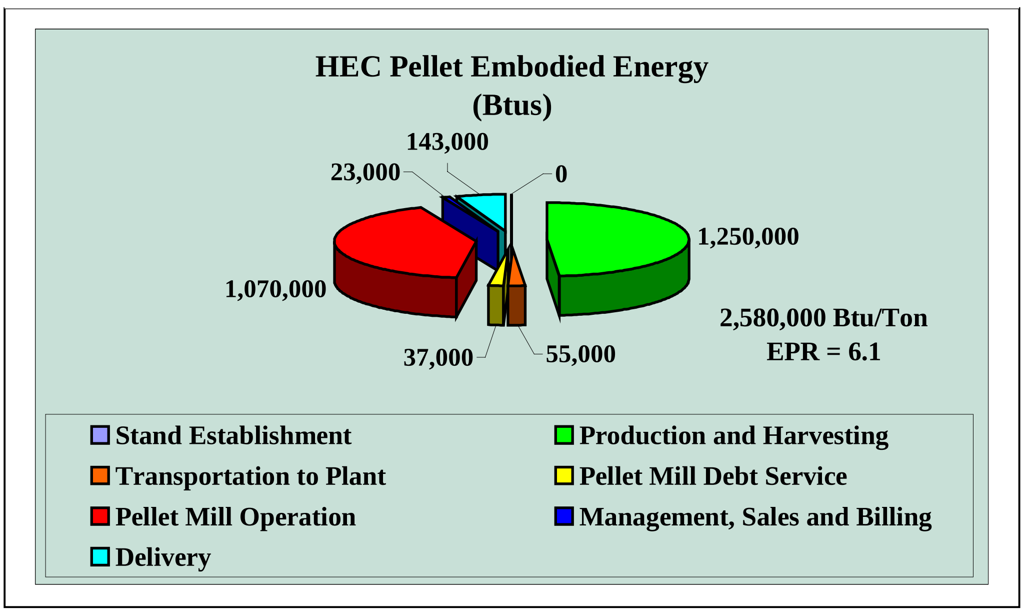
Figure 0.6 HEC Pellet Production Cost



0.2.5 HEC Pellet Embodied Energy

For any biomass development strategy to be truly renewable it must have a high energy profit ratio (EPR), energy out divided by energy in. The estimated embodied energy of HEC pellets totals 2,580,000 Btu/ton for an EPR of 6.1.

Figure 0.7 HEC Pellet Embodied Energy



Reduction in fertilizer use and green electricity for pellet plant operation could reduce embodied energy to 1,525,000 Btus with an EPR of 10.4. Other steps such as biodiesel for harvesting and delivery and the use of thermophotovoltaics or alkali metal thermal to electric conversion (AMTEC) cogeneration could further increase the EPR of HEC pellets. Figure 0.7 shows a breakdown of embodied energy.

Extensive data on cost and embodied energy are contained in this report, but the complicated character of such a process requires this data be considered preliminary.

0.2.6 Barriers to HEC Biomass Pellet Market Development

An acre of Kansas farmland worth perhaps $1,000 is capable of producing an average annual yield of HEC biomass sufficient to meet the annual space and water heating needs of an average Kansas home with an energy profit ratio above six. A HEC pellet system would be cheaper and environmentally far superior to a ground source heat pump. Yet there are real barriers to the development of such a market.

<u>Harvesting CRP Enrolled Land for Biomass Energy</u>

Biomass energy production can not compete for land use with grain crops in Northeast Kansas, at least when commodity prices are normal. Access to biomass produced on CRP land at something less than hay market value is essential for biomass to compete with fossil fuels. Current CRP regulations preclude harvest for any purpose. Federal initiates to ease this restriction for biomass energy are anticipated and will be tracked closely.

<u>Lack of Suitable Combustion Equipment</u>

Not counting systems designed to burn corn, no high performance residential scale high ash pellet boilers (or furnaces) are readily available at retail in North America today. Companies reportedly developing such equipment appear to be focusing on the European market where fossil fuels are more expensive, incentives for biomass use more widely available, and the general population more supportive of renewable energy use.

<u>Dominance of Relatively Low Cost Natural Gas in the Residential Space/Water Heating Market</u>

Nearly 80% of Northeast Kansas homes are heated with natural gas. With the exception of the occasional ardent environmentalist, natural gas users do not represent a market for HEC biomass pellets at current natural gas prices.

<u>The Importance of Full Plant Operation on Pellet Cost</u>

The encouraging cost and energy profit ratio involved in manufacturing HEC pellets summarized above is highly dependent on the pelleting plant operating three shifts a day, five days per week, 48 weeks per year. Fewer hours and less production would significantly increase per unit cost. The potentially high ash content of HEC pellets and the high cost of transporting them may mean limited potential for markets beyond that created locally. Realistically several years would be required for a sufficient local market to develop to consume the production of the plant envisioned. Future work should include a more thorough evaluation of incremental growth.

<u>Market Acceptance of HEC Pellet Boilers</u>

The market for residential space and water heating equipment is notoriously conservative. A very carefully planned marketing program with appropriate allies such as farmer coops or propane marketers may be essential to achieve the rapid market penetration necessary to bring a pelleting operation into full scale operation.

Hedging the Risk of Poor Harvest

Grains are fungible global commodities. Producing HECs locally for local markets means the risk of inadequate harvest to meet demand as a result of drought or even heavy rain is significantly higher. Several options to address this problem are available: 1) have adequate acres available to meet demand at lower than average yield, 2) import wood pellets, 3) plant a portion of acres to trees that serve as a standing reserve, 4) combine the pellet market with utility co-firing allowing coal to become the buffer.

Low Priority of Small Scale Combustion in Federal Energy Programs

Small scale biomass combustion does not enjoy significant support from the U.S. Department of Energy.

Anti-Renewable Energy Kansas Tax Policy

Since 1979 Kansas residential electric sales have been exempt from Kansas sales tax. Pellets would enjoy no such exemption.

1.0 Biomass Energy Development in Kansas

1.1 Background

The Kansas Electric Utilities Research Program (KEURP) completed ***"An Assessment of the Feasibility of Electric Power Derived from Biomass and Waste Feedstocks"*** in 1998. The following edited section of the project's final report executive summary provides an overview of recent biomass research efforts in Kansas.

1.2 Plantation Biomass

The increasingly competitive electric utility market makes fuel cost a critical factor in biomass use for power generation. The strategy driving this analysis was to prospect for the lowest cost biomass energy resources. A detailed investigation of potential biomass energy crop yields, total production, and edge of field cost per million Btus has been performed, focusing on 74 counties in that portion of Kansas with greater than 22 in. annual rainfall (east of Highway 183). The analysis divided this portion of the state into six climate regions. ALMANAC, a rigorous plant growth model developed by scientists at the U.S. Department of Agriculture, was used to estimate the annual yield for 24 years, fertilizer use, and environmental impact for the most promising herbaceous energy crop (HEC), switchgrass *(Panicum virgatim)*, and the most promising short rotation woody crop (SRWC), black locust *(Robinia pseudoacacia)*, for each of 315 soil series within the six climate regions.

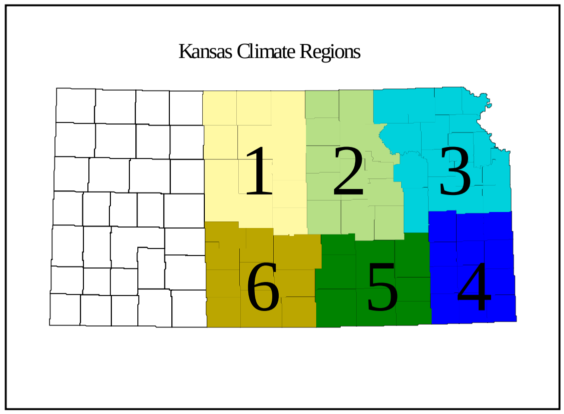


Figure 1.1 Kansas Climate Zones

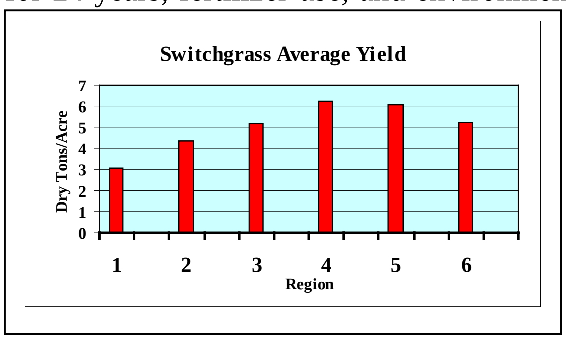


Figure 1.2 Average Switchgrass Yield

1.3 Energy Crop Yields

Yield is a major factor in determining biomass energy costs. The cost of many field operations is essentially constant, changing only slightly as yield increases. Exclusive of land value, a doubling of yield nearly halves cost. Average annual switchgrass yields (tons/acre) were substantially higher than for black locust. Under drought conditions some soils in the two western regions produced almost nothing. The single year highest yield of 14.9 dry tons/acre occurred on a Kansas River valley soil in Shawnee County. Yields were higher for the eastern regions and highest overall for the southeast. Yields varied significantly by year and individual soil series.

While hybrid poplar has become the favored SRWC for much of the U.S., extensive research conducted in Kansas in the early 1980s indicated black locust may perform better under Kansas climate and soil conditions. Black locust offers significant potential for genetic improvement, but regrettably, research has been essentially discontinued in the U.S. Yields were based on eight-year harvest intervals with the tree regrowing from the stump after harvest (coppice). The eight-year cycle allows SRWCs to avoid years of extremely low harvest except for long term droughts. While black locust average annual yields were generally about one third lower than switchgrass; the pattern between regions was similar. The maximum average black locust yield of 5.8 dry tons/acre/yr (eight-year cycle) occurred in Wilson County.

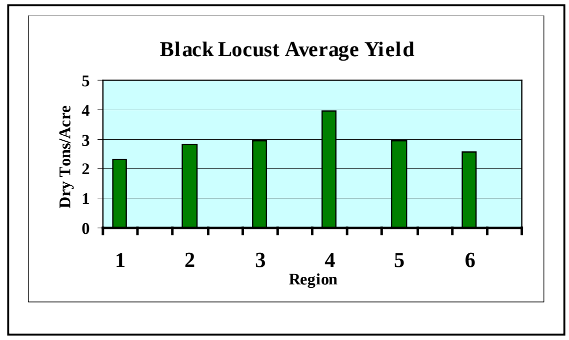


Figure 1.3 Average Black Locust Yield

1.4 Biomass Cost

A detailed Excel workbook, Biomass Energy Production Cost and Embodied Energy (BEPCEE) was developed to estimate all phases of production cost and the associated embodied energy. In addition to yield, land cost is a significant factor in total production cost. Production cost was evaluated without land cost, and with two distinct land cost scenarios. The first was based on land used for biomass production paying conventional land rent, plus yielding a profit equal to the profit yielded by the most profitable grain crop. This scenario was intended to set the upper bound of estimated cost. The second scenario was intended to set a lower bound on estimated cost by assuming use of land potentially eligible for the federal Conservation Reserve Program (CRP). Current eligibility criteria for CRP enrollment are complex, and an erosion index greater than eight was used as a screening factor for potential CRP eligibility. A rent payment of 40% of the CRP rate and a profit of 10% were used for this scenario, the goal of which was to outline a strategy through which the government (taxpayer) would pay less (half of the 40% rent could be used to reduce the federal payment), the land owner would make more (the other half of the 40% rent), and biomass fuels could better compete with fossil fuels. Figures 1.4 and 1.5 show the average edge of field cost for all soils by region based on conventional land rent, before profit. The lowest average regional cost of switchgrass ($24.11/dry ton - $1.52/MBtu) and black locust ($40.20/dry ton - $2.38/MBtu) occur in southeast Kansas where yields of both are highest. Black locust average cost is generally nearly double that of switchgrass due to lower yields, and the cost of deferring recovery of establishment costs and land rent for eight years. Edge of field cost under the two other land value scenarios (biomass vs. grain and CRP) are significantly different and identifying the lowest cost biomass requires evaluation at the soil series level for each region.

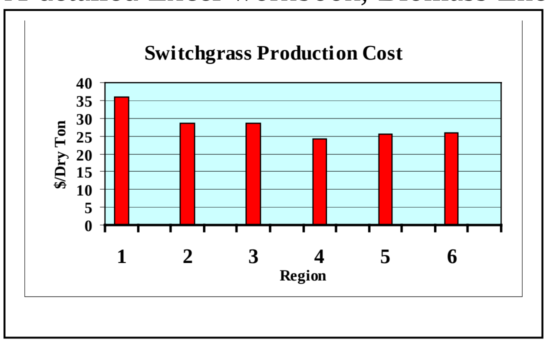


Figure 1.4 Average Switchgrass Cost
(edge of field, regular land rent, no profit)

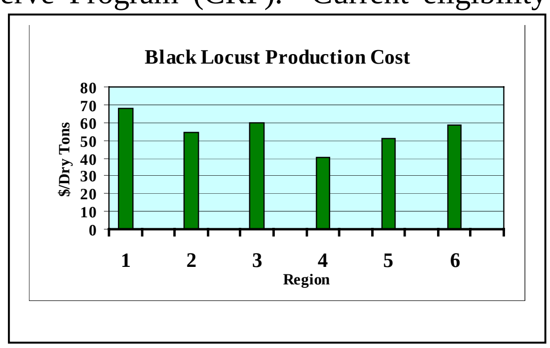


Figure 1.5 Average Black Locust Cost
(edge of field, regular land rent, no profit)

Market conditions would likely preclude a high percentage of land of a particular soil type or of the total land area within a county being dedicated to biomass production. Furthermore, land area covered by water, roads, urban development, public ownership, and woodland are not available for potential biomass production. To exclude these incompatible land uses and to track land parcels by the soil types corresponding to those for which yields and costs were calculated, an extensive set of geographic information system (GIS) maps were developed. These included county level and regional maps of soils from the SSURGO detailed soils database with areas of incompatible land use identified in the Landcover database and road rights-of-way identified in the Census Bureau Tiger road files excluded.

1.5 Biomass Production and Generation Potential

Total biomass energy production potential was estimated by region, using the yields described

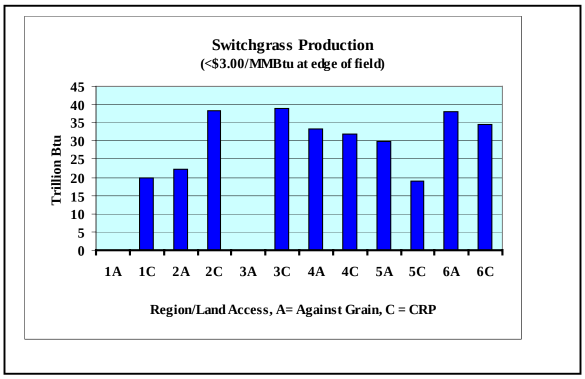


Figure 1.6 Switchgrass Production
(<$3.00/MBtu edge of field)

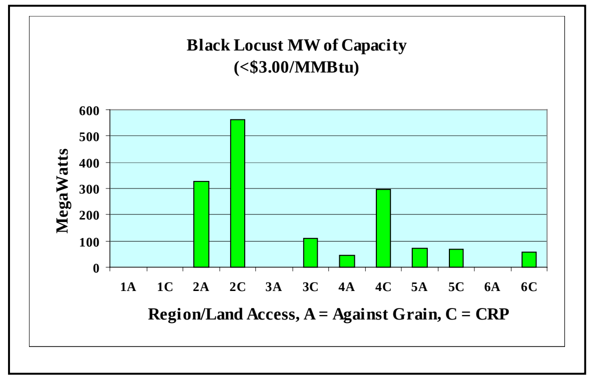


Figure 1.7 Black Locust Production
(<$3.00/MBtu edge of field)

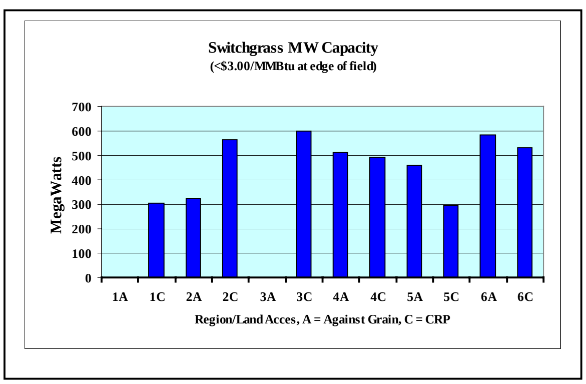


Figure 1.8 Potential Switchgrass Generation
(<$3.00/MBtu edge of field)

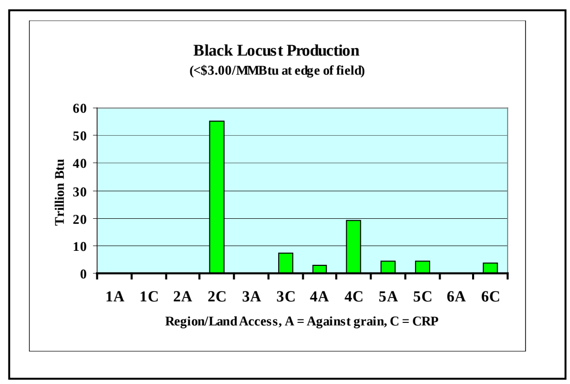


Figure 1.9 Potential Black Locust Generation
(<$3.00/MBtu edge of field)

above and limiting biomass land access to a maximum of 50% of any soil series and 10% of the potentially eligible land within each county. Within these constraints the average annual edge of field energy production for all six regions at a cost less than $3.00/MBtu totaled 182.3 trillion Btus on land potentially eligible for CRP and 121.1 trillion Btus on all land suitable for switchgrass. For black locust comparable values were 72.9 trillion Btus on land potentially eligible for CRP and 27.0 trillion Btus on all suitable land. Figures 1.6 and 1.7 break down the energy production by region for switchgrass and black locust vs. grain on land potentially eligible for CRP. In regions one and two the amount of land on which switchgrass can equal the profit potential of the most profitable grain is very small. The lower yield and higher cost of black locust results in substantially lower production potential and very little production when competing against grain in regions 1, 3, and 6 or land potentially eligible for CRP in region 1.

1.6 Biomass Potential Contribution to Kansas Electricity Consumption

At a conversion efficiency of 30% and an annual plant factor of 65% the total generating capacity in all six regions that could be fueled with biomass with an edge of field cost less than $3.00/MBtu is estimated at 2,787 megaWatt (MW) on land potentially eligible for CRP and 1,885 MW for all suitable land for switchgrass and 1,099 MW on land potentially eligible for CRP and 441 MW for all suitable land for black locust Figures 1.10 and 1.11 provide a regional breakdown of generation potential. These numbers represent an estimated maximum, and do not account for transportation costs from the field edge to the plant gate or the cost of fuel processing. Some land parcels may also be too small or too spatially dispersed to be useable.

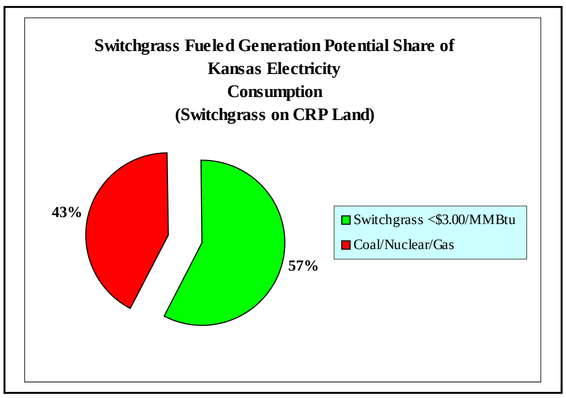


Figure 1.10 Potential Switchgrass Share of Kansas Electricity Use

The biomass fueled generation described above could produce the equivalent of approximately 57% (switchgrass) or 23% (black locust) of Kansas 1995 electrical energy consumption. This high number serves only to characterize the maximum technical potential within the parameters outlined for this project. It is not an indication of currently economically viable biomass fueled generation. The options presented for switchgrass and black locust are generally exclusive of each other, and can not be added together because they are competing for the same land area.

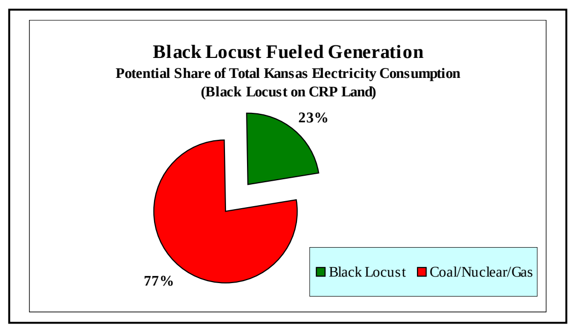


Figure 1.11 Potential Black Locust Share of Kansas Electricity Use

1.7 Waste Energy Resources

Waste resources in Kansas are diffuse due to the lack of large population centers. Municipal solid waste, landfill gas, tires, wood waste, and agricultural residues were inventoried and evaluated. Compared to plantation biomass, the individual and aggregate generation potential of waste resources is limited.

1.8 Co-firing Case Studies

After reviewing detailed maps of switchgrass and black locust yield and cost, and conversations with utility members of the KEURP renewable energy task force, Jeffrey Unit 1, a 734 MW pulverized coal plant and LaCygne Unit 1, a 688 MW cyclone boiler coal plant, were selected for further case study evaluation. Transportation cost was estimated for each SSURGO soil parcel within 50 miles of the plant (in Kansas), based on a fixed $4.00/ton load/unload fee plus ten cents per ton mile. Soil series were sorted by plant gate cost (area weighted) and cost increments. The lowest cost production was selected, limited by not more than 50% of the area of any soil series/cost increment block, and not more than 10% of the total land area in any one county, until the tons required were identified for 2% and 5% co-firing. Results for switchgrass and black locust, including field edge and plant gate biomass cost and energy profit ratio (energy produced divided by energy invested), are summarized in Table 1.1 below.

Table 1.1 Biomass Cost and Energy Profit Ratio (EPR) for 2% and 5% Co-firing

			Edge of Field			Plant Gate		
Crop	Land	Tons	$/ton	$/MBtu	EPR	$/ton	$/MBtu	EPR
Jeffrey – 2% Co-fire								
Switchgrass	CRP Land	58,730	$23.14	$1.46	16.58	$28.31	$1.79	15.40
Switchgrass	Vs. Grain	58,730	$23.22	$1.47	16.01	$28.87	$1.82	13.71
Black Locust	CRP Land	55,631	$45.23	$2.68	40.92	$50.18	$2.98	29.66
Black Locust	Vs. Grain	55,631	$54.87	$3.25	37.49	$63.38	$3.76	26.88
Jeffrey – 5% Co-fire								
Switchgrass	CRP Land	146,788	$23.22	$1.47	16.60	$28.87	$1.82	15.19
Switchgrass	Vs. Grain	146,788	$39.81	$2.51	15.60	$48.22	$3.04	13.36
Black Locust	CRP Land	139,078	$48.87	$2.90	41.47	$55.49	$3.29	32.11
Black Locust	Vs. Grain							
LaCygne – 2% Co-fire								
Switchgrass	CRP Land	52,028	$19.75	$1.25	15.87	$26.00	$1.64	14.33
Switchgrass	Vs. Grain	52,028	$32.68	$2.06	14.57	$38.50	$2.43	13.41
Black Locust	CRP Land	48,966	$36.65	$2.17	56.83	$42.91	$2.54	41.72
Black Locust	Vs. Grain	122,415	$49.36	$2.93	51.49	$56.48	$3.35	36.52
LaCygne – 5% Co-fire								
Switchgrass	CRP Land	130,070	$19.75	$1.25	15.87	$26.09	$1.65	14.29
Switchgrass	Vs. Grain	130,070	$32.68	$2.06	14.67	$38.83	$2.45	13.38
Black Locust	CRP Land	122,415	$37.01	$2.19	57.15	$43.53	$2.58	41.08
Black Locust	Vs. Grain	122,415	$53.50	$3.17	52.58	$60.08	$3.56	38.47

1.9 Environmental Impact of Biomass Energy Crops

The use of switchgrass and black locust results in reduced soil erosion due to rainfall as well as general reductions in nutrient loss in runoff and subsurface flow versus all conventional commodity crops. Soil erosion due to rainfall was reduced an average of 99% and runoff was significantly reduced by bioenergy crop production with the exception of one case. Percent reductions in organic nitrogen and phosphorus loss with sediment due to switchgrass and black locust production exceeded 96% versus the most profitable grain crop.

Average percent reductions in soluble phosphorus loss in runoff and NO_3 loss in surface runoff were generally in the low 90 percent range for both bioenergy crops for all soil types considered. Average reductions in mineral nitrogen loss in subsurface flow were in the upper-80 to mid-90 percent for switchgrass, but ranged from the low 90 percent to plus one percent for black locust production in several cases.

Reductions in mineral nitrogen loss with percolate were generally positive for switchgrass production with the exception of several soils in region 2; however, black locust production showed a marked increase in mineral nitrogen loss with percolate with the exception of region 5.

Overall, the effect of using switchgrass and black locust has a positive impact when considering the loss of nitrogen and phosphorus to sediment, subsurface flow, and percolation when compared to the four conventional commodity crops.

1.10 Co-firing at Jeffrey and LaCygne: BioPower Results

BIOPOWER, a computer program developed by the Electric Power Research Institute (EPRI), was used to evaluate inside the plant gate performance of switchgrass co-fired with coal at rates of 2% and 5% for Jeffrey Unit 1 and LaCygne Unit 1. Based on the costs of coal and biomass feedstocks, operational characteristics of a power plant, and capital requirements to handle and process biomass materials in a co-fire mode, BIOPOWER reports in a comparative manner the levelized cost of electricity generated and resulting atmospheric emissions for "coal-only" and "co-fired" cases. Based on the delivered costs of switchgrass shown in Table 1.1, operational characteristics of the two plants provided by Western Resources and Kansas City Power & Light Company (as presented in Section 5), and estimated capital requirements to handle and process switchgrass in a co-fire mode (also presented in Section 5), BIOPOWER indicates that the levelized cost of switchgrass-fired electricity ranges from $0.050 to $0.085/kWh, as opposed to a levelized cost of coal-fired electricity of $0.025 to $0.028 per kWh. BIOPOWER also provides a breakeven cost for the fuel substituting for coal in a co-fire mode – in this case switchgrass – which ranges from $1.34 to -$33.24, indicating that switchgrass would need to be delivered to the plants at no cost or a negative cost to offset capital requirements and recurring O&M costs associated with switchgrass co-firing. Even though switchgrass delivered to Jeffrey Unit 1 may cost more than switchgrass delivered to LaCygne Unit 1, Jeffrey Unit 1 appears to be a better candidate for switchgrass co-firing (based solely on economic considerations) due primarily to the difference in coal costs at the two plants.

The low sulfur characteristic of switchgrass and other biomass feedstocks has been a significant factor in utility interest in co-firing biomass with coal. In the Jeffrey Unit 1 and LaCygne Unit 1 cases, the sulfur-reduction benefits of using switchgrass as a co-fire material were not as pronounced as anticipated due to two factors: first, both Jeffrey Unit 1 and LaCygne use coal that is relatively low in sulfur content, and second, capping the co-fire rate of switchgrass at 5% (for operational reasons) intrinsically limits the amount of sulfur that can be reduced by a co-fire strategy. When prevailing sulfur allowances ($/ton of sulfur avoided) were input to BIOPOWER to determine the impact on the economic feasibility of switchgrass co-firing, the impacts were found to be negligible.

In order for co-firing switchgrass to be an attractive option for Kansas utilities in the near term, two important economic conditions should be in place. First, the renewable energy production tax credit for "closed loop" biomass must be extended beyond July 1, 1999, as the $0.015/kWh credit narrows the economic gap between coal-fired electricity at $0.025 to $0.0275/kWh and co-fired electricity using switchgrass at $0.05/kWh or higher. Just as important as the extension itself is the broadening of the definition of "qualified facility" to allow utilities to obtain the production credit when co-firing biomass in pre-existing power plants. The second economic condition that should be in place is a green pricing program that serves to cover the incremental cost differences that remain after the renewable production credit is applied. For the best case scenarios using switchgrass as a co-fire material in Kansas, a green pricing program may need to raise $0.01 to $0.015 for each kWh of switchgrass-fired electricity in order to compete with coal.

For the best case scenarios using switchgrass as a co-fire material in Kansas, a green pricing program may need to raise $0.01 to $0.015 for each kWh of switchgrass-fired electricity in order to compete with coal.

While an explicit assessment of the prospects for green pricing support for biomass-fired electrical generation in Kansas is beyond the scope of this assessment, other research efforts conducted by KEURP have indicated many Kansas ratepayers may be supportive of green pricing programs.

2.0 Reducing Bioenergy Cost Project Summary

The most optimistic electric utility plant gate biomass energy cost of $1.64 per MMBtu (2% cofiring at LaCygne No. 1) in Kansas today exceeds average coal and nuclear fuel costs by 60% and 100% respectively. The federal $0.015/kWh tax credit for electricity produced from plantation biomass expired 1 July 1999. While the Clinton Administration called for continuing the credit and extending it to co-firing at a reduced rated of $0.01/kWh, provisions to do so were not included in the omnibus tax legislation passed by Congress in the summer of 1999 (later vetoed). While a renewable portfolio standard (RPS) requiring all utilities to acquire a portion of their electricity from renewable resources has been included in several proposed federal electric industry restructuring bills such a requirement remains highly uncertain. If the goal of producing biomass energy in Kansas is to be achieved in the absence of federal tax credits and mandates one or more of the following appears essential:

- the cost of biomass energy must be reduced by monetizing the numerous environmental benefits perennial trees and grasses can provide under certain circumstances,
- land owners must be allowed to harvest and sell biomass energy crops from land enrolled in the federal Conservation Reserve Program (CRP) at below agricultural market rates,
- energy markets with values higher than electric utility bulk coal and nuclear fuel must be identified and developed.

With these factors in mind the larger research project, of which this report addresses only a part, is focusing on the Delaware River drainage basin flowing into Perry Lake and the North Cottonwood River drainage basin flowing into Marion Reservoir.

2.1 *Task 1 - Evaluate the potential for reservoir sedimentation and nutrient control*

Task 1 involves the evaluation of the potential for reducing reservoir sedimentation and nutrient loading by planting switchgrass on those lands which are classified as moderately to severely erodable within the reservoir drainage basin. The Soil and Water Assessment Tool (SWAT) software developed by USDA-ARS is being used to establish a baseline case of sediment and nutrient loading for each reservoir based on current land-use practices within the entire watershed. SWAT is also being used to analyze the effects on sediment and nutrient loading into the reservoir resulting from replacing conventional commodity crops currently grown within the reservoir watershed with switchgrass on highly erodable lands (HEL), combinations of land capability classes 2-4E, and lands with slopes greater than 4%.

Task 1.1 Divide the reservoir watershed into sub-basins.

Task 1.2 Describe each sub-basin based on current cropping practices and management, physical characteristics of the soil, and weather.

Task 1.3 Run SWAT to establish a “baseline” sediment and nutrient loading output level from each sub-basin based on current cropping practices.

Task 1.4 Run SWAT within each sub-basin replacing current cropping practices with switchgrass on highly erodable soils, land capability class 2-4E soils, and soils with slopes greater than 4%.

Task 1.5 Determine the percent reduction in sediment and nutrient loading throughout the reservoir basin based on optimum combinations of land parcels.

2.1.1 Task 1 Results

(These tasks are being performed by Dr. Richard Nelson and others at Kansas State University under a separate contract.)

Considerable difficulty was experienced in attempting to use the SWAT model in conjunction with USDA's Blacklands Research Center in Temple, Texas.[7] Acceptable definition of slope conditions was not achieved and modeled grain crop yields were not within one standard deviation of historical yields. Grass yields also deviated significantly from earlier work with the ALMANAC model which has been evaluated for use with switchgrass. No method was available to consider the impact of the extensive terracing and waterway soil conservation improvements that exist in the basin. After a yearlong effort that greatly delayed the project, the decision was made to pursue SWAT modeling under Task 1 elsewhere and to proceed with Task 2 analysis using previously developed ALMANAC data.

2.2 ***Task 2 - Determine yield, production, cost, and potential markets for switchgrass***

(Task 2 is covered by this contract and is reported on in the following section.)

The recent KEURP project included detailed modeling of potential biomass crop yield, including switchgrass, as a function of soil type; sub-state regional climate zone; fertilizer application rates; and general management practices. The ALMANAC model, a version of EPIC, was used for this project. The cost of biomass crop production was compared with potential conventional commodity crop profits for each soil/climate condition to determine the cost of energy at which biomass crops could compete. Fueling electric power generation would allow biomass to become a significant energy source, yet results indicated current costs of nuclear and coal are substantially less than biomass. The methods and model output files developed for this project will be used to estimate potential switchgrass yields and production costs for each parcel of land within the reservoir basin(s) meeting the criteria outlined above under Task 1. Per acre yield and parcel size will be analyzed in the same order as sediment and nutrient control to yield potential production volume.

High cost heat provided by electricity, propane, or fuel oil, offers the highest value bioenergy markets for switchgrass. Markets for specific heating uses currently met by these fuels, including space, water, and process, will be evaluated to identify a market size equal to the various levels of production being analyzed. Strategies for entering these markets will be investigated.

Task 2.1 Using previously developed yield values, estimate the per acre yield and total production volume of switchgrass in parallel with the acreages identified in Task 1.

Task 2.2 Identify existing heating markets, including space, water, and process for the residential, commercial, and industrial sectors, ranking them in order of current cost. Limit market area to within 50 miles of the reservoir drainage basin boundary to control transportation cost.

Task 2.3 Evaluate processing options and costs for marketing switchgrass for heat end uses identified in Task 2.2. Some markets may accept bulk pellets, others will require

[7] Staff at the Blacklands Research Center were irreplaceable contributors to the previous project.

bagging. Investigate the potential for contract pelleting at existing mills. Attempt to identify the lowest cost processing and packaging methods acceptable to each major market category and estimate cost.

Task 2.4 Estimate total biofuel energy cost based on the combinations of production volumes and costs determined in Task 2.1, end use markets identified in Task 2.2, processing methods and costs estimated in Task 2.3, other expenses and realistic profit, and overhead. Based on market price required to gain market entry, potential CRP payments identified in Task 3, and total product cost, estimate required economic value of other environmental benefits and compare with their value estimated in Task 1.

2.3 *Task 3 - Identify and evaluate strategies for reducing market cost of biomass energy from switchgrass*

Profits from conventional commodity crops are generally too high to justify planting productive cropland to switchgrass. Where switchgrass is planted, the hay market generally results in a price per ton too high for it to compete in energy markets. Direct payments to the farmer will likely be required to cause switchgrass to be planted on desired land areas and to achieve an edge-of-field cost that will allow switchgrass to be competitive in energy markets. To determine this, the following will be investigated:

Task 3.1 Evaluate the eligibility of selected land parcels for enrollment in the Conservation Reserve Program (CRP) based on prevailing rules, available enrollment, and likely payments.

Task 3.2 Investigate the feasibility of obtaining a USDA waiver for marketing switchgrass for energy from CRP-enrolled lands, similar to Chariton Valley in Iowa.

Task 3.3 Evaluate the potential for Kansas water quality improvement support payments and likely range. Compare these with the value required to enter the market as estimated in Task 2.4. Evaluate the economic impact of appropriate scenarios.

2.3.1 Task 3 Results

(These tasks are being performed by Dr. Richard Nelson and others at Kansas State University under a separate contract.)

3.0 Switchgrass Yield on Tilled Land with High Erosion

Data for the Perry and the Marion Basins were extracted from a prior ALMANAC analysis of the Kansas climate regions three and two respectively. The original analysis was based on the SSURGO data set providing high resolution by soil type and parcel for mapping and further analysis.

3.0.1 Perry Basin

The Delaware River basin covers approximately 1,160 square miles in Nemaha, Brown, Jackson, Atchison, and Jefferson Counties of northeast Kansas.

Land Use

The Delaware River Basin flowing into Lake Perry covers approximately 744,116 acres of which 295,037 are cropland according to the 1991 KARS land use data. Adjusted for road and other non-agricultural uses the net land area in cultivation is estimated at 270,000 acres, about 36% of the basin. Grassland and woodland cover about 57% of the basin. Table 3.1 provides data on land use and map 3.1P ***Delaware Basin Land Cover***, shows land use (see separate map Gazetteer). While grasslands are generally not considered a significant opportunity for soil conservation (it is not eligible for CRP) visual inspection in the field suggests many grassland parcels are overgrazed weed patches with considerable erosion.

LAND USE	ACRES	PERCENT
Commercial/Industrial	893	0.120%
Cropland	295,037	39.649%
Grassland	372,890	50.112%
Other	889	0.119%
Residential	2,844	0.382%
Urban-Grassland	460	0.062%
Urban-Water	32	0.004%
Urban-Woodland	16	0.002%
Water	16,640	2.236%
Woodland	54,415	7.313%
Total	**744,116**	

Table 3.1 Perry Basin Land Use
Source: KARS 1991

Soil Types

This region of Kansas was once glaciated and the soils are generally similar to SE Nebraska, NW Missouri and SW Iowa. Map 3.2P ***Delaware Basin Soils***, shows land use (see separate map Gazetteer). The acres of each soil in the basin are shown in Table 3.2 and additional information is provided by sub-basin later in Table 3.13.

Soil	Acres	Soil	Acres
STEINAUER	701	EUDORA	130
KIPSON	1,462	OLMITZ	1,773
GOSPORT	8	GRUNDY	13,515
READING	2,226	WYMORE	24,697
SOGN	290	COLO	1,612
SIBLEYVILLE	763	JUDSON	411
BURCHARD	9,972	KIMO	6
ARMSTER	1	HAIG	1,751
MORRILL	1,052	KENNEBEC	22,818
OSKA	78	WABASH	11,846
MARTIN	8,948	CHASE	5,354
VINLAND	3,550	ZOOK	4,712
SHELBY	20,963	SARPY	20
GYMER	408	MAYBERRY	27,847
PAWNEE	99,993	NODAWAY	3,921
		TOTAL	**270,826**

Table 3.2 Perry Basin Soils

3.0.2 Marion Basin

The North Cottonwood River Basin flowing into Marion Lake totals approximately 134,763 acres in McPherson and Marion Counties in east central Kansas.

Land Use

Cropland in the basin totals 78,719 acres according to the 1991 KARS land use data. Unadjusted for roads and other non-agricultural uses this represents about 58% of the basin. Table 3.3 provides a breakdown of land use by area and map 3.3M ***Marion Basin Land Cover***, shows land use (see separate map Gazetteer).

LAND USE	ACRES	PERCENT
Commercial/Industrial	117	0.087%
Cropland	78,719	58.413%
Grassland	47,544	35.280%
Other	65	0.048%
Residential	245	0.182%
Urban-Grassland	0	-
Urban-Water	4	0.003%
Urban-Woodland	0	-
Water	5,530	4.104%
Woodland	2,538	1.884%
Total	**134,763**	

Table 3.3 Marion Basin Land Use
Source: KARS 1991

Soil Types

Soils of the Marion Basin are quite different from the Perry Basin. Table 3.4 presents the number of acres for the soils of the Marion Basin and Map 3.4M ***Marion Basin Soils*** shows their location (see separate map Gazetteer).

Soil	Acres	Soil	Acres
KIPSON	150	CRETE	213
LANCASTER	7,019	LONGFORD	67
HEDVILLE	202	GOESSEL	107
WELLS	9,500	DWIGHT	12
FARNUM	565	SMOLAN	161
CLIME	11,224	OSAGE	54
READING	442	TOBIN	362
ROSEHILL	2,500	LADYSMITH	4,945
TULLY	1	CHASE	1,053
IRWIN	27,468	VERDIGRIS	5,724
EDALGO	1,017	TOTAL	**72,785**

Table 3.4 Marion Basin Soils

3.1 Identifying Tilled Land with High Erosion – the Erosion Index (EI)

An individual soil's propensity to erode is characterized by its erosion index, a value calculated by formula 1 below. The higher the EI, the greater the risk of erosion.

Formula 1: $EI = (R * K * LS)/T$

Where:
- EI = Erosion Index
- R = is a calculated value for each county
- K = $k_{SSURGO} \times k_{adjust}$ where k_{SSURGO} is the k value from the SSURGO database for each soil and k_{adjust} is the correction for each county
- LS = L x S, length and slope values for each soil type

Where: $L = (\text{slope length}/72.6)^m$

Where:

slope length …
is obtained by finding the slope length from SSURGO for each soil, rounding the value to the nearest whole number if greater than 1, and looking up the slope length in Table 1 which follows,

$$m = \frac{[\sin \Theta/0.0896] /([3 \times \sin \Theta^{0.08}] + 0.56)}{[1 + (\sin \Theta/0.0896)] /([3 \times \sin \Theta^{0.08}] + 0.56)}$$

Where:

Θ = ATAN (% slope/100)

S = if % slope ≥ 0.09, then
16.8 x SIN Θ -0.50
else,
10.8 x SIN Θ + 0.03

T = tolerable soil loss from SSURGO for each soil

3.1.1 Perry Basin Soil Erosion Index

The erosion index (EI) was calculated for each soil, by county, for the Delaware Basin. They are shown in Table 3.5 and map 3.5P, ***Delaware Basin Erosion Index*** (see separate map Gazetteer).

Soil	EI	Soil	EI
STEINAUER	22.8	EUDORA	7.6
KIPSON	27.4	OLMITZ	8.4
GOSPORT	108.1	GRUNDY	3.7
READING	3.2	WYMORE	6.3
SOGN	27.4	COLO	2.9
SIBLEYVILLE	14.3	JUDSON	8.6
BURCHARD	16.6	KIMO	3.4
ARMSTER	7.2	HAIG	3.9
MORRILL	7.2	KENNEBEC	2.8
OSKA	35.3	WABASH	3.7
MARTIN	14.2	CHASE	3.7
VINLAND	45.1	ZOOK	1.3
SHELBY	12.3	SARPY	5.3
GYMER	4.7	MAYBERRY	na
PAWNEE	11.3	NODAWAY	na

Table 3.5 Perry Basin Soil Erosion Index

3.1.2 Marion Basin Soil Erosion Index

The erosion index (EI) was also calculated for each soil, by county, for the Marion Basin. They are shown in Table 3.6 and map 3.6M, ***Marion Basin Erosion Index*** (see separate map Gazetteer).

Soil	EI	Soil	EI
KIPSON	29.27	CRETE	4.15
LANCASTER	25.77	LONGFORD	12.75
HEDVILLE	25.77	GOESSEL	1.39
WELLS	9.17	DWIGHT	11.54
FARNUM	1.04	SMOLAN	21.09
CLIME	28.1	OSAGE	3.44
READING	3.44	TOBIN	3.44
ROSEHILL	6.99	LADYSMITH	3.97
TULLY	7.32	CHASE	3.97
IRWIN	1.83	VERDIGRIS	3.44
EDALGO	22.47		

Table 3.6 Marion Basin Soil Erosion Index

3.2 Cumulative Cropland Erosion

Cumulative ALMANAC estimated 24 year erosion is summarized below for each basin.

3.2.1 Perry Basin 24 Year Cumulative Cropland Erosion

Table 3.7 shows the 24 year cumulative erosion for each soil type in the Perry Basin, the number of acres for each soil, and the estimated total tons of erosion for each soil. The soil area data is derived from the SSURGO database and the erosion estimates are from the ALMANAC model.

Table 3.7 Perry Basin Soil Erosion (24 Year Cumulative)

Soil	Acres	Erosion (t/a)	Erosion Tons	Soil	Acres	Erosion (t/a)	Erosion Tons
STEINAUER	701	180.5	126,488	EUDORA	130	20.8	2,700
KIPSON	1,462	100.2	146,505	OLMITZ	1,773	17.5	31,062
GOSPORT	8	97.7	796	GRUNDY	13,515	17.1	230,976
READING	2,226	77.8	173,133	WYMORE	24,697	14.0	345,221
SOGN	290	63.8	18,490	COLO	1,612	12.3	19,787
SIBLEYVILLE	763	59.2	45,183	JUDSON	411	12.0	4,922
BURCHARD	9,972	59.2	590,150	KIMO	6	11.9	66
ARMSTER	1	53.6	59	HAIG	1,751	11.3	19,717
MORRILL	1,052	53.2	55,983	KENNEBEC	22,818	11.1	252,502
OSKA	78	49.1	3,820	WABASH	11,846	11.0	130,559
MARTIN	8,948	48.6	434,778	CHASE	5,354	10.7	57,335
VINLAND	3,550	46.7	165,876	ZOOK	4,712	10.5	49,558
SHELBY	20,963	43.5	912,458	SARPY	20	2.6	52
GYMER	408	41.9	17,103	MAYBERRY	27,847	0.0	-
PAWNEE	99,993	33.4	3,342,182	NODAWAY	3,921	0.0	0
				TOTAL	**270,826**		**7,177,460**

3.2.2 Marion Basin 24 Year Cumulative Cropland Erosion

Table 3.8 shows 24 year cumulative erosion for each soil type in the Marion Basin, the number of acres for each soil, and the estimated total tons of erosion for each soil. The soil area data is derived from the SSURGO database and the erosion estimates are from the ALMANAC model.

Table 3.8 Marion Basin Soil Erosion (24 Year Cumulative)

Soil	Acres	Erosion (t/a)	Erosion Tons	Soil	Acres	Erosion (t/a)	Erosion Tons
KIPSON	150	79.9	11,998	CRETE	213	6.1	1,292
LANCASTER	7,019	41.6	292,297	LONGFORD	67	4.7	318
HEDVILLE	202	26.5	5,369	GOESSEL	107	4.3	455
WELLS	9,500	26.3	249,807	DWIGHT	12	3.5	42
FARNUM	565	23.9	13,501	SMOLAN	161	3.3	537
CLIME	11,224	15.9	178,782	OSAGE	54	2.5	135
READING	442	14.5	6,410	TOBIN	362	2.4	878
ROSEHILL	2,500	8.9	22,244	LADYSMITH	4,945	2.2	10,790
TULLY	1	8.6	8	CHASE	1,053	2.0	2,114
IRWIN	27,468	6.5	178,214	VERDIGRIS	5,724	1.8	10,221
EDALGO	1,017	6.4	6,520	TOTAL	**72,785**	0.0	**991,931**

SWAT Analysis

The project work plan called for the use of the SWAT model which would have permitted the analysis of sediment to the reservoir, not just field erosion. Despite very extensive efforts by Dr. Richard Nelson of Kansas State University to coordinate the SWAT analysis process with staff of the Blacklands Research Center, acceptable results have not been produced. A more extensive analysis of previously generated ALMANAC data has been used instead for Task 2 work.

3.3 Switchgrass Yield

ALMANAC estimated switchgrass yields are summarized below for each basin.

3.3.1 Perry Basin ALMANAC Yield Analysis

Table 3.9 shows the ALMANAC estimated maximum, minimum, and average switchgrass yields over a 24 year period for Perry Basin soils with a cumulative erosion greater than 40 tons/acre. Soils with average switchgrass yield greater than 5 tons/acre are shown in bold. Steinauer, Reading, Burchard, Morrill, and Martin soils appear to offer the best opportunity for erosion control and high biomass energy yields.

Table 3.9 Perry Basin Erosion and Switchgrass Yield by Soil (ALMANAC 24 year max, min, average)

		Switchgrass Yield (dry ton/a/ yr)		
Soil	**Erosion (tons/yr/a)**	**Max**	**Min**	**Ave**
Steinauer	**181**	**12.4**	**0.3**	**5.2**
Kipson	100	6.8	0	2.7
Reading	**78**	**12.5**	**1.4**	**6.2**
Sogn	64	4.5	0	1.8
Burchard	**59**	**11.4**	**1.3**	**5.6**
Morrill	**53**	**10.7**	**1.2**	**5.4**
Oska	49	9.0	0.2	4.1
Martin	**49**	**12.8**	**1.5**	**6.3**
Vinland	47	6.2	0	2.6
Shelby	**44**	**11.4**	**1.3**	**5.4**
Gosport	98	9.0	0.9	4.6
Sibleyville	59	7.8	.1	3.3
Armster	**54**	**10.6**	**.3**	**5.0**
Gymer	**42**	**12.9**	**1.5**	**6.4**

3.3.2 Marion Basin ALMANAC Yield Analysis

Table 3.10 shows the ALMANAC estimated maximum, minimum, and average switchgrass yields over a 24 year period for Marion Basin soils with a cumulative erosion greater than 20 tons/acre. Soils with average switchgrass yield greater than 5 tons/acre are shown in bold. Wells and Farnum soils appear to offer the best opportunity for erosion control and high biomass yields. While yields on these soils are comparable to those of the Perry Basin the erosion control opportunity appears to be substantially lower due primarily to lower slopes and less precipitation.

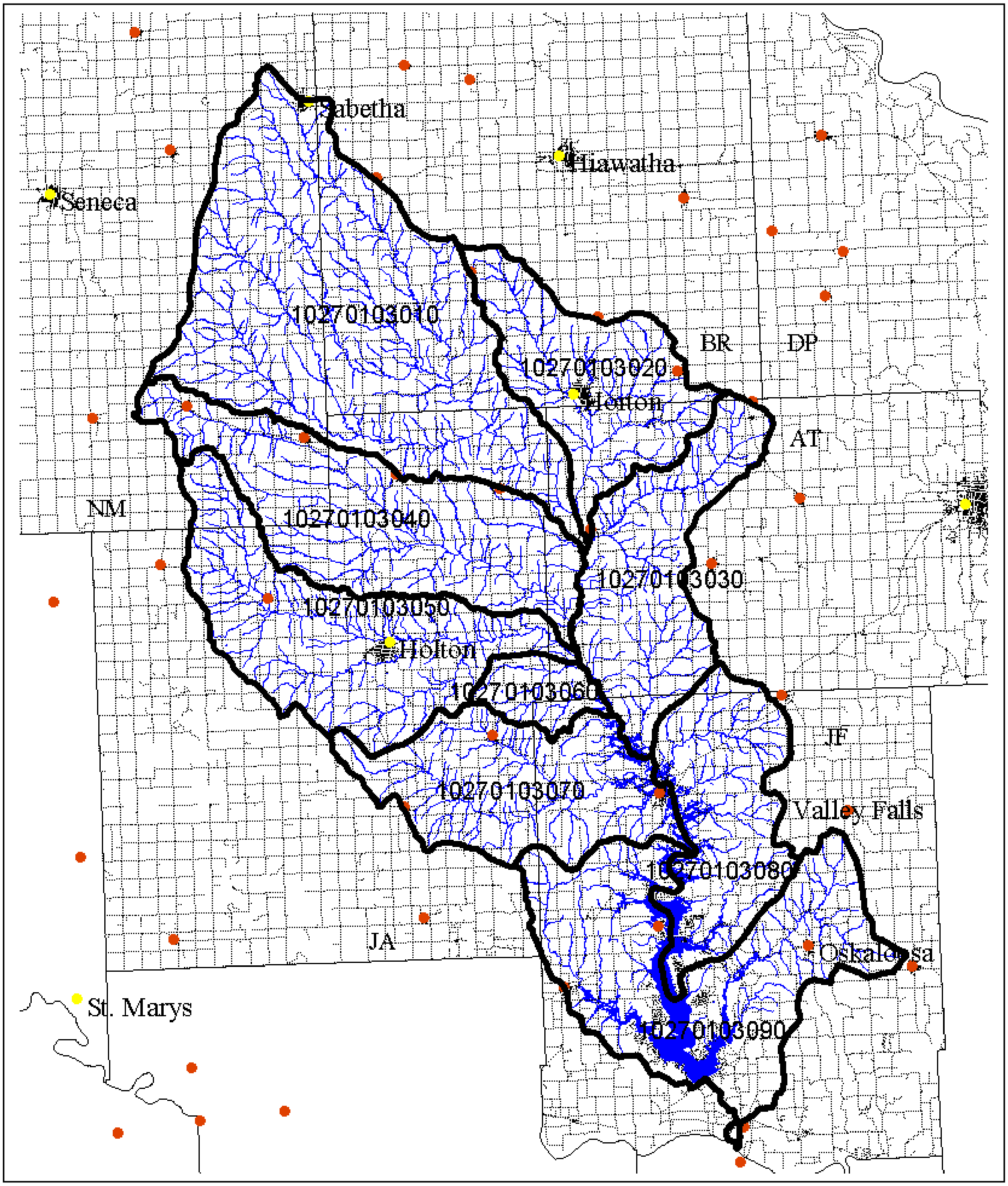
Table 3.10 Marion Basin Erosion and Switchgrass Yield

		Switchgrass Yield (dry ton/a/ yr)		
Soil	**Erosion (tons/yr/a)**	**Max**	**Min**	**Ave**
KIPSON	80	5.7	0.1	2.7
LANCASTER	42	7.2	0.1	3.4
HEDVILLE	27	5.1	0	2.6
WELLS	**26**	**10.4**	**1.1**	**5.0**
FARNUM	**24**	**10.6**	**1.3**	**5.3**

3.4 Perry Sub-Basin Soil Erosion and Switchgrass Yield

To better target opportunities for erosion control and high biomass yields data for the basin was sorted by the 11 digit hydrologic unit codes (HUC) which divide the basin into nine sub-basins.

Figure 3.1 Perry Sub-Basin Map (Northeast Kansas)



Note: The last two digits of the 11 digit Hydrologic Unit Code (HUC) shown are used as identifiers in tables and text.

3.4.1 High Erosion Areas of the Perry Basin

Table 3.11 below shows total acres, erosion by several categories, average switchgrass yield, and total switchgrass average production potential from soils with estimated average cumulative erosion greater than 40 t/a/yr, by sub-basin. About 18% of tilled land within the basin has estimated erosion greater than 40 t/a/yr. It is concentrated in sub-basins 80 and 90. Average switchgrass production from these lands totals over 240,000 tons/year.

Table 3.11 Switchgrass Yield on Tilled High Erosion Soils in the Perry Basin (ALMANAC)

Erosion and Switchgrass Yield by Perry Sub-Basin										
ALMANAC Model Results Summary								Switchgrass Production		
Area		Erosion						(soils w/ > 40 t/yr erosion and > 5 dt/a switchgrass yield)		
Perry Sub-basin	Total Acres	Total Erosion Tons/yr	Ave (t/a/yr)	Acres > 40 t/a/yr	Percent > 40 t/a/yr	Total Erosion Tons/yr	Ave (t/a/yr)	Acres	Ave (t/a/yr)	Total S'grass Tons/yr
10	86,419	4,324,741	50.0	9,012	10.4%	1,159,986	128.7	7,524	5.6	42,279
20	37,414	1,436,260	38.4	1,283	3.4%	162,353	126.5	950	5.6	5,348
30	31,082	1,518,027	48.8	6,113	19.7%	626,293	102.5	5,743	5.6	32,090
40	32,344	1,690,997	52.3	6,116	18.9%	678,296	110.9	6,046	5.6	33,646
50	19,506	1,044,030	53.5	3,434	17.6%	341,295	99.4	3,317	5.6	18,467
60	5,984	310,899	52.0	852	14.2%	82,638	97.0	576	6.2	3,581
70	20,655	1,261,812	61.1	5,008	24.2%	506,023	101.0	3,561	5.9	21,042
80	19,074	1,256,200	65.9	7,984	41.9%	745,477	93.4	7,268	5.6	40,463
90	17,710	1,334,737	75.4	8,956	50.6%	901,738	100.7	7,632	5.9	45,214
Totals	270,188	14,177,704	52.5	48,759	18.0%	5,204,098	106.7	42,618	5.7	242,129

Note: Sub-basin two digit identification numbers correspond to the last two digits of the 11 digit HUC numbers shown on the sub-basin map shown above.

Table 3.12 below shows the number of acres by soil type, for soils with estimated annual erosion greater than 40 t/a/year, for each Perry Sub-basin.

Table 3.12 Acres of High Erosion Soils by Perry Sub-Basins (ALMANAC)

Soils With ALMANAC Estimated Erosion > 40 t/a/yr										
	Sub-Basin Acres (**bold** values indicate switchgrass estimated average yield > 5 d.t./a)									Total Acres
Soil	10	20	30	40	50	60	70	80	90	
Steinauer	**162**	**55**	**379**	**103**	**1**	**0**	**0**	**0**	**0**	**701**
Kipson	1,184	278	0	0	0	0	0	0	0	1,462
Reading	**79**	**59**	**206**	**0**	**281**	**0**	**496**	**380**	**725**	**2,226**
Sogn	106	0	0	48	51	23	59	0	2	290
Burchard	**5,645**	**0**	**0**	**3,717**	**610**	**0**	**0**	**0**	**0**	**9,972**
Morrill	**232**	**163**	**0**	**0**	**0**	**5**	**59**	**189**	**404**	**1,052**
Oska	0.0	0	0	0	0	0	0	29	49	78
Martin	**479**	**165**	**815**	**196**	**123**	**528**	**1,541**	**953**	**4,147**	**8,948**
Vinland	197	56	340	22	65	253	1,098	556	962	2,452
Shelby	**930**	**563**	**4,712**	**2,061**	**2,303**	**43**	**1,502**	**5,980**	**2,869**	**20,962**
Gosport	0	0	3	0	0	5	0	0	0	8
Sibleyville	0	0	26	0	0	0	295	131	311	763
Armster	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Gymer	**0**	**0**	**9**	**0**	**0**	**0**	**42**	**146**	**212**	**408**
SubTotal > 5 dt/a)	**7,526**	**1,005**	**6,122**	**6,077**	**3,319**	**576**	**3,641**	**7,648**	**8,357**	**44,271**
SubTotal < 5 dt/a)	1,487	334	370	70	117	281	1,452	716	1,325	5,052
SubTotal	9,014	1,338	6,492	6,147	3,435	857	5,092	8,364	9,681	49,323

Note: Sub-basin two digit identification numbers correspond to the last two digits of the 11 digit HUC numbers shown on the sub-basin map shown above.

Cumulative cropland soil erosion is shown on maps 3.7P ***Delaware Basin Cropland Erosion*** and 3.8M ***Marion Basin Cropland Erosion*** (see separate map Gazetteer). Average estimated switchgrass yield is shown on maps 3.9P ***Delaware Basin Switchgrass Yield*** and 3.10M ***Marion Basin Switchgrass Yield*** (see separate map Gazetteer). Map 3.11P***Delaware Basin Switchgrass Yield on High Erosion Sites,*** shows the location of land parcels with estimated cumultive 24 year soil erosion greater than 24 tons/acre with estimated average switchgrass yield of 5 tons/acre or more.

Table 3.13 below provides detailed data on erosion and switchgrass production potential for each Perry sub-basin.

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance

Perry Basin Cropland Erosion, Switchgrass N and Yield, By Soil Type for Nine Sub-Basins

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
10	005SS	2	**180.5**	399	12.4	0.2	5.2	155.7	18.5	**STEINAUER**	SHELBY-STEINAUER LOAMS, 12 TO 25 PERCENT SLOPES	jq
10	013BX	126	**180.5**	22702	12.4	0.2	5.2	155.7	0.0	**STEINAUER**		jq
10	131ST	34	**180.5**	6163	12.4	0.2	5.2	155.7	18.5	**STEINAUER**	STEINAUER CLAY LOAM, 12 TO 25 PERCENT SLOPES	jq
10	013KP	127	**100.2**	12685	6.8	0.0	2.7	68.2	0.0	KIPSON		fa
10	013PD	1018	**100.2**	102003	6.8	0.0	2.7	68.2	0.0	KIPSON		fa
10	013PE	13	**100.2**	1326	6.8	0.0	2.7	68.2	0.0	KIPSON		fa
10	131KP	26	**100.2**	2652	6.8	0.0	2.7	68.2	15.0	KIPSON	KIPSON SILTY CLAY LOAM, 5 TO 25 PERCENT SLOPES	fa
10	131RE	79	**77.8**	6148	12.4	1.4	6.2	148.2	0.5	**READING**	READING SILT LOAM	iq
10	085VC	106	**63.8**	6767	4.5	0.0	1.8	32.2	10.0	SOGN	VINLAND-SOGN COMPLEX, 5 TO 20 PERCENT SLOPES	jl
10	131BS	5645	**59.2**	334051	11.4	1.3	5.6	133.2	10.0	**BURCHARD**	BURCHARD-STEINAUER CLAY LOAMS, 6 TO 12 PERCENT SLOPES	az
10	013PM	114	**53.2**	6045	10.7	1.3	5.4	134.2	0.0	**MORRILL**		gw
10	131MB	88	**53.2**	4668	10.7	1.3	5.4	134.2	6.0	**MORRILL**	MORRILL LOAM, 4 TO 8 PERCENT SLOPES	gw
10	131ME	30	**53.2**	1613	10.7	1.3	5.4	134.2	6.0	**MORRILL**	MORRILL CLAY LOAM, 4 TO 8 PERCENT SLOPES, ERODED	gw
10	013PF	0	**49.1**	1	9.0	0.2	4.1	101.9	0.0	OSKA		ht
10	005MC	31	**48.6**	1482	12.8	1.5	6.3	170.2	5.0	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 7 PERCENT SLOPES	gg
10	013MF	74	**48.6**	3610	12.8	1.5	6.3	170.2	0.0	**MARTIN**		gg
10	085MA	244	**48.6**	11856	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES	gg
10	085MB	130	**48.6**	6316	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES, ERODED	gg
10	005VS	13	**46.7**	596	6.2	0.0	2.6	54.0	9.5	VINLAND	VINLAND SILTY CLAY LOAM, 4 TO 15 PERCENT SLOPES	ko
10	085MC	13	**46.7**	612	6.2	0.0	2.6	54.0	7.5	VINLAND	MARTIN-VINLAND SILTY CLAY LOAMS, 5 TO 10 PERCENT SLOPES	ko
10	085VA	171	**46.7**	8010	6.2	0.0	2.6	54.0	10.0	VINLAND	VINLAND SILTY CLAY LOAM 6 TO 14 PERCENT SLOPES	ko
10	005SM	57	**43.5**	2471	11.4	1.3	5.4	141.5	11.0	**SHELBY**	SHELBY CLAY LOAM, 7 TO 15 PERCENT SLOPES, ERODED	jf
10	085BA	142	**43.5**	6203	11.4	1.3	5.4	141.5	9.5	**SHELBY**	BURCHARD-SHELBY CLAY LOAMS, 7 TO 12 PERCENT SLOPES	jf
10	085BB	172	**43.5**	7501	11.4	1.3	5.4	141.5	9.5	**SHELBY**	BURCHARD-SHELBY CLAY LOAMS, 7 TO 12 PERCENT SLOPES, ERODED	jf
10	085BC	12	**43.5**	544	11.4	1.3	5.4	141.5	18.5	**SHELBY**	BURCHARD-SHELBY COMPLEX, 12 TO 25 PERCENT SLOPES	jf
10	085SA	224	**43.5**	9758	11.4	1.3	5.4	141.5	6.0	**SHELBY**	SHELBY CLAY LOAM, 4 TO 8 PERCENT SLOPES	jf
10	085SB	322	**43.5**	14011	11.4	1.3	5.4	141.5	6.0	**SHELBY**	SHELBY CLAY LOAM, 4 TO 8 PERCENT SLOPES, ERODED	jf
10	005PC	315	33.4	10513	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
10	005PD	41	33.4	1369	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY, 3 TO 7 PERCENT SLOPES, ERODED	hy
10	013BS	807	33.4	26976	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a)			Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
					Max	Min	Ave					
10	013MD	97	33.4	3233	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
10	013OM	264	33.4	8840	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
10	013PN	4396	33.4	146932	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
10	013SG	29	33.4	962	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
10	013SM	22	33.4	736	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
10	013WE	25	33.4	837	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
10	013WG	59	33.4	1980	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
10	013WM	12584	33.4	420610	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
10	085PA	81	33.4	2700	11.0	1.3	5.6	121.4	2.0	PAWNEE	PAWNEE CLAY LOAM, 1 TO 3 PERCENT SLOPES	hy
10	085PB	869	33.4	29039	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
10	085PC	1144	33.4	38244	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES, ERODED	hy
10	131PA	5071	33.4	169496	11.0	1.3	5.6	121.4	2.5	PAWNEE	PAWNEE CLAY LOAM, 1 TO 4 PERCENT SLOPES	hy
10	131PB	10715	33.4	358141	11.0	1.3	5.6	121.4	6.0	PAWNEE	PAWNEE CLAY LOAM, 4 TO 8 PERCENT SLOPES	hy
10	131PE	456	33.4	15253	11.0	1.3	5.6	121.4	6.0	PAWNEE	PAWNEE CLAY, 4 TO 8 PERCENT SLOPES, ERODED	hy
10	085OA	180	17.5	3150	12.2	0.3	5.6	137.6	3.5	OLMITZ	OLMITZ CLAY LOAM, 2 TO 5 PERCENT SLOPES	ho
10	131OM	366	17.5	6407	12.2	0.3	5.6	137.6	3.0	OLMITZ	OLMITZ LOAM, 1 TO 5 PERCENT SLOPES	ho
10	005GR	95	17.1	1628	11.7	1.4	5.9	159.0	1.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	dr
10	005GU	125	17.1	2136	11.7	1.4	5.9	159.0	4.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 2 TO 6 PERCENT SLOPES	dr
10	013MH	127	14.0	1779	9.9	1.1	5.0	130.3	0.0	WYMORE		ld
10	085WB	1708	14.0	23875	9.9	1.1	5.0	130.3	2.0	WYMORE	WYMORE SILTY CLAY LOAM, 1 TO 3 PERCENT SLOPES	ld
10	085WC	1786	14.0	24966	9.9	1.1	5.0	130.3	3.5	WYMORE	WYMORE SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPES, ERODED	ld
10	131WB	9060	14.0	126641	9.9	1.1	5.0	130.3	2.5	WYMORE	WYMORE SILTY CLAY LOAM, 1 TO 4 PERCENT SLOPES	ld
10	131WC	523	14.0	7304					6.0	WYMORE	WYMORE SILTY CLAY LOAM, 4 TO 8 PERCENT SLOPES	ld
10	005JU	33	12.0	390	13.8	0.8	6.3	116.3	4.5	JUDSON	JUDSON SILT LOAM, 2 TO 7 PERCENT SLOPES	el
10	013GA	293	11.3	3295	10.6	1.0	5.3	142.0	0.0	HAIG		dt
10	005KE	547	11.1	6049	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
10	005KF	5	11.1	54	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM, CHANNELED	et
10	013JU	140	11.1	1550	14.9	1.5	7.0	92.0	0.0	KENNEBEC		et
10	013KD	31	11.1	345	14.9	1.5	7.0	92.0	0.0	KENNEBEC		et
10	013MT	94	11.1	1037	14.9	1.5	7.0	92.0	0.0	KENNEBEC		et
10	013MY	1705	11.1	18868	14.9	1.5	7.0	92.0	0.0	KENNEBEC		et
10	013PO	758	11.1	8386	14.9	1.5	7.0	92.0	0.0	KENNEBEC		et
10	085KA	985	11.1	10904	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
10	085KB	185	11.1	2052	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS	et
10	085KC	3	11.1	29	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS, CHANNELED	et
10	131KE	3593	11.1	39764	14.9	1.5	7.0	92.0	0.5	KENNEBEC	KENNEBEC SILT LOAM	et
10	131KN	71	11.1	787	14.9	1.5	7.0	92.0	0.5	KENNEBEC	KENNEBEC SILT LOAM, CHANNELED	et
10	005WA	580	11.0	6388	12.2	1.3	5.8	128.7	1.0	WABASH	WABASH SILTY CLAY LOAM	ks
10	005WB	237	11.0	2615	12.2	1.3	5.8	128.7	1.0	WABASH	WABASH SILTY CLAY	ks
10	085WA	552	11.0	6081	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY	ks
10	131WA	493	11.0	5431	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY LOAM	ks
10	005CH	113	10.7	1206	13.9	1.5	6.8	160.0	1.0	CHASE	CHASE SILTY CLAY LOAM	bo
10	013CH	1429	10.7	15307	13.9	1.5	6.8	160.0	0.0	CHASE		bo
10	085CA	330	10.7	3532	13.9	1.5	6.8	160.0	1.0	CHASE	CHASE SILTY CLAY LOAM	bo
10	131CH	132	10.7	1410	13.9	1.5	6.8	160.0	0.5	CHASE	CHASE SILTY CLAY LOAM	bo
10	013RE	56	10.5	586	12.5	1.3	6.2	119.1	0.0	ZOOK		li
10	085ZA	1176	10.5	12366	12.5	1.3	6.2	119.1	1.0	ZOOK	ZOOK SILTY CLAY LOAM	li
10	005PT	3	0.0	0					0.0			
10	005WA	22	0.0	0					0.0			
10	013KE	2952	0.0	0	13.0	1.4	6.0	134.3	0.0	NODAWAY		hi
10	013MU	22	0.0	0					0.0			
10	013PT	12	0.0	0					0.0			
10	013WA	37	0.0	0					0.0			
10	013WN	9794	0.0	0	11.2	1.2	5.5	143.6	0.0	MAYBERRY		gj
10	085WA	19	0.0	0					0.0			
10	131PT	18	0.0	0					0.0			
	131WA	43	0.0	0					0.0			
Totals		**86,419**	acres	**4,324,741**	**tons**	**50.0**	**ave tons/acre**					
Totals >40 t/a		**9,012**	acres	**1,159,986**	**tons**	**128.7**	**ave tons/acre for soils > 40 tons/acre**					

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
20	005SS	55	**180.5**	9893	12.4	0.2	5.2	155.7	18.5	**STEINAUER**	SHELBY-STEINAUER LOAMS, 12 TO 25 PERCENT SLOPES	jq
20	013KP	7	**100.2**	686	6.8	0.0	2.7	68.2	0.0	KIPSON		fa
20	013PD	271	**100.2**	27152	6.8	0.0	2.7	68.2	0.0	KIPSON		fa
20	005RE	59	**77.8**	4624	12.4	1.4	6.2	148.2	1.0	**READING**	READING SILT LOAM	iq
20	013AD	135	**53.2**	7197	10.7	1.3	5.4	134.2	0.0	**MORRILL**		gw
20	013AE	21	**53.2**	1143	10.7	1.3	5.4	134.2	0.0	**MORRILL**		gw
20	013PM	6	**53.2**	322	10.7	1.3	5.4	134.2	0.0	**MORRILL**		gw
20	005MC	164	**48.6**	7981	12.8	1.5	6.3	170.2	5.0	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 7 PERCENT SLOPES	gg
20	013MF	0	**48.6**	21	12.8	1.5	6.3	170.2	0.0	**MARTIN**		gg
20	005VS	56	**46.7**	2607	6.2	0.0	2.6	54.0	9.5	VINLAND	VINLAND SILTY CLAY LOAM, 4 TO 15 PERCENT SLOPES	ko
20	005SH	41	**43.5**	1763	11.4	1.3	5.4	141.5	7.5	**SHELBY**	SHELBY CLAY LOAM, 5 TO 10 PERCENT SLOPES	jf
20	005SM	522	**43.5**	22733	11.4	1.3	5.4	141.5	11.0	**SHELBY**	SHELBY CLAY LOAM, 7 TO 15 PERCENT SLOPES, ERODED	jf
20	005PC	1715	33.4	57318	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
20	005PD	156	33.4	5202	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY, 3 TO 7 PERCENT SLOPES, ERODED	hy
	013MD	53	33.4	1784	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
20	013OM	22	33.4	727	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
20	013PN	4624	33.4	154543	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
20	013SG	80	33.4	2681	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
	013SM	87	33.4	2913	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
20	013WE	537	33.4	17945	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
20	013WG	53	33.4	1783	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
20	013WM	9937	33.4	332123	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
20	085PB	4	33.4	137	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
20	005GR	465	17.1	7948	11.7	1.4	5.9	159.0	1.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	dr
20	005GU	398	17.1	6806	11.7	1.4	5.9	159.0	4.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 2 TO 6 PERCENT SLOPES	dr
20	013MH	251	14.0	3511	9.9	1.1	5.0	130.3	0.0	WYMORE		ld
20	085WB	124	14.0	1728	9.9	1.1	5.0	130.3	2.0	WYMORE	WYMORE SILTY CLAY LOAM, 1 TO 3 PERCENT SLOPES	ld
20	085WC	82	14.0	1144	9.9	1.1	5.0	130.3	3.5	WYMORE	WYMORE SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPES, ERODED	ld
20	005KG	181	12.3	2217	12.9	1.3	5.9	127.2	1.0	COLO	KENNEBEC-COLO SILT LOAMS	bz
20	005JU	159	12.0	1905	13.8	0.8	6.3	116.3	4.5	JUDSON	JUDSON SILT LOAM, 2 TO 7 PERCENT SLOPES	el
20	013GA	650	11.3	7324	10.6	1.0	5.3	142.0	0.0	HAIG		dt
20	005KE	858	11.1	9496	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
20	005KF	130	11.1	1435	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM, CHANNELED	et
20	013JU	53	11.1	588	14.9	1.5	7.0	92.0	0.0	KENNEBEC		et

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
20	013KD	73	11.1	804	14.9	1.5	7.0	92.0	0.0	KENNEBEC		et
20	013MT	112	11.1	1235	14.9	1.5	7.0	92.0	0.0	KENNEBEC		et
20	013MY	11	11.1	118	14.9	1.5	7.0	92.0	0.0	KENNEBEC		et
20	013PO	77	11.1	857	14.9	1.5	7.0	92.0	0.0	KENNEBEC		et
20	005WA	348	11.0	3841	12.2	1.3	5.8	128.7	1.0	WABASH	WABASH SILTY CLAY LOAM	ks
20	005WB	41	11.0	449					1.0	WABASH	WABASH SILTY CLAY	ks
20	005CH	202	10.7	2168	13.9	1.5	6.8	160.0	1.0	CHASE	CHASE SILTY CLAY LOAM	bo
20	013CH	546	10.7	5847	13.9	1.5	6.8	160.0	0.0	CHASE		bo
20	013RE	36	10.5	374	12.5	1.3	6.2	119.1	0.0	ZOOK		li
20	005DA	1	0.0	0					0.0			
20	005QU	44	0.0	0					0.0			
20	005WA	52	0.0	0					0.0			
20	013KE	968	0.0	0	13.0	1.4	6.0	134.3	0.0	NODAWAY		hi
20	013SW	1	0.0	0					0.0			
20	013WA	67	0.0	0					0.0			
20	013WN	12934	0.0	0	11.2	1.2	5.5	143.6	0.0	MAYBERRY		gj
	085WA	0	0.0	0					0.0			
Totals		**37,414**	acres	**1,436,260**	**tons**	**38.4**	**ave tons/acre**					
Totals >40 t/a		**1,283**	acres	**162,353**	**tons**	**126.5**	**ave tons/acre for soils > 40 tons/acre**					

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
30	005SS	379	**180.5**	68427	12.4	0.2	5.2	155.7	18.5	**STEINAUER**	SHELBY-STEINAUER LOAMS, 12 TO 25 PERCENT SLOPES	jq
30	005GO	3	**97.7**	332	9.0	0.9	4.6	128.2	35.0	GOSPORT	GOSPORT SILTY CLAY LOAM, 25 TO 45 PERCENT SLOPES	dn
30	005RE	12	**77.8**	927	12.4	1.4	6.2	148.2	1.0	**READING**	READING SILT LOAM	iq
30	087RE	194	**77.8**	15075	12.4	1.4	6.2	148.2	0.5	**READING**	READING SILT LOAM	iq
30	087SV	26	**59.2**	1542	7.8	0.1	3.3	84.3	9.5	SIBLEYVILLE	SIBLEYVILLE COMPLEX, 7 TO 12 PERCENT SLOPES	ji
30	005AR	1	**53.6**	59	10.6	0.3	5.0	146.1	9.0	**ARMSTER**	ARMSTER CLAY LOAM, 6 TO 12 PERCENT SLOPES	ah
30	005MC	567	**48.6**	27564	12.8	1.5	6.3	170.2	5.0	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 7 PERCENT SLOPES	gg
30	087MC	231	**48.6**	11213	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES	gg
30	087MH	13	**48.6**	619	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SOILS, 3 TO 8 PERCENT SLOPES, ERODED	gg
30	087MO	5	**48.6**	221	12.8	1.5	6.3	170.2	4.5	**MARTIN**	MARTIN-OSKA SILTY CLAY LOAMS, 3 TO 6 PERCENT SLOPES	gg
30	005VS	174	**46.7**	8114	6.2	0.0	2.6	54.0	9.5	VINLAND	VINLAND SILTY CLAY LOAM, 4 TO 15 PERCENT SLOPES	ko
30	087VC	138	**46.7**	6436	6.2	0.0	2.6	54.0	5.0	VINLAND	VINLAND COMPLEX, 3 TO 7 PERCENT SLOPES	ko
30	087VO	29	**46.7**	1342	6.2	0.0	2.6	54.0	11.0	VINLAND	VINLAND COMPLEX, 7 TO 15 PERCENT SLOPES	ko
30	087VX	0	**46.7**	10	6.2	0.0	2.6	54.0	30.0	VINLAND	VINLAND-ROCK OUTCROP COMPLEX, 20 TO 40 PERCENT SLOPES	ko
30	005SH	305	**43.5**	13288	11.4	1.3	5.4	141.5	7.5	**SHELBY**	SHELBY CLAY LOAM, 5 TO 10 PERCENT SLOPES	jf
30	005SM	4075	**43.5**	177389	11.4	1.3	5.4	141.5	11.0	**SHELBY**	SHELBY CLAY LOAM, 7 TO 15 PERCENT SLOPES, ERODED	jf
30	087SC	327	**43.5**	14228	11.4	1.3	5.4	141.5	5.5	**SHELBY**	SHELBY-PAWNEE COMPLEX, 3 TO 8 PERCENT SLOPES	jf
30	087SO	4	**43.5**	191	11.4	1.3	5.4	141.5	10.0	**SHELBY**	SHELBY-PAWNEE COMPLEX, 8 TO 12 PERCENT SLOPES	jf
30	087GY	9	**41.9**	384	12.8	1.4	6.4	165.0	5.0	**GYMER**	GYMER SILT LOAM, 3 TO 7 PERCENT SLOPES	ds
30	005PC	6554	33.4	219053	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
30	005PD	660	33.4	22057	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY, 3 TO 7 PERCENT SLOPES, ERODED	hy
30	013PN	0	33.4	9	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
30	013WM	976	33.4	32632	11.0	1.3	5.6	121.4	0.0	PAWNEE		hy
30	087PC	256	33.4	8540	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
30	087PH	0	33.4	3	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE SOILS, 3 TO 7 PERCENT SLOPES, ERODED	hy
30	005GR	1633	17.1	27907	11.7	1.4	5.9	159.0	1.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	dr
30	005GU	3485	17.1	59562	11.7	1.4	5.9	159.0	4.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 2 TO 6 PERCENT SLOPES	dr
30	005GX	170	17.1	2912	11.7	1.4	5.9	159.0	5.0	GRUNDY	GRUNDY SILTY CLAY, 3 TO 7 PERCENT SLOPES, ERODED	dr
30	087GB	135	17.1	2302	11.7	1.4	5.9	159.0	1.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	dr
30	087GC	112	17.1	1913	11.7	1.4	5.9	159.0	3.5	GRUNDY	GRUNDY SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPES	dr
30	005KG	1379	12.3	16926	12.9	1.3	5.9	127.2	1.0	COLO	KENNEBEC-COLO SILT LOAMS	bz
30	005JU	219	12.0	2622	13.8	0.8	6.3	116.3	4.5	JUDSON	JUDSON SILT LOAM, 2 TO 7 PERCENT SLOPES	el
30	013GA	21	11.3	234	10.6	1.0	5.3	142.0	0.0	HAIG		dt

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
30	005KE	746	11.1	8252	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
30	005KF	221	11.1	2449	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM, CHANNELED	et
30	087KB	297	11.1	3282	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
30	087KC	1	11.1	9	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS, CHANNELED	et
30	005WA	725	11.0	7990	12.2	1.3	5.8	128.7	1.0	WABASH	WABASH SILTY CLAY LOAM	ks
30	005WB	1606	11.0	17696	12.2	1.3	5.8	128.7	1.0	WABASH	WABASH SILTY CLAY	ks
	087WC	345	11.0	3801	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY LOAM	ks
30	087WH	18	11.0	198	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY	ks
30	005CH	515	10.7	5515	13.9	1.5	6.8	160.0	1.0	CHASE	CHASE SILTY CLAY LOAM	bo
	005QU	1	0.0	0					0.0			
	005WA	130	0.0	0					0.0			
30	013WN	4752	0.0	0	11.2	1.2	5.5	143.6	0.0	MAYBERRY		gj
	087WA	13	0.0	0					0.0			
Totals		**31,082**	acres	**1,518,027**	**tons**	**48.8**	**ave tons/acre**					
Totals >40 t/a		**6,113**	acres	**626,293**	**tons**	**102.5**	**ave tons/acre for soils > 40 tons/acre**					

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
40	005SS	31	**180.5**	5549	12.4	0.2	5.2	155.7	18.5	**STEINAUER**	SHELBY-STEINAUER LOAMS, 12 TO 25 PERCENT SLOPES	jq
40	131ST	73	**180.5**	13096	12.4	0.2	5.2	155.7	18.5	**STEINAUER**	STEINAUER CLAY LOAM, 12 TO 25 PERCENT SLOPES	jq
40	085VC	48	**63.8**	3034	4.5	0.0	1.8	32.2	10.0	SOGN	VINLAND-SOGN COMPLEX, 5 TO 20 PERCENT SLOPES	jl
40	131BS	3717	**59.2**	219948	11.4	1.3	5.6	133.2	10.0	**BURCHARD**	BURCHARD-STEINAUER CLAY LOAMS, 6 TO 12 PERCENT SLOPES	az
40	005MC	40	**48.6**	1942	12.8	1.5	6.3	170.2	5.0	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 7 PERCENT SLOPES	gg
40	085MA	27	**48.6**	1295	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES	gg
40	085MB	130	**48.6**	6305	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES, ERODED	gg
40	005VS	14	**46.7**	644	6.2	0.0	2.6	54.0	9.5	VINLAND	VINLAND SILTY CLAY LOAM, 4 TO 15 PERCENT SLOPES	ko
40	085MC	8	**46.7**	378	6.2	0.0	2.6	54.0	7.5	VINLAND	MARTIN-VINLAND SILTY CLAY LOAMS, 5 TO 10 PERCENT SLOPES	ko
40	085VA	0	**46.7**	22	6.2	0.0	2.6	54.0	10.0	VINLAND	VINLAND SILTY CLAY LOAM 6 TO 14 PERCENT SLOPES	ko
40	005SH	38	**43.5**	1650	11.4	1.3	5.4	141.5	7.5	**SHELBY**	SHELBY CLAY LOAM, 5 TO 10 PERCENT SLOPES	jf
40	005SM	232	**43.5**	10098	11.4	1.3	5.4	141.5	11.0	**SHELBY**	SHELBY CLAY LOAM, 7 TO 15 PERCENT SLOPES, ERODED	jf
40	085BA	311	**43.5**	13531	11.4	1.3	5.4	141.5	9.5	**SHELBY**	BURCHARD-SHELBY CLAY LOAMS, 7 TO 12 PERCENT SLOPES	jf
40	085BB	801	**43.5**	34886	11.4	1.3	5.4	141.5	9.5	**SHELBY**	BURCHARD-SHELBY CLAY LOAMS, 7 TO 12 PERCENT SLOPES, ERODED	jf
40	085BC	48	**43.5**	2082	11.4	1.3	5.4	141.5	18.5	**SHELBY**	BURCHARD-SHELBY COMPLEX, 12 TO 25 PERCENT SLOPES	jf
40	085SA	166	**43.5**	7235	11.4	1.3	5.4	141.5	6.0	**SHELBY**	SHELBY CLAY LOAM, 4 TO 8 PERCENT SLOPES	jf
40	085SB	465	**43.5**	20229	11.4	1.3	5.4	141.5	6.0	**SHELBY**	SHELBY CLAY LOAM, 4 TO 8 PERCENT SLOPES, ERODED	jf
40	005PC	743	33.4	24821	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
40	005PD	0	33.4	0	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY, 3 TO 7 PERCENT SLOPES, ERODED	hy
40	085PA	289	33.4	9663	11.0	1.3	5.6	121.4	2.0	PAWNEE	PAWNEE CLAY LOAM, 1 TO 3 PERCENT SLOPES	hy
40	085PB	2472	33.4	82624	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
40	085PC	3316	33.4	110845	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES, ERODED	hy
40	131PA	1351	33.4	45150	11.0	1.3	5.6	121.4	2.5	PAWNEE	PAWNEE CLAY LOAM, 1 TO 4 PERCENT SLOPES	hy
40	131PB	367	33.4	12267	11.0	1.3	5.6	121.4	6.0	PAWNEE	PAWNEE CLAY LOAM, 4 TO 8 PERCENT SLOPES	hy
40	131PE	43	33.4	1426	11.0	1.3	5.6	121.4	6.0	PAWNEE	PAWNEE CLAY, 4 TO 8 PERCENT SLOPES, ERODED	hy
40	085OA	685	17.5	12008	12.2	0.3	5.6	137.6	3.5	OLMITZ	OLMITZ CLAY LOAM, 2 TO 5 PERCENT SLOPES	ho
40	131OM	213	17.5	3732	12.2	0.3	5.6	137.6	3.0	OLMITZ	OLMITZ LOAM, 1 TO 5 PERCENT SLOPES	ho
40	005GR	141	17.1	2407	11.7	1.4	5.9	159.0	1.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	dr
40	005GU	310	17.1	5304	11.7	1.4	5.9	159.0	4.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 2 TO 6 PERCENT SLOPES	dr

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
40	005GX	40	17.1	682	11.7	1.4	5.9	159.0	5.0	GRUNDY	GRUNDY SILTY CLAY, 3 TO 7 PERCENT SLOPES, ERODED	dr
40	085WB	2632	14.0	36783	9.9	1.1	5.0	130.3	2.0	WYMORE	WYMORE SILTY CLAY LOAM, 1 TO 3 PERCENT SLOPES	ld
40	085WC	3568	14.0	49869	9.9	1.1	5.0	130.3	3.5	WYMORE	WYMORE SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPES, ERODED	ld
40	131WB	372	14.0	5204	9.9	1.1	5.0	130.3	2.5	WYMORE	WYMORE SILTY CLAY LOAM, 1 TO 4 PERCENT SLOPES	ld
40	005KE	449	11.1	4968	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
40	005KF	36	11.1	396	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM, CHANNELED	et
40	085KA	1232	11.1	13634	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
40	085KB	646	11.1	7147	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS	et
40	085KC	7	11.1	74	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS, CHANNELED	et
40	131KE	983	11.1	10881	14.9	1.5	7.0	92.0	0.5	KENNEBEC	KENNEBEC SILT LOAM	et
40	131KN	7	11.1	82	14.9	1.5	7.0	92.0	0.5	KENNEBEC	KENNEBEC SILT LOAM, CHANNELED	et
40	005WA	979	11.0	10787	12.2	1.3	5.8	128.7	1.0	WABASH	WABASH SILTY CLAY LOAM	ks
40	005WB	847	11.0	9337	12.2	1.3	5.8	128.7	1.0	WABASH	WABASH SILTY CLAY	ks
40	085WA	1420	11.0	15648	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY	ks
40	131WA	468	11.0	5163	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY LOAM	ks
40	005CH	100	10.7	1075	13.9	1.5	6.8	160.0	1.0	CHASE	CHASE SILTY CLAY LOAM	bo
40	085CA	782	10.7	8375	13.9	1.5	6.8	160.0	1.0	CHASE	CHASE SILTY CLAY LOAM	bo
40	131CH	5	10.7	50	13.9	1.5	6.8	160.0	0.5	CHASE	CHASE SILTY CLAY LOAM	bo
40	085ZA	1516	10.5	15948	12.5	1.3	6.2	119.1	1.0	ZOOK	ZOOK SILTY CLAY LOAM	li
40	005WA	66	0.0	0					0.0			
40	013WN	105	0.0	0	11.2	1.2	5.5	143.6	0.0	MAYBERRY		gj
40	085WA	28	0.0	0					0.0			
	131WA	9	0.0	0					0.0			
Totals		**32,344**	acres	**1,690,997**	**tons**	**52.3**	**ave tons/acre**					
Totals >40 t/a		**6,116**	acres	**678,296**	**tons**	**110.9**	**ave tons/acre for soils > 40 tons/acre**					

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
50	131ST	1	**180.5**	260	12.4	0.2	5.2	155.7	18.5	**STEINAUER**	STEINAUER CLAY LOAM, 12 TO 25 PERCENT SLOPES	jq
50	085RA	281	**77.8**	21835	12.4	1.4	6.2	148.2	1.0	**READING**	READING SILT LOAM	iq
50	085CB	21	**63.8**	1330	4.5	0.0	1.8	32.2	10.0	SOGN	CLIME-SOGN COMPLEX, 5 TO 20 PERCENT SLOPES	jl
50	085VC	30	**63.8**	1941	4.5	0.0	1.8	32.2	10.0	SOGN	VINLAND-SOGN COMPLEX, 5 TO 20 PERCENT SLOPES	jl
50	131BS	610	**59.2**	36122	11.4	1.3	5.6	133.2	10.0	**BURCHARD**	BURCHARD-STEINAUER CLAY LOAMS, 6 TO 12 PERCENT SLOPES	az
50	005MC	25	**48.6**	1205	12.8	1.5	6.3	170.2	5.0	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 7 PERCENT SLOPES	gg
50	085MA	85	**48.6**	4122	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES	gg
50	085MB	14	**48.6**	668	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES, ERODED	gg
50	005VS	3	**46.7**	127	6.2	0.0	2.6	54.0	9.5	VINLAND	VINLAND SILTY CLAY LOAM, 4 TO 15 PERCENT SLOPES	ko
50	085MC	58	**46.7**	2696	6.2	0.0	2.6	54.0	7.5	VINLAND	MARTIN-VINLAND SILTY CLAY LOAMS, 5 TO 10 PERCENT SLOPES	ko
50	085VA	3	**46.7**	133	6.2	0.0	2.6	54.0	10.0	VINLAND	VINLAND SILTY CLAY LOAM 6 TO 14 PERCENT SLOPES	ko
50	085VB	2	**46.7**	101	6.2	0.0	2.6	54.0	25.0	VINLAND	VINLAND-ROCK OUTCROP COMPLEX, 20 TO 40 PERCENT SLOPES	ko
50	005SM	21	**43.5**	923	11.4	1.3	5.4	141.5	11.0	**SHELBY**	SHELBY CLAY LOAM, 7 TO 15 PERCENT SLOPES, ERODED	jf
50	085BA	773	**43.5**	33629	11.4	1.3	5.4	141.5	9.5	**SHELBY**	BURCHARD-SHELBY CLAY LOAMS, 7 TO 12 PERCENT SLOPES	jf
50	085BB	659	**43.5**	28689	11.4	1.3	5.4	141.5	9.5	**SHELBY**	BURCHARD-SHELBY CLAY LOAMS, 7 TO 12 PERCENT SLOPES, ERODED	jf
50	085BC	53	**43.5**	2291	11.4	1.3	5.4	141.5	18.5	**SHELBY**	BURCHARD-SHELBY COMPLEX, 12 TO 25 PERCENT SLOPES	jf
50	085SA	606	**43.5**	26358	11.4	1.3	5.4	141.5	6.0	**SHELBY**	SHELBY CLAY LOAM, 4 TO 8 PERCENT SLOPES	jf
50	085SB	192	**43.5**	8347	11.4	1.3	5.4	141.5	6.0	**SHELBY**	SHELBY CLAY LOAM, 4 TO 8 PERCENT SLOPES, ERODED	jf
50	005PC	35	33.4	1174	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
50	005PD	5	33.4	151	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY, 3 TO 7 PERCENT SLOPES, ERODED	hy
50	085PA	278	33.4	9284	11.0	1.3	5.6	121.4	2.0	PAWNEE	PAWNEE CLAY LOAM, 1 TO 3 PERCENT SLOPES	hy
50	085PB	3655	33.4	122176	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
50	085PC	1902	33.4	63558	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES, ERODED	hy
50	131PA	890	33.4	29743	11.0	1.3	5.6	121.4	2.5	PAWNEE	PAWNEE CLAY LOAM, 1 TO 4 PERCENT SLOPES	hy
50	131PB	736	33.4	24584	11.0	1.3	5.6	121.4	6.0	PAWNEE	PAWNEE CLAY LOAM, 4 TO 8 PERCENT SLOPES	hy
50	131PE	11	33.4	370	11.0	1.3	5.6	121.4	6.0	PAWNEE	PAWNEE CLAY, 4 TO 8 PERCENT SLOPES, ERODED	hy
50	085OA	265	17.5	4639	12.2	0.3	5.6	137.6	3.5	OLMITZ	OLMITZ CLAY LOAM, 2 TO 5 PERCENT SLOPES	ho
50	131OM	30	17.5	525	12.2	0.3	5.6	137.6	3.0	OLMITZ	OLMITZ LOAM, 1 TO 5 PERCENT SLOPES	ho
50	085WB	1086	14.0	15180	9.9	1.1	5.0	130.3	2.0	WYMORE	WYMORE SILTY CLAY LOAM, 1 TO 3 PERCENT SLOPES	ld

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
50	085WC	686	14.0	9585	9.9	1.1	5.0	130.3	3.5	WYMORE	WYMORE SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPES, ERODED	ld
50	131WB	120	14.0	1678	9.9	1.1	5.0	130.3	2.5	WYMORE	WYMORE SILTY CLAY LOAM, 1 TO 4 PERCENT SLOPES	ld
50	005KE	214	11.1	2370	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
50	005KF	23	11.1	257	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM, CHANNELED	et
50	085KA	2382	11.1	26360	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
50	085KB	345	11.1	3814	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS	et
50	085KC	14	11.1	159	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS, CHANNELED	et
50	131KE	162	11.1	1793	14.9	1.5	7.0	92.0	0.5	KENNEBEC	KENNEBEC SILT LOAM	et
50	131KN	23	11.1	256	14.9	1.5	7.0	92.0	0.5	KENNEBEC	KENNEBEC SILT LOAM, CHANNELED	et
50	005WA	146	11.0	1614	12.2	1.3	5.8	128.7	1.0	WABASH	WABASH SILTY CLAY LOAM	ks
50	005WB	268	11.0	2951	12.2	1.3	5.8	128.7	1.0	WABASH	WABASH SILTY CLAY	ks
50	085WA	91	11.0	1002	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY	ks
50	131WA	30	11.0	325	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY LOAM	ks
50	005CH	35	10.7	377	13.9	1.5	6.8	160.0	1.0	CHASE	CHASE SILTY CLAY LOAM	bo
50	085CA	753	10.7	8060	13.9	1.5	6.8	160.0	1.0	CHASE	CHASE SILTY CLAY LOAM	bo
50	085ZA	1843	10.5	19381	12.5	1.3	6.2	119.1	1.0	ZOOK	ZOOK SILTY CLAY LOAM	li
50	005WA	2	0.0	0					0.0			
50	085PT	9	0.0	0					0.0			
50	085WA	34	0.0	0					0.0			
	131WA	2	0.0	0					0.0			
Totals		**19,506**	acres	**1,044,030**	**tons**	**53.5**	**ave tons/acre**					
Totals >40 t/a		**3,434**	acres	**341,295**	**tons**	**99.4**	**ave tons/acre for soils > 40 tons/acre**					

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
60	005GO	5	**97.7**	464	9.0	0.9	4.6	128.2	35.0	GOSPORT	GOSPORT SILTY CLAY LOAM, 25 TO 45 PERCENT SLOPES	dn
60	085VC	23	**63.8**	1491	4.5	0.0	1.8	32.2	10.0	SOGN	VINLAND-SOGN COMPLEX, 5 TO 20 PERCENT SLOPES	jl
60	087MV	5	**53.2**	288	10.7	1.3	5.4	134.2	5.0	**MORRILL**	MORRILL LOAM, 3 TO 7 PERCENT SLOPES	gw
60	005MC	206	**48.6**	10004	12.8	1.5	6.3	170.2	5.0	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 7 PERCENT SLOPES	gg
60	085MA	39	**48.6**	1887	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES	gg
60	085MB	149	**48.6**	7231	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES, ERODED	gg
60	087MC	80	**48.6**	3885	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES	gg
60	087MH	15	**48.6**	714	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SOILS, 3 TO 8 PERCENT SLOPES, ERODED	gg
	087MO	40	**48.6**	1938	12.8	1.5	6.3	170.2	4.5	**MARTIN**	MARTIN-OSKA SILTY CLAY LOAMS, 3 TO 6 PERCENT SLOPES	gg
	005VS	84	**46.7**	3944	6.2	0.0	2.6	54.0	9.5	VINLAND	VINLAND SILTY CLAY LOAM, 4 TO 15 PERCENT SLOPES	ko
	085MC	31	**46.7**	1455	6.2	0.0	2.6	54.0	7.5	VINLAND	MARTIN-VINLAND SILTY CLAY LOAMS, 5 TO 10 PERCENT SLOPES	ko
60	085VA	5	**46.7**	233	6.2	0.0	2.6	54.0	10.0	VINLAND	VINLAND SILTY CLAY LOAM 6 TO 14 PERCENT SLOPES	ko
60	085VB	1	**46.7**	57	6.2	0.0	2.6	54.0	25.0	VINLAND	VINLAND-ROCK OUTCROP COMPLEX, 20 TO 40 PERCENT SLOPES	ko
60	087SW	5	**46.7**	255	6.2	0.0	2.6	54.0	12.5	VINLAND	SOGN-VINLAND COMPLEX, 5 TO 20 PERCENT SLOPES	ko
60	087VC	114	**46.7**	5331	6.2	0.0	2.6	54.0	5.0	VINLAND	VINLAND COMPLEX, 3 TO 7 PERCENT SLOPES	ko
60	087VO	11	**46.7**	524	6.2	0.0	2.6	54.0	11.0	VINLAND	VINLAND COMPLEX, 7 TO 15 PERCENT SLOPES	ko
60	005SM	13	**43.5**	550	11.4	1.3	5.4	141.5	11.0	**SHELBY**	SHELBY CLAY LOAM, 7 TO 15 PERCENT SLOPES, ERODED	jf
60	085BA	17	**43.5**	738	11.4	1.3	5.4	141.5	9.5	**SHELBY**	BURCHARD-SHELBY CLAY LOAMS, 7 TO 12 PERCENT SLOPES	jf
60	085SA	13	**43.5**	563	11.4	1.3	5.4	141.5	6.0	**SHELBY**	SHELBY CLAY LOAM, 4 TO 8 PERCENT SLOPES	jf
60	005PC	229	33.4	7640	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
60	005PD	32	33.4	1053	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY, 3 TO 7 PERCENT SLOPES, ERODED	hy
60	085PA	12	33.4	404	11.0	1.3	5.6	121.4	2.0	PAWNEE	PAWNEE CLAY LOAM, 1 TO 3 PERCENT SLOPES	hy
60	085PB	1309	33.4	43758	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
60	085PC	326	33.4	10889	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES, ERODED	hy
	087PB	12	33.4	404	11.0	1.3	5.6	121.4	2.0	PAWNEE	PAWNEE CLAY LOAM, 1 TO 3 PERCENT SLOPES	hy
60	087PC	539	33.4	18022	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
60	087PH	85	33.4	2844	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE SOILS, 3 TO 7 PERCENT SLOPES, ERODED	hy
60	005GU	10	17.1	170	11.7	1.4	5.9	159.0	4.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 2 TO 6 PERCENT SLOPES	dr
60	087GB	56	17.1	963	11.7	1.4	5.9	159.0	1.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	dr

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
60	087GC	49	17.1	837	11.7	1.4	5.9	159.0	3.5	GRUNDY	GRUNDY SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPES	dr
60	085WB	620	14.0	8662	9.9	1.1	5.0	130.3	2.0	WYMORE	WYMORE SILTY CLAY LOAM, 1 TO 3 PERCENT SLOPES	ld
60	085WC	78	14.0	1095	9.9	1.1	5.0	130.3	3.5	WYMORE	WYMORE SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPES, ERODED	ld
60	005KG	38	12.3	468	12.9	1.3	5.9	127.2	1.0	COLO	KENNEBEC-COLO SILT LOAMS	bz
60	005KE	284	11.1	3144	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
60	005KF	35	11.1	388	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM, CHANNELED	et
60	085KA	153	11.1	1696	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
60	085KB	8	11.1	92	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS	et
60	085KC	11	11.1	122	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS, CHANNELED	et
60	087KB	59	11.1	657	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
60	005WA	202	11.0	2231	12.2	1.3	5.8	128.7	1.0	WABASH	WABASH SILTY CLAY LOAM	ks
60	005WB	205	11.0	2263	12.2	1.3	5.8	128.7	1.0	WABASH	WABASH SILTY CLAY	ks
	087WC	231	11.0	2542	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY LOAM	ks
60	087WH	246	11.0	2713	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY	ks
	005CH	0	10.7	5	13.9	1.5	6.8	160.0	1.0	CHASE	CHASE SILTY CLAY LOAM	bo
60	085CA	100	10.7	1069	13.9	1.5	6.8	160.0	1.0	CHASE	CHASE SILTY CLAY LOAM	bo
60	005WA	39	0.0	0					0.0			
60	013WN	151	0.0	0	11.2	1.2	5.5	143.6	0.0	MAYBERRY		gj
	085WA	9	0.0	0					0.0			
	087WA	2	0.0	0					0.0			
Totals		**5,984**	acres	**310,899**	**tons**	**52.0**	**ave tons/acre**					
Totals >40 t/a		**852**	acres	**82,638**	**tons**	**97.0**	**ave tons/acre for soils > 40 tons/acre**					

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a)			Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
					Max	Min	Ave					
70	085RA	84	**77.8**	6546	12.4	1.4	6.2	148.2	1.0	**READING**	READING SILT LOAM	iq
70	087RE	412	**77.8**	32053	12.4	1.4	6.2	148.2	0.5	**READING**	READING SILT LOAM	iq
70	085VC	59	**63.8**	3775	4.5	0.0	1.8	32.2	10.0	SOGN	VINLAND-SOGN COMPLEX, 5 TO 20 PERCENT SLOPES	jl
70	087SS	286	**59.2**	16918	7.8	0.1	3.3	84.3	5.0	SIBLEYVILLE	SIBLEYVILLE COMPLEX, 3 TO 7 PERCENT SLOPES	ji
70	087SV	9	**59.2**	530	7.8	0.1	3.3	84.3	9.5	SIBLEYVILLE	SIBLEYVILLE COMPLEX, 7 TO 12 PERCENT SLOPES	ji
70	087MV	59	**53.2**	3158	10.7	1.3	5.4	134.2	5.0	**MORRILL**	MORRILL LOAM, 3 TO 7 PERCENT SLOPES	gw
70	085MA	114	**48.6**	5522	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES	gg
70	085MB	13	**48.6**	628	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES, ERODED	gg
70	087MB	4	**48.6**	210	12.8	1.5	6.3	170.2	2.0	**MARTIN**	MARTIN SILTY CLAY LOAM, 1 TO 3 PERCENT SLOPES	gg
70	087MC	1098	**48.6**	53331	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES	gg
70	087MH	269	**48.6**	13061	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SOILS, 3 TO 8 PERCENT SLOPES, ERODED	gg
70	087MO	44	**48.6**	2144	12.8	1.5	6.3	170.2	4.5	**MARTIN**	MARTIN-OSKA SILTY CLAY LOAMS, 3 TO 6 PERCENT SLOPES	gg
70	085MC	392	**46.7**	18306	6.2	0.0	2.6	54.0	7.5	VINLAND	MARTIN-VINLAND SILTY CLAY LOAMS, 5 TO 10 PERCENT SLOPES	ko
	085VA	44	**46.7**	2037	6.2	0.0	2.6	54.0	10.0	VINLAND	VINLAND SILTY CLAY LOAM 6 TO 14 PERCENT SLOPES	ko
70	085VB	20	**46.7**	935	6.2	0.0	2.6	54.0	25.0	VINLAND	VINLAND-ROCK OUTCROP COMPLEX, 20 TO 40 PERCENT SLOPES	ko
70	087SW	73	**46.7**	3428	6.2	0.0	2.6	54.0	12.5	VINLAND	SOGN-VINLAND COMPLEX, 5 TO 20 PERCENT SLOPES	ko
70	087VC	463	**46.7**	21628	6.2	0.0	2.6	54.0	5.0	VINLAND	VINLAND COMPLEX, 3 TO 7 PERCENT SLOPES	ko
70	087VO	100	**46.7**	4666	6.2	0.0	2.6	54.0	11.0	VINLAND	VINLAND COMPLEX, 7 TO 15 PERCENT SLOPES	ko
70	087VX	6	**46.7**	293	6.2	0.0	2.6	54.0	30.0	VINLAND	VINLAND-ROCK OUTCROP COMPLEX, 20 TO 40 PERCENT SLOPES	ko
70	085BA	162	**43.5**	7068	11.4	1.3	5.4	141.5	9.5	**SHELBY**	BURCHARD-SHELBY CLAY LOAMS, 7 TO 12 PERCENT SLOPES	jf
70	085BB	482	**43.5**	20967	11.4	1.3	5.4	141.5	9.5	**SHELBY**	BURCHARD-SHELBY CLAY LOAMS, 7 TO 12 PERCENT SLOPES, ERODED	jf
70	085BC	0	**43.5**	16	11.4	1.3	5.4	141.5	18.5	**SHELBY**	BURCHARD-SHELBY COMPLEX, 12 TO 25 PERCENT SLOPES	jf
70	085SA	23	**43.5**	980	11.4	1.3	5.4	141.5	6.0	**SHELBY**	SHELBY CLAY LOAM, 4 TO 8 PERCENT SLOPES	jf
70	085SB	18	**43.5**	767	11.4	1.3	5.4	141.5	6.0	**SHELBY**	SHELBY CLAY LOAM, 4 TO 8 PERCENT SLOPES, ERODED	jf
70	087SC	798	**43.5**	34724	11.4	1.3	5.4	141.5	5.5	**SHELBY**	SHELBY-PAWNEE COMPLEX, 3 TO 8 PERCENT SLOPES	jf
70	087SO	19	**43.5**	844	11.4	1.3	5.4	141.5	10.0	**SHELBY**	SHELBY-PAWNEE COMPLEX, 8 TO 12 PERCENT SLOPES	jf
70	087GY	42	**41.9**	1748	12.8	1.4	6.4	165.0	5.0	**GYMER**	GYMER SILT LOAM, 3 TO 7 PERCENT SLOPES	ds
70	085PA	453	33.4	15153	11.0	1.3	5.6	121.4	2.0	PAWNEE	PAWNEE CLAY LOAM, 1 TO 3 PERCENT SLOPES	hy
70	085PB	3344	33.4	111787	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
70	085PC	1706	33.4	57025	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES, ERODED	hy
70	087PB	56	33.4	1874	11.0	1.3	5.6	121.4	2.0	PAWNEE	PAWNEE CLAY LOAM, 1 TO 3 PERCENT SLOPES	hy
70	087PC	3120	33.4	104280	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
70	087PH	264	33.4	8826	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE SOILS, 3 TO 7 PERCENT SLOPES, ERODED	hy
70	085OA	34	17.5	601	12.2	0.3	5.6	137.6	3.5	OLMITZ	OLMITZ CLAY LOAM, 2 TO 5 PERCENT SLOPES	ho
70	087GB	171	17.1	2921	11.7	1.4	5.9	159.0	1.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	dr
70	087GC	63	17.1	1075	11.7	1.4	5.9	159.0	3.5	GRUNDY	GRUNDY SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPES	dr
70	085WB	1205	14.0	16843	9.9	1.1	5.0	130.3	2.0	WYMORE	WYMORE SILTY CLAY LOAM, 1 TO 3 PERCENT SLOPES	ld
70	085WC	538	14.0	7522	9.9	1.1	5.0	130.3	3.5	WYMORE	WYMORE SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPES, ERODED	ld
70	087KM	2	11.9	27	11.6	1.3	5.6	142.0	0.5	KIMO	KIMO SILTY CLAY LOAM	ew
70	087HC	503	11.3	5663	10.6	1.0	5.3	142.0	1.0	HAIG	HAIG SILTY CLAY LOAM	dt
70	085KA	471	11.1	5215	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
70	085KB	218	11.1	2410	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS	et
70	085KC	66	11.1	735	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS, CHANNELED	et
70	087KB	1373	11.1	15188	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
70	087KC	138	11.1	1529	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS, CHANNELED	et
70	085WA	266	11.0	2936	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY	ks
70	087WC	845	11.0	9317	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY LOAM	ks
70	087WH	248	11.0	2728	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY	ks
70	085CA	312	10.7	3338	13.9	1.5	6.8	160.0	1.0	CHASE	CHASE SILTY CLAY LOAM	bo
70	085ZA	86	10.5	903	12.5	1.3	6.2	119.1	1.0	ZOOK	ZOOK SILTY CLAY LOAM	li
70	013WN	111	0.0	0	11.2	1.2	5.5	143.6	0.0	MAYBERRY		gj
70	085PT	2	0.0	0					0.0			
70	085WA	19	0.0	0					0.0			
70	087QU	1	0.0	0					0.0			
	087WA	30	0.0	0					0.0			
Totals		**20,655**	acres	**1,261,812**	**tons**	**61.1**	**ave tons/acre**					
Totals >40 t/a		**5,008**	acres	**506,023**	**tons**	**101.0**	**ave tons/acre for soils > 40 tons/acre**					

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
80	087RE	380	**77.8**	29545	12.4	1.4	6.2	148.2	0.5	**READING**	READING SILT LOAM	iq
80	087SS	117	**59.2**	6907	7.8	0.1	3.3	84.3	5.0	SIBLEYVILLE	SIBLEYVILLE COMPLEX, 3 TO 7 PERCENT SLOPES	ji
80	087SV	15	**59.2**	863	7.8	0.1	3.3	84.3	9.5	SIBLEYVILLE	SIBLEYVILLE COMPLEX, 7 TO 12 PERCENT SLOPES	ji
80	087MV	189	**53.2**	10078	10.7	1.3	5.4	134.2	5.0	**MORRILL**	MORRILL LOAM, 3 TO 7 PERCENT SLOPES	gw
80	087OC	29	**49.1**	1417	9.0	0.2	4.1	101.9	4.0	OSKA	OSKA SILTY CLAY LOAM, 2 TO 6 PERCENT SLOPES	ht
80	087MB	29	**48.6**	1407	12.8	1.5	6.3	170.2	2.0	**MARTIN**	MARTIN SILTY CLAY LOAM, 1 TO 3 PERCENT SLOPES	gg
80	087MC	710	**48.6**	34478	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES	gg
80	087MH	38	**48.6**	1848	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SOILS, 3 TO 8 PERCENT SLOPES, ERODED	gg
80	087MO	176	**48.6**	8561	12.8	1.5	6.3	170.2	4.5	**MARTIN**	MARTIN-OSKA SILTY CLAY LOAMS, 3 TO 6 PERCENT SLOPES	gg
80	087SW	53	**46.7**	2474	6.2	0.0	2.6	54.0	12.5	VINLAND	SOGN-VINLAND COMPLEX, 5 TO 20 PERCENT SLOPES	ko
80	087VC	175	**46.7**	8171	6.2	0.0	2.6	54.0	5.0	VINLAND	VINLAND COMPLEX, 3 TO 7 PERCENT SLOPES	ko
80	087VO	292	**46.7**	13650	6.2	0.0	2.6	54.0	11.0	VINLAND	VINLAND COMPLEX, 7 TO 15 PERCENT SLOPES	ko
80	087VX	36	**46.7**	1692	6.2	0.0	2.6	54.0	30.0	VINLAND	VINLAND-ROCK OUTCROP COMPLEX, 20 TO 40 PERCENT SLOPES	ko
80	005SH	426	**43.5**	18535	11.4	1.3	5.4	141.5	7.5	**SHELBY**	SHELBY CLAY LOAM, 5 TO 10 PERCENT SLOPES	jf
80	005SM	49	**43.5**	2124	11.4	1.3	5.4	141.5	11.0	**SHELBY**	SHELBY CLAY LOAM, 7 TO 15 PERCENT SLOPES, ERODED	jf
80	087SC	5180	**43.5**	225490	11.4	1.3	5.4	141.5	5.5	**SHELBY**	SHELBY-PAWNEE COMPLEX, 3 TO 8 PERCENT SLOPES	jf
80	087SO	326	**43.5**	14169	11.4	1.3	5.4	141.5	10.0	**SHELBY**	SHELBY-PAWNEE COMPLEX, 8 TO 12 PERCENT SLOPES	jf
80	087GY	146	**41.9**	6100	12.8	1.4	6.4	165.0	5.0	**GYMER**	GYMER SILT LOAM, 3 TO 7 PERCENT SLOPES	ds
80	005PC	424	33.4	14188					5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
80	005PD	11	33.4	372					5.0	PAWNEE	PAWNEE CLAY, 3 TO 7 PERCENT SLOPES, ERODED	hy
80	087PB	45	33.4	1489					2.0	PAWNEE	PAWNEE CLAY LOAM, 1 TO 3 PERCENT SLOPES	hy
80	087PC	3889	33.4	129973					5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
80	087PH	343	33.4	11471					5.0	PAWNEE	PAWNEE SOILS, 3 TO 7 PERCENT SLOPES, ERODED	hy
80	005GR	116	17.1	1984					1.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	dr
80	005GU	451	17.1	7716					4.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 2 TO 6 PERCENT SLOPES	dr
80	005GX	3	17.1	57					5.0	GRUNDY	GRUNDY SILTY CLAY, 3 TO 7 PERCENT SLOPES, ERODED	dr
80	087GB	1154	17.1	19730					1.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	dr
80	087GC	2961	17.1	50605					3.5	GRUNDY	GRUNDY SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPES	dr
80	005KG	14	12.3	175					1.0	COLO	KENNEBEC-COLO SILT LOAMS	bz
80	087HC	82	11.3	919					1.0	HAIG	HAIG SILTY CLAY LOAM	dt

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
80	005KE	2	11.1	23					1.0	KENNEBEC	KENNEBEC SILT LOAM	et
80	005KF	2	11.1	21					1.0	KENNEBEC	KENNEBEC SILT LOAM, CHANNELED	et
80	087KB	987	11.1	10924					1.0	KENNEBEC	KENNEBEC SILT LOAM	et
80	087KC	206	11.1	2278					1.0	KENNEBEC	KENNEBEC SOILS, CHANNELED	et
80	087WC	272	11.0	2994					0.5	WABASH	WABASH SILTY CLAY LOAM	ks
80	087WH	40	11.0	444					0.5	WABASH	WABASH SILTY CLAY	ks
80	005WA	3	0.0	0					0.0			
80	087QU	1	0.0	0					0.0			
	087WA	83	0.0	0					0.0			
Totals		**19,074**	acres	**1,256,200**	**tons**	**65.9**	**ave tons/acre**					
Totals >40 t/a		**7,984**	acres	**745,477**	**tons**	**93.4**	**ave tons/acre for soils > 40 tons/acre**					

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
90	087RE	725	**77.8**	56379	12.4	1.4	6.2	148.2	0.5	**READING**	READING SILT LOAM	iq
90	085VC	2	**63.8**	151	4.5	0.0	1.8	32.2	10.0	SOGN	VINLAND-SOGN COMPLEX, 5 TO 20 PERCENT SLOPES	jl
90	087SS	305	**59.2**	18073	7.8	0.1	3.3	84.3	5.0	SIBLEYVILLE	SIBLEYVILLE COMPLEX, 3 TO 7 PERCENT SLOPES	ji
90	087SV	6	**59.2**	349	7.8	0.1	3.3	84.3	9.5	SIBLEYVILLE	SIBLEYVILLE COMPLEX, 7 TO 12 PERCENT SLOPES	ji
90	087MV	404	**53.2**	21470	10.7	1.3	5.4	134.2	5.0	**MORRILL**	MORRILL LOAM, 3 TO 7 PERCENT SLOPES	gw
90	087OC	49	**49.1**	2402	9.0	0.2	4.1	101.9	4.0	OSKA	OSKA SILTY CLAY LOAM, 2 TO 6 PERCENT SLOPES	ht
90	085MA	188	**48.6**	9124	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES	gg
90	085MB	6	**48.6**	284	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES, ERODED	gg
90	087MB	228	**48.6**	11063	12.8	1.5	6.3	170.2	2.0	**MARTIN**	MARTIN SILTY CLAY LOAM, 1 TO 3 PERCENT SLOPES	gg
90	087MC	2646	**48.6**	128551	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SILTY CLAY LOAM, 3 TO 8 PERCENT SLOPES	gg
90	087MH	506	**48.6**	24593	12.8	1.5	6.3	170.2	5.5	**MARTIN**	MARTIN SOILS, 3 TO 8 PERCENT SLOPES, ERODED	gg
90	087MO	574	**48.6**	27891	12.8	1.5	6.3	170.2	4.5	**MARTIN**	MARTIN-OSKA SILTY CLAY LOAMS, 3 TO 6 PERCENT SLOPES	gg
90	085MC	4	**46.7**	192	6.2	0.0	2.6	54.0	7.5	VINLAND	MARTIN-VINLAND SILTY CLAY LOAMS, 5 TO 10 PERCENT SLOPES	ko
90	087SW	188	**46.7**	8801	6.2	0.0	2.6	54.0	12.5	VINLAND	SOGN-VINLAND COMPLEX, 5 TO 20 PERCENT SLOPES	ko
90	087VC	445	**46.7**	20803	6.2	0.0	2.6	54.0	5.0	VINLAND	VINLAND COMPLEX, 3 TO 7 PERCENT SLOPES	ko
90	087VO	264	**46.7**	12356	6.2	0.0	2.6	54.0	11.0	VINLAND	VINLAND COMPLEX, 7 TO 15 PERCENT SLOPES	ko
90	087VX	60	**46.7**	2819	6.2	0.0	2.6	54.0	30.0	VINLAND	VINLAND-ROCK OUTCROP COMPLEX, 20 TO 40 PERCENT SLOPES	ko
90	087SC	2697	**43.5**	117384	11.4	1.3	5.4	141.5	5.5	**SHELBY**	SHELBY-PAWNEE COMPLEX, 3 TO 8 PERCENT SLOPES	jf
90	087SO	172	**43.5**	7503	11.4	1.3	5.4	141.5	10.0	**SHELBY**	SHELBY-PAWNEE COMPLEX, 8 TO 12 PERCENT SLOPES	jf
90	087GY	212	**41.9**	8871	12.8	1.4	6.4	165.0	5.0	**GYMER**	GYMER SILT LOAM, 3 TO 7 PERCENT SLOPES	ds
90	085PA	10	33.4	333	11.0	1.3	5.6	121.4	2.0	PAWNEE	PAWNEE CLAY LOAM, 1 TO 3 PERCENT SLOPES	hy
90	085PB	129	33.4	4328	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
90	085PC	37	33.4	1243	10.99	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES, ERODED	hy
90	087PB	224	33.4	7497	11.0	1.3	5.6	121.4	2.0	PAWNEE	PAWNEE CLAY LOAM, 1 TO 3 PERCENT SLOPES	hy
90	087PC	4068	33.4	135975	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE CLAY LOAM, 3 TO 7 PERCENT SLOPES	hy
90	087PH	544	33.4	18181	11.0	1.3	5.6	121.4	5.0	PAWNEE	PAWNEE SOILS, 3 TO 7 PERCENT SLOPES, ERODED	hy
90	087EC	114	20.8	2375	10.7	1.2	5.3	134.2	1.0	EUDORA	EUDORA COMPLEX, OVERWASH	db

Table 3.13 Perry Sub-Basin Erosion and Switchgrass Performance (cont'd)

HUC Sub-Basin	MUID	Acres	Cropland Erosion (t/a/yr)	Total Erosion (tons)	Switchgrass Yld (dt/a) Max	Min	Ave	Switch-grass N (lbs/acre)	Ave Slope	Series Name	Description	BRC Code
90	087KO	16	20.8	325	10.7	1.2	5.3	134.2	0.5	EUDORA	KIMO-EUDORA COMPLEX	db
90	087GB	619	17.1	10574	11.7	1.4	5.9	159.0	1.0	GRUNDY	GRUNDY SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	dr
90	087GC	751	17.1	12835	11.7	1.4	5.9	159.0	3.5	GRUNDY	GRUNDY SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPES	dr
90	085WB	89	14.0	1238	9.9	1.1	5.0	130.3	2.0	WYMORE	WYMORE SILTY CLAY LOAM, 1 TO 3 PERCENT SLOPES	ld
90	085WC	44	14.0	614	9.9	1.1	5.0	130.3	3.5	WYMORE	WYMORE SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPES, ERODED	ld
90	087JU	0	12.0	5	13.8	0.8	6.3	116.3	0.5	JUDSON	JUDSON SILT LOAM	el
90	087KM	3	11.9	39	11.6	1.3	5.6	142.0	0.5	KIMO	KIMO SILTY CLAY LOAM	ew
90	087HC	203	11.3	2282	10.6	1.0	5.3	142.0	1.0	HAIG	HAIG SILTY CLAY LOAM	dt
90	085KC	11	11.1	125	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS, CHANNELED	et
90	087KB	1316	11.1	14561	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SILT LOAM	et
90	087KC	257	11.1	2848	14.9	1.5	7.0	92.0	1.0	KENNEBEC	KENNEBEC SOILS, CHANNELED	et
90	087WC	84	11.0	925	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY LOAM	ks
90	087WH	13	11.0	144	12.2	1.3	5.8	128.7	0.5	WABASH	WABASH SILTY CLAY	ks
	087SB	20	2.6	52	8.7	1.0	4.5	126.2	1.0	SARPY	SARPY-EUDORA COMPLEX, OVERWASH	ja
90	085WA	1	0.0	0					0.0			
90	087QU	100	0.0	0					0.0			
	087WA	101	0.0	0					0.0			
Totals		**17,710**	acres	**1,334,737**	**tons**	**75.4**	**ave tons/acre**					
Totals >40 t/a		**8,956**	acres	**901,738**	**tons**	**100.7**	**ave tons/acre for soils > 40 tons/acre**					

3.4.2 High Erosion Areas of the Marion Basin

The Perry Basin, with higher precipitation resulting in higher switchgrass yields, and much larger regional population, offers a better opportunity for development of an HEC pellet heating fuel market than the Marion Basin. As a result of decreased Task 2 funding the Marion Basin was not evaluated in the same detail as the Perry Basin.

4.0 Space and Water Heating Markets

Barring federal mandates, biomass, even with some monetary value for environmental benefits, is not likely to find a near-term market as an electric generating fuel in this area. Markets where biomass can compete locally at the retail level with higher cost fuels appear to offer a better opportunity, specifically rural residential space and water heating markets currently served by propane and electricity. A few of these homes use wood, primarily as a supplemental heat source. A few pellet stoves have been sold, with wood pellets trucked in from Missouri selling at retail for about $150/ton in 40 pound plastic bags.[8] Is there a market for switchgrass pellets? In this region the potential for pellet stoves appears limited for several reasons:

- The U.S. pellet fuel market emerged as a substitute for cordwood.
- Pellet stoves can have significantly lower emissions than most wood stoves, and people in air quality compliance problem zones bought pellet stoves as an alternative to banned or restricted use of wood stoves. The use of cordwood stoves is not limited or prohibited in the Marion Lake or Perry Lake basins.
- In areas without regulatory pressure people dedicated to burning wood will likely continue to do so, except where pellet convenience is a major concern. Many of this group, and almost everybody else, have a central heating system.
- Barring another energy “crisis”, it seems unlikely that many who have elected the convenience of central heat are likely to jump to a pellet stove with the possible exception of dedicated environmentalists.
- Another limitation of pellet stoves is that they provide only localized space heat. Other portions of the house are often heated with other systems, and in a new energy efficient dwelling, with even modest passive heating, water heating may be just as big a load. Use of pellets for space and water heating would increase sales per customer and eliminate having propane only for water heating or use of expensive electricity for water heating.
- If switchgrass pellets are to compete with propane and heat pumps, and eventually gas, they must not only be equal or better in price, but in convenience as well.

4.0.1 Perry Basin Heating Energy Markets

To control transportation costs the market for HEC pellets must be local. Map 4.1P shows the Perry Basin and the local market areas within 50 miles of the basin boundary. The pie chart in each county shows the breakdown of space heating fuels based on the 1990 Census. The number for each county is the total number of homes. Map 4.5M provides similar data for the Marion Basin. Maps 4.2P, 4.3P, and 4.4P show electric and gas service territories for both basins. Utility rates were reviewed and were used in developing the range of competing energy costs used later in the report. Table 4.1 provides a detailed breakdown of residential heating fuels in the Perry Basin.

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[8] A Fall 1999 Orscheln Farm&Home flyer listed Lignetics wood pellet fuel at $2.99/40 lb bag ($149.50/ton), on sale for $2.79/bag ($139.50/ton) or $2.49/bag ($124.50/ton) if purchased by the ton. The customer must pick up and transport the pellets.

Table 4.1 Potential HEC Pellet Customers within 50 Miles of Perry Basin – 1990 Census

Perry Basin Residential Customers

(homes in counties 50% or more within 50 miles of Perry Basin – **counties in bold are closest**)

Kansas Home Space Heating Fuel by County: 1990 Census Data

COUNTY	Utility Gas	Bottled, tank, or LP Gas	Electric	Fuel Oil, Kerosene	Coal or Coke	Wood	Solar Energy	Other	None	Total	Target Market 1990
Johnson	116,390	1,733	17,469	126	0	447	85	128	55	136,433	4,138
Shawnee	49,986	2,340	10,016	210	0	959	33	163	61	63,768	4,544
Wyandotte	54,273	779	5,753	60	0	498	14	82	55	61,514	1,926
Douglas	23,777	1,711	3,698	119	0	729	59	45	0	30,138	2,988
Leavenworth	**14,611**	**2,474**	**1,836**	**84**	**0**	**635**	**21**	**47**	**7**	**19,715**	**3,673**
Jefferson	**2,581**	**1,833**	**436**	**79**	**0**	**822**	**0**	**27**	**0**	**5,778**	**2,843**
Atchison	**4,301**	**817**	**477**	**86**	**0**	**424**	**0**	**13**	**11**	**6,129**	**1,446**
Jackson	**1,557**	**1,503**	**404**	**40**	**0**	**750**	**0**	**15**	**8**	**4,277**	**2,394**
Franklin	5,696	1,310	565	51	0	649	5	32	0	8,308	2,156
Osage	3,329	1,357	508	14	0	564	5	19	10	5,806	2,067
Pottawatomie	3,512	1,331	570	28	0	497	0	0	0	5,938	1,999
Nemaha	2,263	1,090	336	53	0	250	2	0	2	3,996	1,479
Marshall	3,029	1,048	274	44	0	247	0	47	0	4,689	1,408
Wabaunsee	967	922	238	37	0	300	0	18	0	2,482	1,319
Brown	2,846	945	212	97	0	231	0	16	0	4,347	1,326
Doniphan	1,626	771	264	126	0	275	0	10	2	3,074	1,238
REGION	**290,744**	**21,964**	**43,056**	**1,254**	**0**	**8,277**	**224**	**662**	**211**	**366,392**	**36,943**
Target Market: LP, Fuel Oil, Wood, Solar, plus 10% of electric in urban counties and 25% of electric in other counties											
Targeted residences in closest counties (1990)											**10,356**
Total targeted residences in region (1990)											**36,943**

The data in Table 4.1 above is from the 1990 Census. A target retrofit market of homes heated with propane, wood, solar, and electricity (10% of the urban customers, 25% of rural) totals almost 37,000 in the region and over 10,000 in the counties actually in the basin. There has been significant population growth and housing construction in some portions of the target market region since the Census. Table 4.2 provides data on new housing permits for 1995-97, indicating approximately 7,500 new homes in the region and around 600 in the core counties.

Getting homeowners to switch to a renewable space and water heating fuel that has a higher up-front equipment cost and about the same energy cost poses the greatest challenge to developing an HEC pellet fuel market.

4.0.2 Marion Basin Heating Energy Markets

No analysis beyond information presented in Map 4.1M was performed regarding space heating fuels and housing population in the Marion Basin.

Table 4.2 Potential HEC Pellet Customers Within 50 Miles of Perry Basin – New Homes, 1995-97

New Home Permits (all fuels)			
County	**1995**	**1996**	**1997**
Johnson	4,550	4,639	5,470
Shawnee	684	785	671
Wyandotte	134	156	169
Douglas	841	1,692	619
Leavenworth	**437**	**327**	**362**
Jefferson	**118**	**164**	**129**
Atchison	**31**	**15**	**61**
Jackson	**65**	**48**	**100**
Franklin	95	163	74
Osage	128	99	78
Pottawatomie	149	118	91
Nemaha	18	15	19
Marshall	5	7	8
Wabaunsee	41	12	3
Brown	26	14	11
Doniphan	20	22	21
REGION	**7,342**	**8,276**	**7,886**
No data for other years.			
TARGET Co's	**651**	**554**	**652**
TOTAL TARGET Co's (3 years)			**1,857**

The Perry Basin is clearly the better opportunity, not only because of the need to reduce reservoir sedimentation and greater acres of higher switchgrass yields, but because there are more local markets. The rural housing population is higher, and the Jeffrey and Tecumseh power plants are relatively near if utility co-firing is further considered.

4.1 Combustion Equipment and Bulk Pellet Delivery

European pellet fuel markets have undergone greater evolution than the U.S. market. In Sweden pellets made from wood waste are used for residential space and water heating based on the following infrastructure:

- Pellet fuels are manufactured from sawmill wood waste.
- Pellets are hauled in bulk up to 200 miles from their point of manufacture.
- Pellets are downloaded into smaller grain trucks for local delivery.
- Pellets are delivered to individual residences where they are blown through a hose into a bulk bin in the basement or outdoors.
- Pellets are automatically augered from the bulk bin into a boiler that provides hot water for space heating and domestic hot water.
- The truck delivery system is capable of accurately measuring the weight of material delivered at each stop.
- Bagged pellets are inventoried at local participating home centers for emergencies and for marketing purposes.

This system provides a level of convenience similar to propane in the U.S. at a comparable price.

4.1.1 Whitfield Hearth Products

Whitfield Hearth Products of Burlington, Washington, now owned by Lennox, is developing a pellet combustion system that they call the Bio-Logic pellet burner. The unit is described below and illustrated on the following page. The illustration includes a bin for bulk pellets. The near term target market is reportedly Northern Europe.

Whitfield Hearth Products Bio-Logic Systems Pellet Burner Description

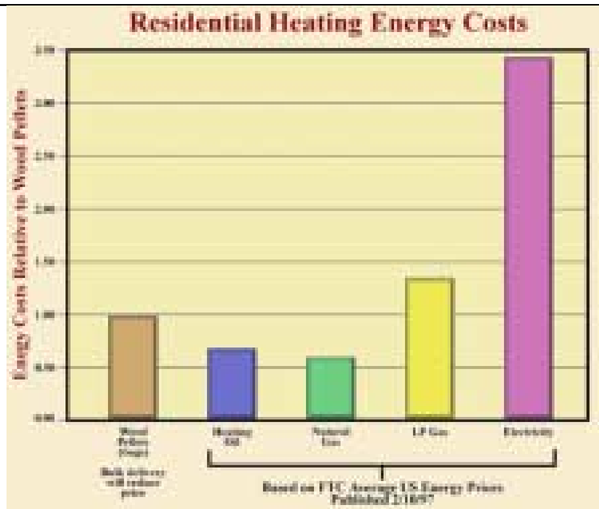
- Automatic burner system fueled by wood pellets.
- Forced air furnace package available.
- Compact configuration
- Externally mounted, for easy retrofit to most boilers.
- Control design for remote fuel storage delivery.
- Emissions, efficiency, and thermal performance comparable to oil or gas.

Applications

- Residential Central Heating
- Hydronic Boilers
- Forced Air Furnaces

Heating Capacities

- Residential Model
6Kw-20Kw (20,000-70,000 BTU/hr)



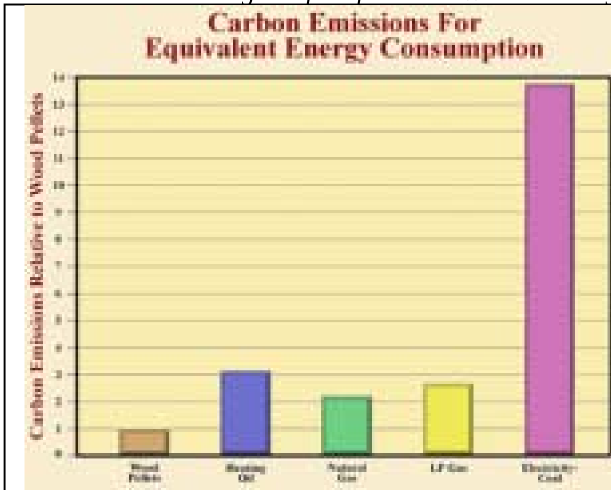


Table 4.3 Relative Energy Costs and Carbon Emissions of Wood Pellets and Other Heating Fuels
Source: **http://www.whitfield.com**

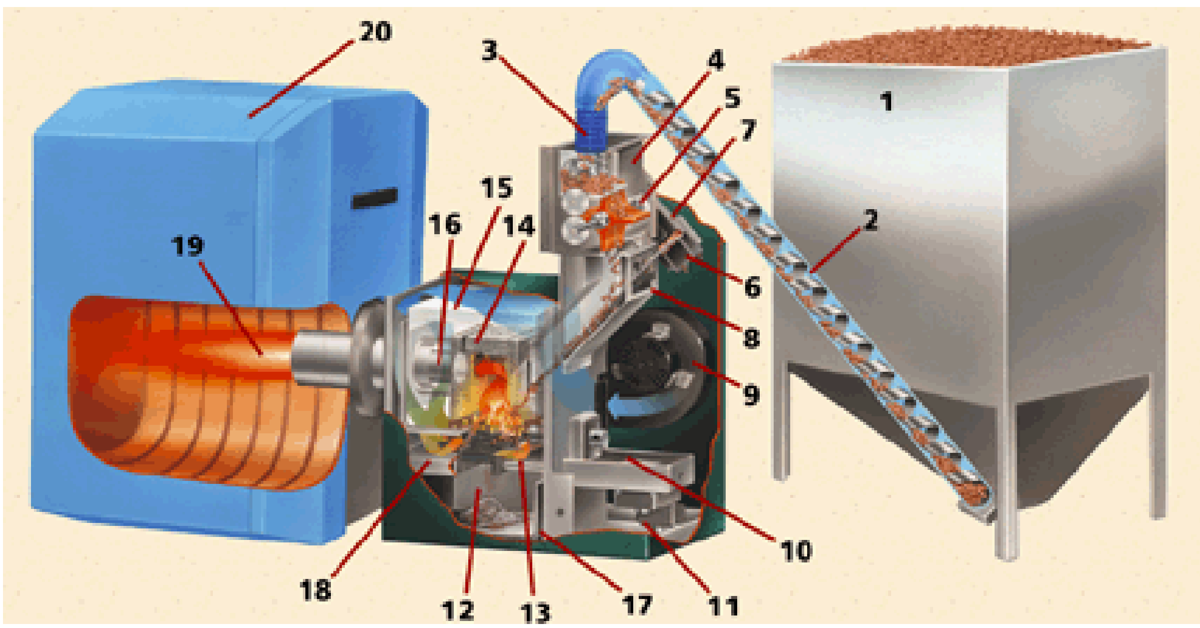
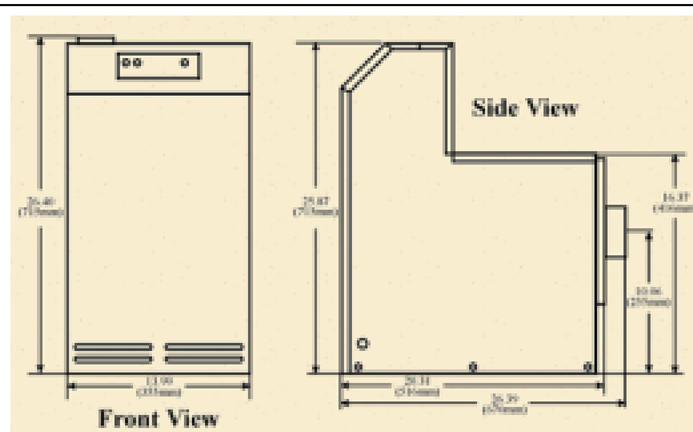


Figure 4.4 Whitfield Hearth Products Bio-Logic Systems Pellet Burner
http://www.whitfield.com



Performance
- Exhaust gas temperature 2200° F (1200° C)
- CO² Emissions <100 ppm
- NO Emissions <100 ppm

1 Remote Fuel Supply, 2 Feed Supply, 3 Fuel Level Sensor, 4 Metering Auger, 5 Rotary Air Lock, 6 Flame Detector, 7 Feed Drive Motor, 8 Viewing Port, 9 Combustion Blower, 10 Self Ignitor, 11 Grate Actuator , 12 Grate Rake, 13 Burn Grate, 14 Refractory Firebox, 15 Firebox Insulation, 16 Exhaust Tube, 17 Ash Pan, 18 Preheated Combustion Air, 19 Hot Exhaust Gases, 20 Residential Hot Water Boiler

4.1.2 European Wood Pellet Residential Pellet Space Heating Equipment

Bags vs. Bulk

Wood pellets have traditionally been purchased in 40 – 50 pound plastic bags at retail dealers and transported by homeowners. Bagging pellets adds $12 – 15 per ton. Retail dealer mark-up ranges from 20 – 40 per cent. U.S. and European pellet manufacturers offer bulk delivery of bagged pellets on shrink-wrapped pallets. This strategy could partially or fully skip the retail middleman, but does not avoid the bagging cost and adds to the delivery cost. Swedish pellet manufacturers have begun providing bulk home delivery using grain and animal feed delivery type equipment. Bulk unbagged pellets are pneumatically moved from trucks to a storage bin located outside or inside the home. A typical three metric ton delivery takes about 20 minutes.[9] Load cells on the truck permit weight measurement. Figure 4.5 illustrates the Swedish approach. Pellets are then automatically augered into the boiler. While ash removal is not currently part of this system, perhaps because they are using low ash wood pellets, doing so appears technically feasible and would increase customer convenience significantly.

Figure 4.5 Bulk Pellet Delivery

Figure 4.6 Pellet Burner
Source: EcoTec

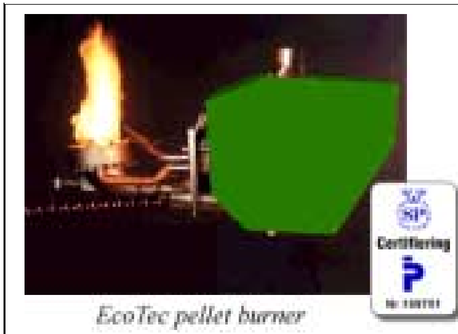


Figure 4.7 Pellet Boiler
Source: Eco-Tec

Pellet Burners

Expansion of the European pellet market is constrained by available combustion equipment and U.S. manufacturers developing advanced pellet combustion equipment view Europe as the primary near term market. Much of the combustion equipment currently being installed in Northern Europe is designed for retrofit of existing oil fired boilers. Combustion units typically replace the lower access door of the boiler. A pellet burner is shown in Figure 4.6 and a pellet burner installed in a boiler and fed by bulk pellets augered from a tub is show in Figure 4.7. More advanced designs are anticipated. A list of Swedish pellet burner manufacturers can be found at http:/www/sp.se /energy/CertProd/Ppellets.htm.

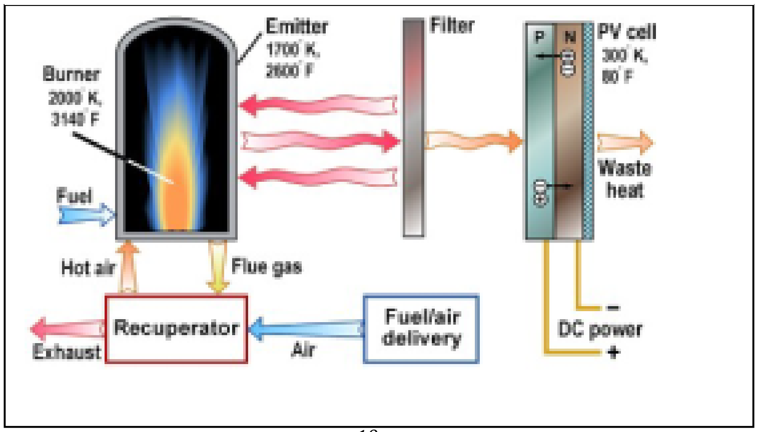
[9] Brannestam, K., **sabi Pellets AB**, Pellet Fuels Institute annual meeting, Mt. Snow, Vermont, 1999.

4.1.3 Cogeneration

Cogeneration is the simultaneous production of two useful forms of energy, usually electricity and heat. Most cogeneration systems have significant economy of scale and residential systems are not economically practical. Several emerging technologies may soon change this. Two technologies targeting a range of applications, including the on-grid self-powered furnace market are thermophotovoltaics and alkali metal thermal electric conversion.

Thermophotovoltaics (TPV)

Figure 4.8 How Thermophotovoltaics Work
Source: McDermott Technology, Inc.



"TPV systems produce electricity by burning fuel to heat an incandescent emitter. The emitter radiates energy to photovoltaic (PV) cells that convert the radiant energy into electrical energy. The portion of energy absorbed by the PV cell not converted to electricity is removed as waste heat. In some cases, a filter is used to reflect energy that is unusable by the PV cells back into the system. A recuperator boosts system efficiency by transferring the waste heat in the exhaust stream to the incoming combustion air."[10]

"For a system containing a propane burner, GaSb PV cells and a radiator at 1500 K, we find a thermodynamical limit efficiency of 60% and a power density of 3 W/cm. For an idealized system model, an efficiency of 32% and a power density of 2 W/cm are determined. For a realistic system with a broadband radiator-filter combination, 10% and a 1 W/cm are estimated; using a selective radiator without filter, 15% and 1 W/cm are found. Performance values of this order should be achievable with a sufficient development effort."[11]

Thermophotovoltaic research and development is being pursued by a variety of public agencies and private companies in numerous countries.

JXCrystals, Inc. of Issaquah, Washington has developed a *"propane-fired heating stove that puts out 25,000 Btu/hr of heat and simultaneously generates 100 Watts of electricity."*[12] The company is developing equipment to power fans and controls of on-grid home heating furnaces, allowing them to continue operating during a power outage.

A pellet fueled boiler consuming six tons of pellets to produce heat could produce an average of approximately 250 kWh per month if equipped with a 10% efficient thermophotovoltaic system, roughly the equivalent of a 1.5 kW solar photovoltaic array. At least one North American pellet

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[10] McDermott Technology, Inc., http://www.tpv.org/tpv4.html.

[11] Heinzel, A., Luther, J., Stollwerck, G., Zenker, M., ***Efficiency and Power Density Potential of Combustion-Driven Thermophotovoltaic Systems Using Low Bandgap Photovoltaic Cells,*** 1998. http://www.tpv.org/tpv4.html.

[12] http://www.jxcrystals.com/profile.htm

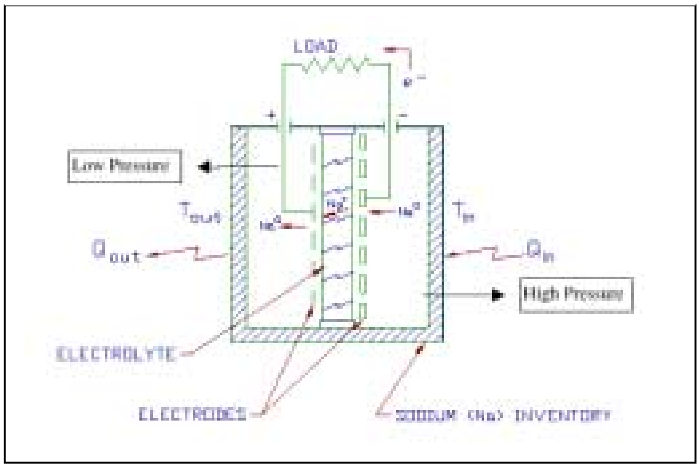
fuel combustion equipment manufacturer is believed to be seriously investigating integrating thermophotovoltaics into some of their products.

Alkali Metal Thermal Electric Conversion (AMTEC)

AMTEC was developed at the Ford Scientific Laboratories in 1968. First known as the sodium heat engine, it has evolved significantly in recent years. *"The AMTEC cell has a very simple and elegant energy conversion process. The general principles of AMTEC operation can be illustrated using Figure 1* (Figure 4.9) *which shows two chambers separated by the BASE. Beginning in the heated, high pressure zone to the right side of the BASE, the alkali metal, sodium, ionizes, enters, and passes through the BASE wall. The freed electrons pass from the anode (high pressure electrode) out to the electrical load and back to the cathode (on the low pressure side) where they recombine with the ions emerging at the BASE surface. The neutral sodium then evaporates into the low pressure zone, condenses on the cooled inner surface of the chamber and is returned to the hot zone by a capillary structure (shown as a hashed layer) to complete the cycle. Evaporator and condenser temperature ranges from 900 - 1100 K and 500 - 650 K, respectively, are typical."*

Figure 4.9 AMTEC Cell Operation

Source: Advanced Modular Power Systems, Inc.



" The cells, which are the building blocks of power systems, have gone from 2% efficiency (heat input to electric power output) to 20% efficiency and the rapid improvements that are under progress are expected to exceed 30% efficiency".[13]

The current developer of AMTEC, Advanced Modular Power Systems, Inc., has identified residential self-powered furnaces as a major market opportunity.[14]

A pellet fueled boiler consuming six tons of pellets to produce heat could produce an average of approximately 500 kWh per month if equipped with a 20% efficient AMTEC system, roughly the equivalent of a 3 kW solar photovoltaic array. No North American pellet fuel combustion equipment manufacturer is known to be seriously investigating AMTEC, but the technology's simplicity and lower operating temperature may eventually allow it to challenge thermophotovoltaics.

Cogeneration with either thermophotovoltaic or AMTEC technology would significantly improve the total system energy profit ratio (EPR) of HEC pellet boilers. While companies like JXCrystals and AMPSYS no doubt see the enormous number of installed gas and propane

[13] Mital, R., Sievers, R., Rasmussen, J., Hunt, T., ***Performance Evaluation of Gas-Fired AMTEC Power Systems***, Advanced Modular Power Systems, Inc.

[14] http://www.ampsys.com

furnaces as the best potential market, home owners who purchase pellet boiler systems in lieu of new or replacement gas fired units will likely do so at least in part for environmental reasons, making them strong prospects for renewable electric generation.

5.0 HECs As a Pellet Feed Stock

5.0.1 Pellet Fuel Standards

Pellet quality is widely regarded as a major factor in pellet combustion equipment performance and customer satisfaction. The Pellet Fuels Institute has established the standards summarized in the table below for residential pellet fuels.

Table 5.1 Pellet Fuel Institute Residential Pellet Fuel Standards

Pellet Characteristic	Premium Grade	Standard Grade
Bulk Density per Cubic Foot	Not less than 40 pounds	Not less than 40 pounds
Size	Diameter of ¼ to 5/16 inch	Diameter of ¼ to 5/16 inch
Fines	Not more than 0.5% < 1/8 inch	Not more than 0.5% < 1/8 inch
Inorganic Ash	Less than 1 %	Less than 3 %

Manufacturers are encouraged to perform daily in-house tests for basic pellet characteristics and to regularly have independent laboratories test their pellet's chemical characteristics and to label their products. Almost all current pellet manufacturers marketing to residential consumers strive to produce premium grade pellets by controlling their raw materials. Soft and hard wood residue from primary and secondary wood processors dominate. Bark, agricultural residues, and some process trimmings such as plywood are generally not used to reduce risk of increased ash or sodium content. Several manufacturers also produce standard grade pellets, but very few produce pellets with ash content exceeding 3%.

5.0.2 Chemical Composition of Switchgrass and Big Bluestem

Chemical composition, particularly ash and silica content, are important factors affecting the performance and marketability of biomass fuels for any end use, but particularly for residential

Table 5.2 Chemical Composition of Herbaceous Energy Crops and Other Fuels

Property	Switchgrass	Big Bluestem	Wood (poplar)	Coal (Wyoming)
HHV (1000 Btu/lb)	7.92		8.5	12.0
Volatile Matter (%)	80.1			39.1
Fixed Carbon (%)	9.4			44
Moisture (harvest - %)	15		45[2]	9.6
Ash (%)	5.3, 4.5[2], 3.5–7.3[3]	2.1-5.1[3]	1.6[2]	7.3
Carbon (%)	44.0		46.7	66.9
Hydrogen (%)	5.3		6.4	4.9
Nitrogen (%)	0.5		.10	1.2
Sulfur (%)	0.1		.01	0.6
Oxygen (%)	38.7		48.9	9.6
Chlorine (%)	0.1		Na	0.0

Sources: 1) King, J., et. al., ***An Assessment of the Feasibility of Electric Power Derived from Biomass and Waste Feedstocks*** (data source for above table unless otherwise noted), 2) McLaughlin, S., et. al., ***Evaluating Physical, Chemical, and Energetic Properties of Perennial Grasses as Biofuels***, 3) Johnson, D., et. al., ***Compositional Variability in Herbaceous Energy Crops***.

pellets. Plant species, soil and climate conditions, fertilizer and chemical use, harvesting method, transportation, storage, and processing can all affect the chemical composition of herbaceous energy crop feedstock and pellets made from it. The table below summarizes public data for switchgrass composition. Big bluestem, wood, and coal are included for comparison.

Ash and alkali content are critical factors. Alkali can cause buildup on heat exchange surfaces reducing efficiency. High ash creates increased disposal requirements and requires appropriate pellet combustion system design. For several years switchgrass was considered high in both. More recent information suggests samples used in earlier tests were contaminated yielding very misleading results. McLaughlin reported that analysis of 36 switchgrass samples from a wide variety of sites in DOE's Biomass Fuels Development Program (BFDP) had a range of 2.8 – 7.6% (average 4.5%).[15] Unless variety selection or management methods can be identified that keep the average switchgrass ash content consistently below 3% it will impair development of a switchgrass pelleting business in two critical ways.

- Combustion equipment capable of handling high ash pellets will be required.
- Secondary marketing of switchgrass pellets will be severely limited.

While high efficiency, high ash residential pellet boilers are under development, none are known to be available at present in North America. If the only market for switchgrass pellets is the one developed locally, production capacity and use will need to evolve in parallel with the marketing of pellet combustion equipment. This may reduce plant annual operating hours below profitability levels and suggests contracting for pelleting be considered in early years, despite added transportation costs. McLaughlin[16] points out that the high ash content of HECs may be caused at least in part by contamination.

- HECs are typically harvested like hay, either swathed or mowed and raked.
- Baling can pick up soil with the grass.
- Bales left in the field or along unpaved roads gather dust.
- Bales transported uncovered on unpaved roads gather dust.
- Bales stored on bare ground or even gravel pick up dirt.

No studies that attempt to determine the uncontaminated ash content of HECs have been found. If contamination is a significant ash source several relatively simple measures could mitigate it substantially.

- Post frost harvest at low moisture content would permit use of a combined swather/baler that would prevent the grass from touching the ground.
- Catching the bales on a trailer behind the baler would preclude ground contamination.
- Transferring bales from the field trailer to a flat bed with a full tarp cover for immediate transportation to the pelleting plant would reduce contamination risk.
- Covered storage on a concrete slab until processing would further reduce the risk of contamination or decay.

[15] McLaughlin, S. B., et. al., ***Evaluating Physical, Chemical, and Energetic Properties of Perennial Grasses as Biofuels.***
[16] Ibid.

Additional research on the affects of variety, soils, and management, harvesting, transportation, and processing practices on switchgrass ash content should be pursued.

5.0.3 Switchgrass vs. Big Bluestem

Switchgrass, particularly the Alamo variety, has emerged as the most popular among many candidate HECs based primarily on exceptional yields from mono-crop stands achieved during field trials. Several factors suggest relying solely on switchgrass should be reconsidered. Natural pure stands of Big Bluestem are more common in the tallgrass prairie of Kansas than switchgrass. Bluestem is generally more palatable as hay and grass in the latter part of the season and producers concerned about long term options may prefer it. Some landowners also consider switchgrass excessively invasive.

If biomass energy is to be harvested from CRP enrolled lands on $/ton fee basis, modest variation in yield has limited impact on edge of field cost.

6.0 HEC Pellet Fuel Business Development

6.0.1 Competing Fuels

To compete, pelletized switchgrass must be equal to or lower in price and essentially equal in convenience to heat from propane, electricity, and trucked in wood pellets from plants as close as western Missouri. Table 6.1 shows cost ranges and equipment efficiency for various fuels and space and water heating systems.

Table 6.1 HEC Pellet Competition for Residential Space and DHW Heating

		Equipment Efficiency				Cost of Heating ($/MBtu)			
Energy ($/MBtu)		DHW		Space Heating		DHW		Space Heating	
Range	**Typical**	**Range**	**Typical**	**Range**	**Typical**	**Range**	**Typical**	**Range**	**Typical**
Propane (11 gallons per MBtu) ($.60/$.80/$1.00 per gallon)									
$6.60 – 11.00	**$8.80**	**.55 - .75**	**.55**	**.78 -.94**	**.80**	**$8.80 - $20.00**	**$16.00**	**$7.00 - $14.10**	**$11.00**
Electric Resistance (293 kWh per Mbtu) ($.05/$.08/$.11 per KWh)									
$14.65 - 32.23	**$23.44**	**.90 - .98**	**.95**	**.9-1.0**	**.95**	**$14.95 – $35.80**	**$24.65**	**$14.65 - $35.80**	**$24.65**
Electric Air-source Heat Pump ($.05/$.08/$.11 per KWh)									
$14.65 - 32.23	**$23.44**	**.90 – 2.0**	**.95**	**6.8 – 8.2 HSPF**	**7.2**	**$14.95 – $35.80**	**$24.65**	**$6.10 - $16.20**	**$11.10**
Electric Ground-source Heat Pump ($.05/$.08/$.11 per KWh)									
$14.65 - 32.23	**$23.44**	**.90 – 3.0**	**.95**	**2.8 – 3.2 SCOP**	**3.0**	**$14.95 – $35.80**	**$24.65**	**$4.60 - $11.50**	**$7.80**
Wood Pellets (8,000 Btu/lb) ($125/$150/$175 per ton)									
$7.80 - $10.94	**$9.40**	Current wood pellet equipment does not provide water heating – use electric values		**.55 - .80**	**.60**	Current wood pellet equipment does not provide water heating – use electric cost		**$9.75 - $19.90**	**$15.70**
HEC Pellets (7,900 Btu/lb) ($125/$150/$175 per ton)									
$7.90 – 11.00	**$9.50**	**.80**	**.80**	**.80**	**.80**	**$9.90 - $13.75**	**$11.90**	**$9.90 - $13.75**	**$11.90**

Notes: Highly variable installed system cost strongly affects overall economics.

6.0.2 Residential Energy Use

Table 6.2 shows typical annual energy use for propane and electric water heating for different levels of equipment efficiency, water conservation, and family size. Table 6.3 shows typical NE Kansas annual space heating use for different sized homes constructed to a range of energy efficiency standards. Table 6.4 shows the space heating system efficiency ratings assumed for the different levels of home energy efficiency. Table 6.5 shows the range and typical annual space and water heating cost for homes of three size levels, five energy efficiency levels, and six heating fuels/systems permitting a comparison of HEC pellets with the competition. Table 6.6 translates energy requirements to pellet volumes (tons) for the three house sizes and five energy efficiency levels.

Table 6.2 Domestic Water Heating (DWH) Energy Use (million Btu/yr of site energy)

Family Size	Propane **Water Heater Efficiency**				Electricity **Water Heater Efficiency**			
	Typical (.55)		High (.65)		Typical (.90)		High (.97)	
	Water Conservation		**Water Conservation**		**Water Conservation**		**Water Conservation**	
	Typical	**High**	**Typical**	**High**	**Typical**	**High**	**Typical**	**High**
	12,500 Btu/day/ person	7,500 Btu/day/ person	12,500 Btu/day/ person	7,500 Btu/day/ person	12,500 Btu/day/ person	7,500 Btu/day/ person	12,500 Btu/day/ person	7,500 Btu/day/ person
2	**16.6**	**10.0**	**14.0**	**8.4**	**10.1**	**6.0**	**9.4**	**5.6**
4	**33.2**	**20.0**	**28.0**	**16.8**	**20.2**	**12.0**	**18.8**	**11.2**
6	**49.8**	**30.0**	**42.0**	**25.2**	**30.3**	**18.0**	**28.2**	**16.8**

Table 6.3 Residential Space Heating Energy Use for NE Kansas (million Btu annual heating load)

	House Construction Energy Efficiency Level				
House Size	**Standard Practice**	**Model Energy Code**	**Enhanced Efficiency**	**Advanced Efficiency**	**Advanced Efficiency + Passive Solar**
Small **(960 s.f. duplex)**	**37.4**	**26.5**	**14.1**	**10.3**	**9.4**
Medium **(1,700 s.f.)**	**71.8**	**44.1**	**32.4**	**23.5**	**22.6**
Large **(2,460 s.f.)**	**93.6**	**65.5**	**38.2**	**27.3**	**25.4**

Table 6.4 Residential Heating System Efficiency Levels

	House Construction Energy Efficiency Level				
Heating System	**Standard Practice**	**Model Energy Code**	**Enhanced Efficiency**	**Advanced Efficiency**	**Advanced Efficiency + Passive Solar**
Propane Furnace (AFUE)	**78**	**78**	**83**	**94**	**94**
Electric Resistance (Eff.)	**.95**	**.95**	**.95**	**.95**	**.95**
Air Source HP (HSPF)	**6.8**	**6.8**	**7.8**	**8.2**	**8.2**
Ground Source HP (COP)	**2.8**	**2.8**	**3.0**	**3.2**	**3.2**
Wood Pellet Furnace (AFUE)	**60**	**60**	**65**	**70**	**70**
Grass Pellet Boiler (AFUE)	**80**	**80**	**80**	**80**	**80**

Table 6.5 Residential Combined Space and Water Heating Cost for NE Kansas

	House Construction Energy Efficiency Level									
House Size	**Standard Practice**		**Model Energy Code**		**Enhanced Efficiency**		**Advanced Efficiency**		**Advanced Efficiency + Passive Solar**	
Small (960 s.f. duplex)	**Range**	**Typ.**	**Range**	**Typ.**	**Range**	**Typ.**	**Range**	**Typ.**	**Range**	**Typ.**
Propane	$408 – 859	$667	$332 – 706	$557	$222 - 479	$379	$146 - 313	$248	$140 - 301	$238
Electric Resistance	$807 – 1,933	$1,331	$644 – 1,543	$1,062	$903 – 1,006	$693	$280 - 669	$461	$266 - 637	$439
Electric Air-source	$435 – 1,239	$721	$381 – 1,058	$630	$280 – 748	$463	$177 - 481	$293	$173 – 465	$285
Electric G-source	$255 – 1,024	$701	$205 - $899	$616	$135 - 663	$455	$89 – 419	$287	$85 – 409	$280
Wood Pellets	$555 – 1,706	$893	$452 – 1,397	$721	$304 - 944	$479	$200 - 619	$316	$191 - 593	302
HEC Pellets	$535 - 743	$643	$427 - 593	$513	$278 - 386	$334	$185 - 257	$223	$176 - 245	$212
Medium (1,700 s.f.)	**Range**	**Typ.**	**Range**	**Typ.**	**Range**	**Typ.**	**Range**	**Typ.**	**Range**	**Typ.**
Propane	$795 – 1,676	$1,321	$601 – 1,286	$1,016	$473 – 1,017	$804	$312 - 667	$527	$306 - 655	$517
Electric Resistance	$1,570 – 3,759	$2,588	$1,156 – 2,767	$1,905	$903 – 2,162	$1,489	$602 – 1,443	$993	$589 – 1,411	$971
Electric Air-source	$855 - $2,445	$1,416	$717 - $1,960	$1,186	$581 - $1,569	$960	$369 – 1,013	$610	$364 – 997	$602
Electric G-source	$496 – 2,014	$1,378	$368 – 1,696	$1,162	$289 – 1,375	$943	$192 - 872	$597	$188 - 861	$590
Wood Pellets	$1,082 – 3,328	$1,738	$821 – 2,542	$1,303	$648 – 2,008	$1,024	$427 – 1,320	$678	$418 – 1,294	$664
HEC Pellets	$1,040 – 1,444	$1,250	$765 – 1,063	$920	$598 - 831	$719	$399 - 554	$480	$390 - 542	$469
Large (2,460 s.f.)	**Range**	**Typ.**	**Range**	**Typ.**	**Range**	**Typ.**	**Range**	**Typ.**	**Range**	**Typ.**
Propane	$1,093-2,316	$1,826	$897 – 1,920	$1,517	$637 – 1,379	$1,092	$413 – 889	$704	$400 – 862	$683
Electric Resistance	$2,144 – 5,134	$3,535	$1,723 – 4,128	$2,842	$1,199 – 2,871	$1,977	$785 - $1,880	$1,294	$756 – 1,811	$1,247
Electric Air-source	$1,213 – 3,421	$2,007	$1,072 – 2,929	$1,773	$819 - $2,172	$1,354	$513 – 1,380	$849	$504 – 1,374	$833
Electric G-source	$679 – 2,859	$1,958	$549 – 2,536	$1,738	$385 – 1,943	$1,333	$251 – 1,216	$834	$242 – 1,194	$819
Wood Pellets	$1,490 – 4,592	$2,386	$1,226 – 3,795	$1,945	$874 – 2,717	$1,373	$565 – 1,755	$892	$547 – 1,701	$862
HEC Pellets	$1,420 – 1,972	$1,706	$1,141 - $1,585	$1,372	$794 – 1,103	$955	$520 - 722	$625	$501 - 696	$602

Note: Typical water conservation used for Standard Practice, Model Energy Code, and Enhanced Efficiency cases and high water conservation used for Advanced Efficiency and Advanced Efficiency + Passive Solar cases.

Table 6.6 Residential Combined Space and Water Heating HEC Pellet Requirements

	House Construction Energy Efficiency Level				
House Size	**Standard Practice**	**Model Energy Code**	**Enhanced Efficiency**	**Advanced Efficiency**	**Advanced Efficiency + Passive Solar**
Small (960 s.f. duplex)					
HEC Pellets (dry tons)	4.3	3.4	2.2	1.5	1.4
Medium (1,700 s.f.)					
HEC Pellets (dry tons)	8.3	6.1	4.8	3.2	3.1
Large (2,460 s.f.)					
HEC Pellets (dry tons)	11.3	9.1	6.3	4.1	4.0

Note: Typical water conservation used for Standard Practice, Model Energy Code, and Enhanced Efficiency cases and high water conservation used for Advanced Efficiency and Advanced Efficiency + Passive Solar cases. Combined space and water heating annual efficiency of 80%.

6.0.3 The Cost of Pelletizing and Marketing Biomass

No commercial scale operating HEC pellet mills were identified and estimates of construction and operating costs were based on mills pelleting wood residue and factors unique to an HEC mill. Pelleting is an energy intensive process and the two reviewed studies on wood pelleting include somewhat detailed reviews of energy costs. However, we were unable to identify any detailed evaluation of the total source embodied energy involved in producing and marketing biomass pellets.

- The retail pellet cost in Colorado in 1992 – 93 was approximately $160/ton (1999 = $190), of which $ 70 – 95 (1999 = $83 – 113) went to the manufacturer, $30 – 60 (1999 = $36 – 71) to transportation, and $30 – 40 (1999 = $36 – 48) to dealer mark-up.[17]

- The 1995 retail cost of pellets ranged from $3.50 – 5.00 per forty pound bag (1999 = $192 – 274 per ton) with price highly influenced by transportation cost. Wholesale price was estimated at $115-124/ton (1999 = $126 - 136).[18]

The NEOS 1995 study estimated the cost of a four ton per day plant at $905,100 (1999 = $991,347). Operating at full capacity of 14,000 tons in the 3rd year, estimated production expenses are shown in Table 6.7 below.

Table 6. 7 Wood Pellet Manufacturing Cost, 4 Tons per Day, 14,000 Tons per Year[19]

Expense	Amount	$/Ton	Percent
Interest	$70,726	$5.05	4.66%
Property Tax	$39,452	$2.82	2.60%
Depreciation	$91,250	$6.52	6.02%
Labor	$256,336	$18.31	16.90%
Feedstock	$331,179	$23.66	21.84%
Insurance	$15,840	$1.13	1.04%
Marketing	$36,787	$2.63	2.43%
Electricity	$192,175	$13.73	12.67%
Dryer Fuel	$112,800	$8.06	7.44%
Repair & Maintenance	$125,526	$8.97	8.28%
Bags	$174,734	$12.48	11.52%
Pallets	$69,894	$4.99	4.61%
TOTAL	$1,516,699	**$108**	**100.00%**

The estimated wood pellet manufacturing costs in Table 6.7 above are for a plant using sawmill hardwood waste as feedstock. Pellets from the hypothetical plant would be sold to wholesalers

[17] Haase, S., et. al., ***Wood Pellet Manufacturing in Colorado: An Opportunity Analysis***, NEOS Corporation for State of Colorado Office of Energy Conservation and US DOE Western Regional Biomass Energy Program, 1993.

[18] ***Wood Pelletization Sourcebook: A Sample Business Plan for the Potential Pellet Manufacturer***, NEOS Corporation for the US DOE Great Lakes Regional Biomass Program, 1995.

[19] ***Wood Pelletization Sourcebook: A Sample Business Plan for the Potential Pellet Manufacturer***, NEOS Corporation for the US DOE Great Lakes Regional Biomass Program, 1995.

at $115/ton plus freight with the retail price set by market conditions, probably $150 – 275 per ton range.

6.1 HEC Pelleting

The HEC pellet business envisioned would vary from the wood pellet plant outlined above in several important ways. All sales would be in bulk direct to the consumer to:

- minimize packaging cost and disposal (no bags or pallets),
- eliminate high mark-up of retailer to reduce cost and if possible improve profit.

While these steps may reduce some costs, such a strategy for developing a HEC pellet business will incur higher costs in other areas:

- covered storage for harvested HEC,
- Pellet delivery in 1-3 ton increments to individual customers,
- Increased marketing (expense shifts from retailer to producer)
- Increased billing and accounting of many small transactions.

A preliminary analysis of HEC pellet business development follows. A major concern is plant start-up. While the simplified analysis presented here assumes full operation upon completion, an actual plant would need a shakedown period of a few months to a couple of years. The biggest concern however is adequate market within acceptable hauling distance for the quality of pellets produced. Like many manufacturing processes there is significant economy of scale in pellet production. Larger plants operating longer hours produce pellets at a lower cost. But if no "bridge" market for higher ash pellets can be found, the production of HEC pellets may need to evolve at small scale increments in parallel to the development of local markets for acceptable pellet burning appliances.

6.1.1 HEC Production and Harvesting

Producing HECs at a cost that can compete with current fossil fuel prices will require careful planning and economy of scale. New harvesting equipment and methods may be important in achieving low cost.

6.1.2 Converting Existing Cropland to HEC Plantations

The HEC pellet business development strategy presented here anticipates that all acres dedicated to HEC production will be enrolled in the federal conservation reserve program (CRP). Rental payment rates were reduced when the CRP program was extended by Congress and farmers with productive cropland have been less willing to participate, even for land with high erosion potential. Two program enhancements can increase the economic incentive for landowner participation:

The buffer strip program permits direct enrollment of qualifying parcels with an additional 20 percent CRP rent incentive payment. Land parcels that also qualify for the Kansas Water Quality Buffer Strip Initiative can receive an additional 30 percent incentive payment. The combination of CRP rent + 20% + 30% + the prospect of an additional payment for permitting HEC harvesting for nonagricultural use will hopefully be sufficient to achieve landowner participation. Acquiring a waiver to permit harvesting from CRP enrolled land for non-agricultural use is part of Task 3.

The price at which HECs must be acquired to compete with fossil fuels is much less than the agricultural price of hay. Eight hundred-pound bales of brome grass sell for approximately $12 ($30/ton) and quality prairie hay can sell for $60/ton. To compete with fossil fuels HECs must cost less than $25/ton, of which land "rent" can probably be no more than $5.00. If the HEC harvest fee is based on yield (per ton) instead of land (per acre), yield is not a critical factor in cost as long it is above a minimum level. With an average yield of 5 t/acre and an average CRP rent rate of $65, a fee of $3.90 per ton would be equal to a 30 percent incentive.

6.1.3 HEC Stand Establishment

Stand establishment costs for land enrolling in the CRP program are usually shared between the federal government and the landowner. No cost recovery for stand establishment from the HEC pellet business is anticipated. Information on cost and embodied energy from earlier work and direct personal experience are summarized in Tables 6.8 and 6.9 below.

Table 6.8 Herbaceous Energy Crop Establishment Cost (BEPCEE and Kansas Ag Statistics)

Expense				**Switchgrass**	**Big Bluestem**
Establishment	**Unit**	**Unit Cost**	**Qty**	**$/acre**	**$/acre**
No-till					
Mow (late summer)	acre	$7.00	1	$7.00	$7.00
Glypsophaste (early fall)	acre	$10.00	1	$10.00	$10.00
Glypsophaste (spring)	acre	$10.00	1	$10.00	$10.00
Drill seed	acre	$7.50	1	$7.50	$7.50
Seed Cost					
Switchgrass	lb	$8.00	5	$40.00	
Big Bluestem	lb	$16.00	5		$80.00
Weed control					
Mow (mid-summer)	acre	$7.00	1	$7.00	$7.00
SubTotal No-till establishment				**$81.50**	**$121.50**
Amount paid for bioenergy				**$0.00**	**$0.00**
Till					
Disk (fall)	acre	$6.50	1	$6.50	$6.50
Disk (early spring)	acre	$6.50	1	$6.50	$6.50
Harrow	acre	$4.50	1	$4.50	$4.50
Compact roller	acre	$5.00	1	$5.00	$5.00
Drill seed	acre	$7.50	1	$7.50	$7.50
Seed Cost					
Switchgrass	lb	$8.00	5	$40.00	
Big Bluestem	lb	$16.00	5		$80.00
Weed control					
Mow (mid-summer)	acre	$7.00	1	$7.00	$7.00
SubTotal Till establishment				**$70.50**	**$110.50**
Amount from HEC business				**$0.00**	**$0.00**

Table 6.9 Embodied Energy of Herbaceous Energy Crop Establishment Cost (BEPCEE)

Source	**Million Btu per Acre**			
	Conventional Tillage		**No-Till**	
	Preparation Year (fall before planting)	Plant Year (no harvest)	Preparation Year (fall before planting)	Plant Year (no harvest)
Fertilizer	0	0	0	0
Chemicals	0	0	.032	.032
Materials	0	.015	0	.015
Equipment	.096	.107	.045	.068
Fuel & Oil	.243	.256	.162	.265
Labor	.000	.000	.000	.000
SubTotal	.339	.378	.239	.381
TOTAL	.717		.620	
Per Ton (prorated 10 years, 5 t/a)	.014		.012	

6.1.4 Production and Harvesting

Soil testing and fertilizer application would begin in the spring of the first year after planting. Earlier ALMANAC modeling suggested optimum nitrogen application would range from 100 – 150 pounds per acre in one or two applications. A major goal of buffer strips is mitigation of nitrogen and agricultural chemicals applied to adjacent tilled land, suggesting reduced nitrogen application levels may be possible without adversely affecting yield (a similar amount of nitrogen is available). Any application of nitrogen will need to be carefully monitored to ensure it, as well as any migrating from adjacent tilled land, is substantially consumed. Typical ALMANAC recommended values are used in evaluating cost and embodied energy since they represent a reasonable case.

Large Baler (Vermeer)

HEC harvesting would begin in October or early November following the first hard freeze. Post frost harvesting may improve plant vigor and increase the useful life of the stand. It also reduces plant moisture content, typically below 15%. Some studies have suggested that allowing the plant to remain in the field until late Winter may result in modification of its chemical composition in ways beneficial to energy use, but the strategy outlined here is to harvest all of it within two months to reduce the risk of lodging and possible loss. Conventional swath and bale methods are assumed, although the development of combined mow/bale equipment or field chopping may have merit. Estimated production and harvesting costs for a typical field with an average yield of five tons per acre are shown in Table 6.10 below.

Table 6.10 Switchgrass Production and Harvesting Cost

Item	Unit	Unit Cost	Qty	$/Ton
Land				
Harvest fee (30% of CRP rent of $65/acre, 5 t./acre yield)	ton	$3.90	1	$3.90
Production				
Soil testing	ea	$10.00	.1 per acre	$0.20
Fertilizer application no. 1	acre	$3.50	1	$0.70
Nitrogen	lb	$0.20	140	$5.60
Fertilizer application no. 2	acre	$3.50	0	
Harvesting				
Swather	acre	$7.50	1	$1.50
Bale (incl. twine, no wrap)	ton	$7.50	1	$7.50
SubTotal, in field cost				$19.40
Move to edge of field	ton	$1.00	1	$1.00
Edge of field baled cost ($/ton)				**$20.40**

6.1.5 Switchgrass Production and Harvesting Embodied Energy

The embodied energy required to produce and harvest HEC is highly dependent on the amount of nitrogen fertilizer applied. Field configuration and slope have a modest impact. Low yields can dramatically reduce the net edge of field energy profit ratio. Table 6.11 below provides detailed embodied energy estimates from the BEPCEE model for a typical field for a ten-year period.

Table 6.11 Switchgrass Production and Harvesting Embodied Energy (BEPCEE)

	Production Year										
Energy Use	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Average**
Nitrogen (lbs/acre)	141.2	101.8	137.0	141.6	142.2	142.8	141.3	194.8	101.8	143.5	**138.79**
Yield (d.t./acre)	7.00	2.06	5.77	5.72	7.10	4.76	4.93	5.39	3.91	6.19	**5.28**
Embodied Energy (million Btu/acre)											
Fertilizers	4.657	3.355	4.518	4.668	4.690	4.707	4.660	6.423	3.355	4.731	**4.58**
Chemicals	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	**0.03**
Materials	0.014	0.004	0.012	0.011	0.014	0.010	0.010	0.011	0.008	0.012	**0.01**
Equipment	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161	**0.16**
Fuel & Oil	1.268	1.268	1.268	1.268	1.268	1.268	1.268	1.268	1.268	1.268	**1.27**
Labor	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	**0.00**
TOTAL	6.134	4.822	5.993	6.142	6.168	6.180	6.133	7.897	4.826	6.206	**6.05**
Cumulative (including establishment)	6.851	4.822	5.993	6.142	6.168	6.180	6.133	7.897	4.826	6.206	**6.12**
MBtu/ton	0.98	2.34	1.04	1.07	0.87	1.30	1.24	1.47	1.23	1.00	**1.25**
Energy Profit Ratio (field edge)	16.2	6.8	15.3	14.7	18.2	12.2	12.7	10.8	12.8	15.8	**13.56**

If nitrogen fertilizer application were reduced by 50% through a combination of relying on scavenged nitrogen reclaimed from field run-off or migrating ground water, a key function of buffer strips, and acceptance of a somewhat reduced yield, the embodied energy per ton would decline from an estimated 1,250,000 to 816,300 Btu/dry ton.

6.1.6 Transportation: Edge of Field to Plant

Baled HEC moved to the edge of field by the harvesting crew should be placed directly on a waiting flat bed trailer for transportation to the plant. Storing the bales at the field edge, even temporarily, risks contamination from soil and road dust. Since harvesting is expected to be completed during a two-month window ownership of transportation equipment is not cost effective and the work should be performed by contract. A 25-foot long flat bed with five-foot diameter bales stacked two wide and two high would carry approximately 20 tons. The loaded bales should be fully covered with a tarp to prevent road dust contamination.

Table 6.12 presents an estimate of edge of field to plant transportation cost for a fully operational HEC pelleting plant drawing harvested biomass from an area of approximately 350 square miles with an average haul distance of 12 miles. An estimated six truck tractors and twelve flat bed trailers would be required. Each truck would require a dedicated forklift for loading.

Table 6.12 Field to Plant Transportation Cost

Expense	**Amount**
Annual Production (d.t.)	14,904
Switchgrass average yield (d.t./acre)	5
Acres required to support plant	2,981
Tons per trailor	20
Trailor loads to transport	745
Harvest days	39
Trailor loads per day	19
Miles from plant (ave. one-way)	12
Cycle time (load-move-unload-move hours)	2.75
Tractors required	5
Loading forklifts required	6
Unloading forklifts required	2
Trailors required	10
Miles traveled	17,885
Ton miles traveled	357,696
Miles per day (all units)	932
Truck rental rate per day	$100
Trailor rental rate per day	$20
Loading forklift rate per day	$30
Unloading forklift daily cost	see plant operation
Diesel fuel cost per gallon	$1.25
Truck milage	6
Driver cost per day	$156
Daily cost	$2,136
Cost per ton	**$5.56**

6.1.7 Transportation Embodied Energy

Transportation from edge of field to the pelleting plant is a significant cost and embodied energy event. One ton bales are loaded on a flat bed trailer by a forklift dedicated to each tractor truck serving two trailers. Each trailer is assumed to travel an average distance of 12 miles to the pelleting plant, returning to the field empty. The cost and embodied energy involved include the manufacture and operation of the forklift used to load the bales, the flat bed trucks (two per tractor), and the tractor. The embodied energy for the unloading process is included here while the cost is reflected in plant operation. While estimated transportation cost is significant, embodied energy is not. Table 6.13 provides a breakdown of estimated embodied energy.

6.1.8 Pelletizing Switchgrass

While some work on refuse derived fuels has been done, the biomass pellet fuel market is based almost entirely on sawmill residue from soft and hardwood trees as a fuel source. R.E.A.P.- Canada and DELL-POINT Bioenergy Research conducted pelleting tests on pine needles, willow, and switchgrass using a 2 hp California Pellet Mills Bench Top Pelleter and a 25 hp California Pellet Mills Master Mill, the smallest master mill offered by CPM. It provided a baseline assessment of how larger units (150-300 hp) used by most pellet producers would perform. The pelleting process and switchgrass results are summarized below.

Table 6.13 HEC Transportation Embodied Energy

Energy Use	Amount
Diesel fuel Btu/gal	140,000
Loading bales on flat bed	
Fork lift embodied energy (Btu)	350,000,000
Number of loading forklifts	6
O&M multiple	1.2
Life (yrs)	10
Fraction of year used for bale hauling	17%
Annual embodied energy	42,000,000
Miles per ton loaded	0.038
Milage	20
Fuel (Btu all loading)	3,951,818
SubTotal bale loading	45,951,818
Transportation field to plant	
Truck tractor embodied energy (Btu)	1,200,000,000
Number of tractors	6
Flat bed trailer embodied energy (Btu)	500,000,000
Number of trailers	12
O&M multiple	1.2
Life (yrs)	10
Fraction of year used for bale hauling	17%
Annual embodied energy	264,000,000
Truck miles per gallon	6
Fuel	417,312,000
SubTotal bale hauling	681,312,000
Unloading bales, stacking	
Fork lift(s)	350,000,000
Number of unloading forklifts	2
O&M multiple	1.2
Life	10
Annual embodied energy	84,000,000
Miles per ton unloaded	0.076
Milage	20
Fuel	7,903,636
SubTotal bale unloading	91,903,636
SubTotal Transportation Embodied Energy	819,167,455
Transportation Embodied Energy (Btu/ton)	**54,963**

6.1.9 The Pelleting Process

"The material is fed continuously into the pelleting cavity. It is directed equally to the edges formed by the rollers and the inside face of the die. The rollers turn as the die rotates. The material is forced through the die holes by the extreme pressure caused by the wedging action. As the pellets are extruded, adjustable knives cut them to the length desired. A number of factors are commonly known to affect the success of the process including:

- *moisture content,*
- *density,*
- *particle size,*
- *fiber strength properties of the fuel,*
- *lubricating characteristics of the material*

Material is comminuted to a length of fibre that ensures the pellet can be properly formed with a good hardness and minimum production of fines. Pelleting productivity is measured by manufacturers in production yield in pounds or kg per Hp. In the case of sawdust residues this value varies from about 20-40 lbs per hp. depending on the source of the wood residue with hardwoods being in the low range and softwoods the high end (Drisdelle, 1999). In theory the more pliable the fibre the easier it is to exude through the roller die. Other factors which influence productive yields are steam and residency time (cooking or conditioning) to create a more pliable fibre. The net effect aimed for is to create a more fluid pelleting process, one where a lower friction co-efficient is created between the die extrusion surface and the fibre. The pellet is bound together by the lignin exuded from the feedstock. This process results when fibre passes through the extrusion holes, the die heats up, creating elevating temperatures (75-85 degrees C). Lignin inherent in the material starts to flow from the fibre cell walls and has the effect of binding with other fibres during extrusion. In the process some moisture is also driven off as steam. The resulting product is a uniform flowable material with a bulk density several times that of the beginning raw material and is slightly drier."[20]

6.1.10 Switchgrass Preparation

"Switchgrass was a dry and dusty product to comminute. However one single pass through the comminuting device provided a sample in which 100% of the material could pass through a # 4 mesh. Hot water was added prior to pelleting to ensure the product would run well. The initial test run on the bench top pellet mill proved rather difficult. Good quality pellets were produced. However, on several occasions the bench top mill plugged up and it ran rather hot. The 2.5" thick die appeared to be a bit too thick to run the material easily. The material was then subsequently taken for pelleting on the 25 hp which had a 3/16" diameter die that was 1.5" thick. No problems were experienced on this machine. The product ran well and fairly easily once additional moisture was added. The pellets came off the mill at a temperature of 67 degrees C. The research team felt it ran similar to steam conditioned alfalfa and that production rates of 70-100 lbs/hp would seem a reasonable throughput range for the material based on these initial tests. The die ran best with a thick pad of material on the die face. It was felt that rough surface roller shells could be well suited for this application which would add additional grinding on the face. It was felt that a die specified for wood use or a slightly thicker die on the 25 hp machine would have been ideal along with steam conditioning. Eight kg of the 3/16 inch pellets were subsequently repelleted on the larger 6.9 mm lab die to produce pellets suitable for performing combustion tests. The lab mill ran at 10 amps which was higher than the 6-7 amps experienced with the pine needles." [20]

6.1.11 Switchgrass Pellet Quality

"The pellets produced were of excellent quality and tested over 30 on the Pfizer tablet hardness tester. The 3/16 inch material had a bulk density of 615 gr/l and the 6.4 mm pellets which had gone through a double pelleting process were 700 g/l. Of the three materials pelleted switchgrass produced the most fines although the amount was limited. The pellets had an ash content of 4.6%. The value was considered high. Switchgrass ash levels of spring harvested

[20] Samson, R., Girouard, P., Mehdi, B., Resource Efficient Agricultural Production-Canada and Drisdelle, M., Lapointe, C., DELL-POINT Bioenergy Research, ***Assessment of Pelletized Biofuels***, Quebec, Canada, 1999.

material averaged 2.75 and 3.21% ash for switchgrass from other sites. A desired value would be less than 3%, which would place it in the B grade. Bark pellets are being used commercially and have an ash content of 3.6%. The energy contents of the pellets produced in the current study were high at 19.4 GJ/tonne. Other spring harvested switchgrass tests samples were 18.4 and 19.1 GJ/tonne. On average spring harvested material has a superior energy content to fall harvested material (which is related to the lower ash content of spring harvested switchgrass). The average energy content of three spring harvested materials (19.0 GJ/tonne) is 4% lower than wood pellets at 19.8 GJ. Fall harvested switchgrass is approximately (18.5GJ/tonne) or 6.6% lower than wood. The other advantage of using spring harvested switchgrass is less problematic combustion. Lower nitrous oxide levels will occur as spring harvested switchgrass contains .33% N while fall harvested material was .46%. Potential for clinker formation will be eliminated as the potassium content is reduced by 94% through the overwintering process (Samson and Mehdi, 1998).”[21]

6.1.12 Pelleting Cost

The following analysis attempts to determine if grass could be produced and pelletized at a cost that permits them to be sold profitably in competition with fossil fuels for residential space and water heating in northeast Kansas. Several key points must be noted:

- Harvesting the grass from CRP enrolled land in exchange for a below market rent payment is critical. While this could be viewed as subsidizing biomass it is part of a package of complementary environmental benefits with very real public value.

- Achieving competitive energy prices requires a high annual plant factor for the pelleting equipment and extensive storage capacity for bales and pellets must be provided to achieve it, adding to the capital cost of the plant.

- Today’s market for high ash content biomass pellets is limited and it may not be possible to export excess production if ash content exceeds 3%. The market wound need to be local to avoid high transportation costs and it would need to be created as rapidly as possible to permit economic operation of the pelleting plant.

- Income from the sale of pellet combustion equipment would need to offset losses from pellet plant operation during the start-up period that could last for several years.

6.1.13 Pellet Mill Design and Construction

An HEC pellet mill would need to be somewhat different from a wood pellet mill facility. A detailed preliminary design and component assessment is beyond the scope of this project but a few major distinctions are worth noting. A dryer would probably not be necessary given the expected harvest moisture content of less than 15%. The bulk delivery strategy negates the need for a bagging system. The biggest difference however is the very large need for under-roof bale storage and on-site pellet storage.

[21] Ibid.

Research by Samson[22] suggests delaying harvest until late winter may result in improved chemical composition of switchgrass. However the risk of substantial degradation in the Northeast Kansas winter climate that often includes precipitation and frequent freeze-thaw may require harvest as soon after frost as possible. Transporting bales to the pelleting facility and storing them under-roof will reduce degradation and contamination and stabilize moisture content. Such control may also be essential under terms of a CRP program waiver to permit harvesting for biomass energy use. Table 6.14 details the analysis of storage size requirements for a fully operational three ton/hr pelleting plant.

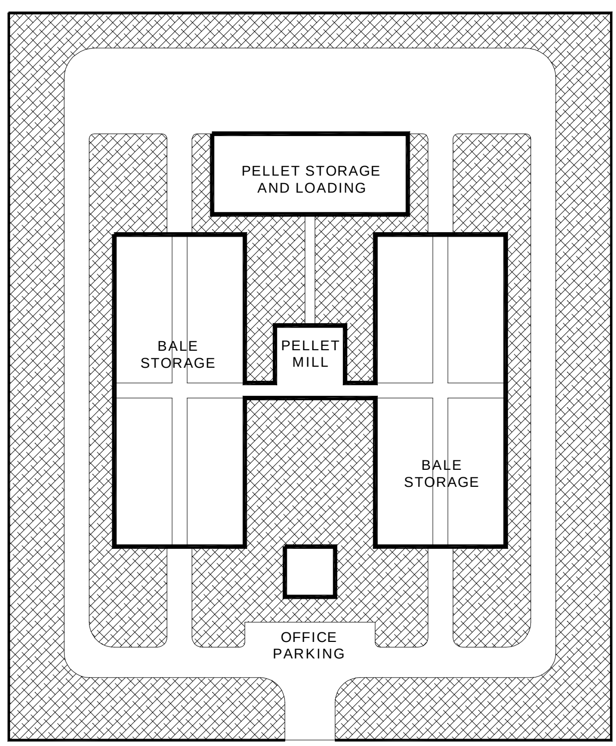
Table 6.14 HEC Bale Storage Requirements

Bale Storage Requirements	**Value**
Bale size	5.5' dia x 5.5'
Bale volume (c.f.)	131
Bale density (lbs/c.f.)	15
Barrel weight (lbs)	2000
Moisture Content	12%
Dry weight per bale (lbs)	1760
Bales requires to make 14,904 d.t.	16,933
Bales processed during 2 mo. harvest	2,822
No. of bales to store	14,111
Area required when stacked 5 high	67,049
Aisles and walls	10,057
Total storage area (s.f.)	77,106
Building width (ft)	125
Building length (ft)	617
Pellet Storage Requirements	
Pellet density (p./c.f.)	40
Pellet moisture content	5.0%
Fraction of annual production stored	65%
Maximum storage (c.f.)	509,874
Storage depth (ft)	30
Building area (s.f.)	16,996
Building width (ft)	80
Building length (ft)	212

6.1.14 Pellet Mill Construction Cost

A detailed analysis of pellet mill construction cost is beyond the scope of this report. Information from NEOS Corporation's 1993 report for Colorado and the Western Regional Biomass Energy Program and their 1995 report for the Great Lakes Regional Biomass Energy Program were used to develop the generalized cost parameters for equipment shown in Table 6.15 below. Other cost components were based on data from other projects. Figure 6.1 provides a schematic diagram of the plant configuration used for cost estimating purposes. Table 6.17 provides a very preliminary estimate of pelleting plant construction embodied energy.

Figure 6.1 HEC Pelleting Plant Schematic Site



[22] Samson, R., R.E.A.P. Canada.

Table 6.15 Pellet Mill Estimated Construction Cost

Plant Cost	Unit	Unit Cost	Quantity	Total
Site				
Land (small town site)	sq. ft.	$0.25	435,600	$108,900
Site improvements	sq. ft.	$0.35	435,600	$152,460
Buildings				
HEC storage	sq. ft.	$10	77,106	$771,058
Pelleting mill	sq. ft.	$25	5,000	$125,000
Pellet storage	sq. ft.	$20	16,996	$339,916
Equipment				
Pelleting Equipment	ton	$200,000	3	$600,000
Other equipment	lot	$100,000	1	$100,000
Engineering fees				$65,920
Less ECO-DEVO grant				$0
Interest during construction				$67,898
Total Plant Cost				**$2,331,152**
	Interest	**Term**	**Monthly**	**Annual**
Annual Plant Amortization	9%	15	$23,644	**$283,729**
Plant Cost (annual P&I/d.t.)				**$19.04**

A $500,000 economic development grant would reduce the plant principal and interest cost from $19.04 to $14.95 per dry ton, but no source for such assistance has been identified.

Pellet mill operating cost is summarized in Table 6.16 below. Annual operating cost is a major factor in plant economics and failure to operate at full capacity significantly increases pelleting cost per ton.

Table 6.16 Pellet Mill Operating Cost

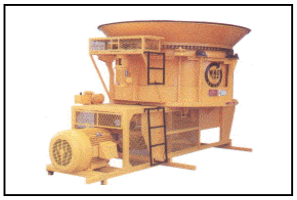
Labor	Unit	Unit Cost	Quantity	Total
Mechanic	hr	$18.20	2000	$36,400
Laborer	hr	$13.00	8930	$116,085
FTE Employees				6
Utilities				
Pellet equipment	kwh	$0.060	1371168	$82,270
Pellet die & roller replacement	ton	$2.50	14904	$37,260
Plant heating	sf	$0.50	5,000	$2,500
Plant Maintenance	sq. ft.	0.25	95,000	$23,750
Insurance				$24,902
Taxes				$37,352
Interest on Inventory				$25,151
SubTotal Plant Operation				$385,675
Plant Production				
Plant production				14,904
Losses				3%
Annual Production (dry tons)				14,457
Pellet Mill Operating Cost				
Bulk pellets ($/ton)				**$26.68**

Table 6.17 Pelleting Plant Construction Embodied Energy

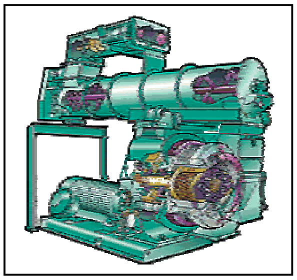
Construction	Unit	Material Unit Energy	Installation Unit Energy Multiplier	Quantity	Total Energy (Btus)
Site					
Grading	s.f.	51	1.00	435,600	22,400,000
Utility installation	lot	1,000,000	1.10	1	1,100,000
Roads					
Paving	s.f.	6,000	1.10	60,000	396,000,000
Bale Storage Buildings					
Foundation/slab (concrete on gravel)	s.f.	6,000	1.25	77,106	578,293,760
Structure (steel)	s.f.	42,000	1.10	77,106	3,562,289,562
Roofing (metal)	s.f.	15,000	1.10	88,672	1,463,083,213
Electrical	s.f.	1,500	1.10	77,106	127,224,627
Fire suppression	s.f.	1,000	1.10	77,106	84,816,418
Pellet Storage Building					
Foundation/slab (concrete on gravel)	s.f.	6,000	1.25	16,996	127,468,421
Structure (steel)	s.f.	42,000	1.10	16,996	785,205,474
Pellet bin in walls (concrete)	s.f.	9,000	1.25	33,500	376,875,000
Roofing (metal)	s.f.	15,000	1.10	19,545	322,495,105
Electrical	s.f.	1,500	1.10	16,996	28,043,053
Fire suppression	s.f.	1,000	1.10	16,996	18,695,368
Pellet Mill Building					
Foundation/slab (concrete on gravel)	s.f.	6,000	1.25	5,000	37,500,000
Structure (steel)	s.f.	41,273	1.1	5,000	226,999,140
Walls (metal)	s.f.	14,961	1.1	5,000	82,287,188
Roofing (metal)	s.f.	14,961	1.1	5,750	94,630,267
Electrical	s.f.	5,000	1.1	5,000	27,500,000
Fire suppression	s.f.	2,000	1.1	5,000	11,000,000
Pelleting Equipment					
Tub grinder	lb	60,000	1.1	8,000	504,000,000
Pellet mill	lb	60,000	1.1	8,000	504,000,000
Conveying equipment	lb	60,000	1.1	25,000	1,575,000,000
Misc. Equipment	lb	60,000	1.1	20,000	1,260,000,000
TOTAL Embodied Energy					**12,216,906,597**
Plant life					**25**
Annual O&M fraction of original embodied energy					**1.0%**
Demolition fraction of original embodied energy					**5.00%**
Fraction recycled					**20.00%**
TOTAL Annual Embodied Energy					**537,543,890**
Embodied Energy/ton					**37,183**

6.1.15 Pelleting Plant Operating Energy Requirements

Pelleting is an energy intensive process. The HEC must be reduced in size with a grinder and then compressed to achieve a tight dense pellet substantially free of fines. Table 6.18 provides a list of the principal electrically driven equipment required and their estimated duty factor. Electrical system losses from generation and transmission are the largest energy inputs. If electricity from renewable resources with an energy profit ratio of 10, such as wind, could be purchased the pelleting embodied energy would decline proportionately from an estimated 1,067,558 to 106,756 Btu/dry Btu. If wind energy cost five cents per kilowatt hour to produce, received a one-and-one-half cent per kilowatt-hour tax credit, and displaced coal costing one cent, the net increase in pelleting cost would be approximately $2.35 per ton. Actually purchasing green electricity at this price in Northeast Kansas will depend on future market developments.



Tub Grinder
(WHO Manufacturing)



Pellet Mill
(CPM)

Table 6.18 Pelleting Equipment Operating Energy Requirements

Equipment	Duty Factor	kW	kWh/hr
Electric fork-lift (unload, move to grinder)	0.75	30.00	22.50
Tub grinder (3 d.t/hr)	1	100.00	100.00
Conveyor to pellet mill	1	5.00	5.00
Pellet mill operation	1	125.00	125.00
Cooling fan	1	5.00	5.00
Elevator	1	5.00	5.00
Conveyor to pellet storage	1	10.00	10.00
Exterior Lighting	0.5	2.00	1.00
Interior Lighting	0.5	5.00	2.50
SubTotal, kWh			**276**
kWh/ton			**92**
Distribution Equipment			
Pellet auger(s) for truck loading	0.500	3.73	**1.87**
TOTAL, kWh/ton			**93.87**
Electrical supply efficiency			30%
Source energy, Btu/dry ton			**1,067,558**
(this could be reduced if green electricity were purchased or generated on-site)			

6.1.16 Retail Pellet Sales

Direct marketing, sale, and delivery of HEC pellets will require a larger staff than pellet mills that market their production through a limited network of retail dealers. This staff and the facilities and equipment required to support them would be a significant cost. Table 6.19 provides a summary of estimated expenses for sales and overall business management. These costs are much higher than typical pellet plants as a result of the direct sales and delivery strategy.

Table 6.19 Retail Pellet Sales and Business Management

Labor	**$/yr**	**Indirect**	**Qty**	**Total**
Manager	$40,000	1.3	1	$52,000
Marketing /sales	$24,000	1.3	1	$31,200
Billing clerk	$16,000	1.3	2	$41,600
SubTotal Labor				$124,800
FTE Employees				4
Travel	20,000 mi/yr	$0.35/mile		$7,000
Office	**Rate ($/sq. ft.)**			
Rent (including tax)	$15.00		1500 s.f.	$22,500
Janitorial	$1.00		1500 s.f.	$1,500
Utilities				
Electrical & Gas	$1.00		1500 s.f.	$1,500
Communications				
	Customer, $/yr		**Customers**	
Telephone	$3.00		2484	$8,452
Internet	$2.00		2484	$5,968
Mailing (billing)	$3.00		2484	$7,452
Delivery	$1.00		2484	$2,484
Equipment				
Office furniture				$2,000
Telephone system				$2,000
Computer network				$5,000
Copying				$2,000
Misc.				$500
Supplies				
Office supplies				$2,500
Services				
Advertising				$25,000
Insurance				$2,500
Accounting				$3,500
Legal				$3,500
TOTAL OFFICE EXPENSES				$223,156
Office Expenses ($/dry ton)				**$15.44**

Table 6.20 below provides an estimate of embodied energy resulting from sales and business management activities.

Table 6.20 Embodied Energy of Retail Pellet Sales and Business Management

Source				Energy
Office construction (Btu/s.f.)				500,000
Future office demolition-recycle (Btu/s.f.)				100,000
Office life (yrs)				30
Annual embodied energy				30,000,000
Annual maintenance				10,000,000
Utilities	**kWh/sf/yr**	**Electrical efficiency**		
Electricity	12	30%		204,720,000
	Btu/sf/hdd	**HDD**	**EPR * AFUE**	
Pellet (space and water htg)	6	5200	4.8	9,750,000
Travel (hybrid gas-electric)				
Vehicle (mfr Btus)				75,000,000
Vehicle life (yrs)				7
Recovered at recycling				20%
Annual vehicle				8,571,429
	Miles	**Btu/gal.**	**Indirect**	
Fuel (60 mpg)	20,000	125,000	1.3	54,166,667
Office supplies and equipment				10,000,000
Services				5,000,000
TOTAL embodied energy				332,208,095
Embodied energy (Btu/dry ton)				**22,979**

6.1.17 Pellet Home Delivery

Bulk delivery of pellets direct from the pelleting plant to the local residential consumer is intended to avoid bagging cost and the high mark-up of retail marketing and increase market potential by improving customer convenience, but it does result in additional costs for the pelleting business. Values in Table 6.21 are based on delivery by trucks of no larger than 12 ton capacity, most of which are operated by seasonal employees. The estimated travel distance per two-ton delivery is six miles. Pellet delivery costs could escalate rapidly if trucks and drivers are not scheduled and routed efficiently or if delivery distances increase.

Table 6.21 Pellet Home Delivery Cost

Equipment	Cost/Unit
Net plant production (d.t.)	14,904
Average pellet sales per customer (d.t./yr)	6.0
Number of customers required	2,484
Pellets per delivery (tons)	2.0
Miles per delivery	6.0
Deliveries per day per truck	10.0
Delivery season (days)	120
Truck capacity (tons)	12.0
Trucks required	6.2
Miles per truck per year	7,200
Delivery truck (per truck)	
Purchase cost (used)	$50,000
Annual cost (10%, 5 year term)	$13,347
Fuel Cost	
Diesel Cost ($/gal.)	$1.25
Miles per gallon	6.0
Fuel cost per mile	$0.21
Fuel cost per truck/year	$1,500
Maintenance	$1,500
Insurance	$750
Taxes	$1,250
Labor	
Driver (seasonal)	$17,280
Employees (seasonal)	6.2
Annual cost per truck	$35,627
Delivery Cost per Ton	**$15.63**

6.1.18 Pellet Delivery Embodied Energy

Pellet delivery embodied energy includes the energy to manufacture and fuel the delivery trucks and equipment. If sales are expanded beyond the area within 50 miles of the basin or customers are spaced greater than an average of six miles apart (including return travel) within the basin, embodied energy for delivery will increase.

Table 6.22 Pellet Delivery Embodied Energy

Delivery Trucks	
Manufacturing energy	1,250,000,000
Life of vehicle	10
Remaining life when purchased	6
O & M multiplier	1.2
Total Truck Embodied Energy per Year	931,500,000
Fuel	
Gallons diesel consumed	7,452
Energy content	140,000
Indirect multiplier	1.15
Gross fuel energy (MBTUs)	1,199,772,000
Total Annual Truck Energy	2,131,272,000
BTU per Ton	**143,000**

6.1.19 Residential Space and Water Heating Equipment Sales

A major impediment to the development of a residential HEC pellet fuels market in NE Kansas is a lack of proven high ash pellet boilers and therefore companies experienced in selling, installing and maintaining them. It might be necessary for a company attempting to start a HEC pelleting business to assume the installation and maintenance role, either directly or through agreements with existing residential heating and cooling contractors. While the goal would be to increase market penetration as rapidly as possible, the sales and installation of systems might help offset likely inevitable negative cash flow during the pelleting plant start-up.

6.1.20 Total HEC Pellet Production Cost

Table 6.23 summarizes the total estimated HEC pelleting cost per ton for a fully operational plant operating at full capacity. Many factors could rapidly escalate cost, including:

- unavailability of adequate raw material,
- unavailability of labor at rates projected,
- equipment start-up problems,
- excessive die replacement,
- higher electricity or diesel fuel costs,
- any factor that prevents the plant from operating at full capacity.

Table 6.23 HEC Pelleting Cost per Ton

Expense	Cost/Ton
Stand establishment	na
Production and harvesting	$20.40
Transportation to plant	$5.56
Pellet mill debt service	$19.04
Pellet mill operation	$26.68
Management, sales and billing	$15.44
Delivery	$15.63
TOTAL Cost	**$102.75**

NEOS's 1995 report estimated the cost of wood pellets from a new four ton per day plant at $82-95 per ton (1999 = $89 - 104 per ton), not including delivery to retailers. The estimated total cost shown in Table 6.23 of $102.75, when adjusted by removing the transportation cost to end-users of $15.63, is $87.12. The savings from not bagging tends to offset the additional cost of bale and pellet storage.

6.1.21 Minimum Retail HEC Pellet Price

The analysis shown here assumes a 3-ton per day plant running at full three-shift capacity with all produced pellets being sold each year and no shortage of raw material. No phased development has been evaluated and no sensitivity or break-even analysis has been performed, key factors in determining the minimum selling price. No survey of potential customers has been made. Table 6.23 indicated that for most conditions HEC pellets priced at $148 per ton would be competitive with propane at $0.80/gallon and most electric systems except for ground source heat pumps that have high initial cost. Propane prices can fluctuate widely in response to weather driven supply and demand conditions, but have generally been in the $0.60-.65/gallon range recently, suggesting the $148/dry ton is the upper end at which HEC pellets could enter the market. That would represent a gross margin of approximately $45 per ton for a total of $650,500 per year for the plant. Such gains could only be realized under a very optimistic scenario.

6.1.22 Total HEC Pellet Embodied Energy

Embodied energy data based primarily on the BEPCEE model indicates a total fossil energy investment of about 2,575,000 Btu/dry ton. This value does not include establishment since it would have occurred as part of the CRP enrollment regardless of energy harvesting. It does include the energy to manufacture and construct equipment and facilities (pro-rated for life) and maintenance and operation. Electrical inputs are source Btus with a system efficiency of 30%. Evaluating embodied energy is not a straightforward process and these values should therefore be considered as reasonable estimates. The energy profit ratio (EPR – energy out/energy in) is 6.15. In other words one Btu of fossil energy is used to produce 6.15 Btus of useable biomass energy. The major energy inputs are natural gas used to produce nitrogen fertilizer and the electricity used to operate the pelleting plant. If applied nitrogen is reduced 50% and green electricity with an EPR of 4.0 is purchased for operation of the pelleting plant, the embodied energy falls to 1,525,000 Btu/ton and the energy profit ratio rises to 10.4. Since a major goal of filter strips is to reduce migrating nitrogen from fertilized fields, reduction in fertilizer application levels may be not only appropriate but also essential.

Table 6.24 HEC Pelleting Embodied Energy – Source Btus

Process	**Btu/Ton**
Stand establishment	na
Production and harvesting	**1,250,000**
Transportation to plant	**54,963**
Pellet mill construction	**37,183**
Pellet mill operation	**1,067,558**
Management,sales and billing	**22,979**
Delivery	**143,000**
TOTAL, Btu/Ton	**2,575,683**
Energy Profit Ratio	**6.15**
Reduced Nitrogen and Green Electricity	
TOTAL, Btu/Ton	**1,525,015**
Energy Profit Ratio	**10.39**

Note: Green electricity EPR of 4.0.

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