West Kentucky Agricultural Biomass Pellet Report

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Introduction

The purpose of this report is to examine the business opportunity to develop renewable energy from agricultural biomass ("ag-biomass") pellet production in the twenty counties of West Kentucky. Since 2000 the cost of fossil fuels has steadily risen and prices are predicted to continue to rise in the long-term as economic growth in China and India lead to increased demand, other emerging economic develop, and U.S. and European markets slowly recover from recession. According to the U.S. Energy Information Administration (EIA), renewable energy is projected to be the fastest growing source of primary energy for the next 25 years.[1]

Globally, interest in using biomass for energy is increasing. This trend is driven by interest in reducing dependency on foreign oil, stimulating local economies and creating jobs, and environmental benefits like greenhouse gas reduction.

Ultimately, biomass-to-energy opportunities will be determined by market economics, which are affected by the availability of feedstock and land, energy demand, new technologies, financial incentives and government policy. Since this report examines the business opportunity for ag-biomass pellet development, the framework for research and analysis is based on assessing the economic feasibility of an ag-biomass pellet facility. For an ag-biomass pellet supply chain to be feasible there needs to be – at a minimum – sufficient economic value at both the farm and factory level; otherwise farmers have no incentive to produce the raw materials for processing and/or a processing facility cannot make a profit from the production of ag-biomass pellets.

Biomass includes any plant-derived organic matter. Biomass pellets can be derived from a number of different feedstock sources. This includes herbaceous and woody energy crops, agricultural crops, agricultural crop residues, wood residues, and aquatic plants. Due to the well-developed forestry and agricultural base in the West Kentucky region, this report will look at opportunities for utilizing herbaceous energy crops, wood residue and crop residue as potential raw material feedstocks for ag-biomass pellet production.

In order to account for the many factors affecting the development of an ag-biomass pellet supply chain in West Kentucky, the report will be broken into several key sections:

1. **Market Opportunities for Agricultural Biomass Pellets** – includes existing and potential opportunities in the residential, commercial, institutional and utility sectors
2. **Agricultural Biomass Pellet Quality** - describes existing market standards for ag-biomass pellets
3. **Agricultural Biomass Pellet Pricing** - describes potential pricing scenarios for ag-biomass pellets
4. **Agricultural Biomass Feedstock Production** – describes current land use in the region, as well as options for utilization of crop residue, wood residue, and dedicated energy crops
5. **Pelletizing Process** – includes description of process, costs, and capital requirements for a 2 ton per hour (TPH) and a 14 TPH pelletizing system
6. **Financial Modeling** – examines the economic feasibility of three business models: a small-scale 2 TPH pellet plant, a commercial-scale 14 TPH pellet plant, and a 14 TPH non-pelletized operation for bulk chopped and ground material; also includes sensitivity analysis

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[1] U.S. Energy Information Administration. (2011). 'International Energy Outlook 2011'. http://www.eia.gov/forecasts/ieo/.

7. **Strategic Recommendations for Advancing the Development of Agricultural Biomass-to-Energy Supply Chains in West Kentucky** – includes recommendations for crop production and technology research, policy, collaborative partnerships and pilot models for learning and demonstration

West Kentucky Region

The West Kentucky Region includes counties: Ballard, Caldwell, Calloway, Carlisle, Christian, Crittenden, Fulton, Graves, Henderson, Hickman, Hopkins, Livingston, Lyon, Marshall, McCracken, Muhlenberg, Todd, Trigg, Union, Webster.

Energy Consumption

The West Kentucky region has six coal power plants, one natural gas and one hydro electric.[2] For a complete list of power companies in the region please refer to ***Appendix 3 - West Kentucky Power Plants***. The primary energy source for the state of Kentucky is coal, followed by natural gas and fuel oil. According to the U.S. Energy Information Administration total electricity consumption from coal in the state equaled 937 trillion Btu in 2009.[3]

Electric utility companies generated over 90 million megawatt hours of power; and another 600 thousand megawatt hours of power came from independent power sources and combined heat and power.[4] Over 90 percent of Kentucky's electric power is produced from coal-fired power plants, with the remainder coming from hydroelectric dams, fuel oil and natural gas. Investor-owned electric companies and non-TVA rural electric cooperatives are regulated by the Kentucky Public Service Commission. Electric power in Kentucky is distributed by four investor-owned electric utilities, 30 municipal electric systems, the Tennessee Valley Authority (TVA), and 26 rural electric cooperatives. The four investor-owned utilities – AEP Kentucky Power, Kentucky Utilities Company, Louisville Gas and Electric Company, and Duke Energy – account for nearly 50 percent of all electric power sales in the state.[5]

Kentucky receives its natural gas from 28 gas distribution companies, 43 intrastate pipeline companies, and 171 municipal, college or housing authority providers. According the U.S. Energy Information Administration total natural gas consumption in the state equaled 214 trillion Btu (about 214 billion cubic feet) in 2009. The majority of this volume is obtained from the interstate pipeline system between the Gulf state and the Northeast, which passes through Kentucky.[6]

In 2009 the energy consumption profile (in trillion Btu) for Kentucky was:

- **Coal - 937.1**
- **Natural Gas - 214**
- **Distillate Fuel Oil - 161.4**
- **Jet Fuel - 55.8**
- **Liquified Petroleum Gases - 30.6**
- **Motor Gasoline - 262**
- **Residual Fuel Oil - 0.4**
- **Other Petroleum Products - 153**
- **Nuclear - 0**
- **Hydroelectric - 32.4**
- **Wood, wood-derived fuels and biomass waste - 26.6**
- **Fuel Ethanol - 16.8**
- **Geothermal - 2.3**
- **Solar - 0.1**
- **Wind – 0**

Source: U.S. Energy Information Administration. www.eia.gov.

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[2] U.S. Energy Information Administration. Kentucky Electricity Profile. http://www.eia.gov/cneaf/electricity/st_profiles/kentucky.html

[3] Kentucky is the third largest producer of coal in the United States. (U.S. Energy Information Administration. www.eia.gov).

[4] U.S. Energy Information Administration. Kentucky Electricity Profile. http://www.eia.gov/cneaf/electricity/st_profiles/kentucky.html

[5] Cabinet for Economic Development. Kentucky. 'Utilities in Kentucky – Availability and Cost.' http://www.ced.ky.gov/kyedc/pdfs/utkyavco.pdf.

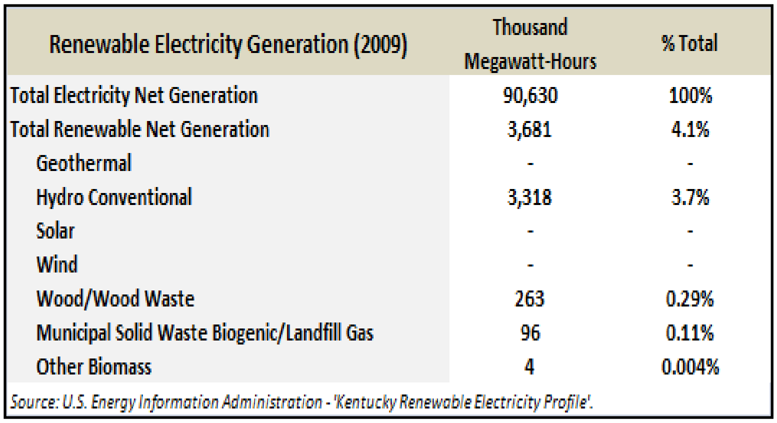
[6] Cabinet for Economic Development. Kentucky. 'Utilities in Kentucky – Availability and Cost.' http://www.ced.ky.gov/kyedc/pdfs/utkyavco.pdf.

Renewable Energy Consumption

Currently, Kentucky's renewable energy usage is quite limited, representing only 4.1% of Kentucky's total electricity generation. The majority of this energy is produced through hydroelectric sources. Only a small amount of energy is actually being produced from biomass sources.[7]

Kentucky's renewable energy goal is described by the Governor's Office in the 2008 document 'Intelligent Energy Choices for Kentucky's Future':

> By 2025, Kentucky's renewable energy generation will triple to provide the equivalent of 1,000 megawatts of clean energy while continuing to produce safe, abundant, and affordable food, feed and fiber.[8]



Renewable Electricity Generation (2009)	Thousand Megawatt-Hours	% Total
Total Electricity Net Generation	90,630	100%
Total Renewable Net Generation	3,681	4.1%
Geothermal	-	-
Hydro Conventional	3,318	3.7%
Solar	-	-
Wind	-	-
Wood/Wood Waste	263	0.29%
Municipal Solid Waste Biogenic/Landfill Gas	96	0.11%
Other Biomass	4	0.004%

Source: U.S. Energy Information Administration - 'Kentucky Renewable Electricity Profile'.

The primary constraint to ag-biomass energy development in Kentucky is economic viability. Ultimately, biomass-to-energy opportunities will be determined by market economics, which are in turn decided by such factors as the availability of feedstock and land, demand, new technologies, financial incentives and government policy. Later sections of this report will examine the availability of feedstock and land, technologies and conditional aspects of economic viability. This section will describe mechanisms for promoting ag-biomass production and energy consumption.

Effective policies and incentives that promote the greater use of biomass, encourage the purchase and application of efficient technologies and stimulate biomass-generated energy consumption are needed. In Kentucky there are a number of existing programs that offer support: [9]

- **Energy Efficiency Tax Credits (Corporate)** – promotes the use of energy efficient technologies, including furnaces and boilers
- **Incentives for Energy Independence** – provides tax credit to companies that build or renovate renewable energy facilities to promote alternative energy generation, including biomass
- **TVA Green Power Providers Program** – incentive program to homeowners and business for the installation of renewable energy generation systems, including biomass energy generation
- **TVA Mid-Sized Renewable Standard Offer Program** – provides incentives for mid-size renewable energy generators to enter into long-term price contracts
- **Energy Efficiency Tax Credits (Personal)** – promotes the use of energy efficient technologies, including furnaces and boilers
- **Office of Agricultural Policy - On Farm Energy Efficiency and Production Grants** – offers grants for farms that incorporate energy efficiency into their operation, including boilers
- **Green Bank of Kentucky's Energy Efficiency Loans for State Government Agencies** – provides financing for energy efficiency improvements, including furnaces, boilers and biomass technologies
- **Pennyrile RECC - Commercial Energy Efficiency Loan Program** – provides financing for energy efficiency improvements

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[7] U.S. Energy Information Administration. 'Kentucky Renewable Electricity Profile'. http://www.eia.gov/cneaf/solar.renewables/page/state_profiles/kentucky.html

[8] Office of the Governor. (2008). 'Intelligent Energy Choices for Kentucky's Future'. http://eec.ky.gov/Documents/Kentucky%20Energy%20Strategy.pdf

[9] DSIRE – Database of State Incentives for Renewable and Energy Efficiency. Kentucky. http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=KY

- **Duke Energy - Non-Residential Energy Efficiency Rebate Program** – provides rebates for purchases of pellet dryer duct installation

Federal policies and incentives include:[10]

- **Business Energy Investment Tax Credit (ITC)**
- **Clean Renewable Energy Bonds (CREBs)**
- **Interconnection Standards for Small Generators**
- **Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008-2012)**
- **Qualified Energy Conservation Bonds (QECBs)**
- **Renewable Electricity Production Tax Credit (PTC)**
- **Renewable Energy Production Incentive (REPI)**
- **Residential Energy Efficiency Tax Credit**
- **Tribal Energy Program Grant**
- **U.S. Department of Treasury - Renewable Energy Grants**
- **U.S. Federal Government - Green Power Purchasing Goal**
- **USDA - High Energy Cost Grant Program**
- **USDA - Rural Energy for America Program (REAP) Grants**
- **USDA - Rural Energy for America Program (REAP) Loan Guarantees**

Other state programs like the Energy Efficiency Programs for State Government Buildings and Schools have goals of improving energy performance in buildings. Although they do not mention any specific technologies, there could be potential to connect technologies like biomass combustion to these programs.[11] Kentucky also offers Renewable Energy Certificates (RECs), also known as renewable energy credits, green certificates, green tags, or tradable renewable certificates, which represent the environmental benefits of one megawatt-hour (MWh) of electricity produced from a renewable energy source. RECs are tradable certificates sold separately from the underlying physical electricity produced from the renewable source. Customers can purchase RECs whether or not they have access to green power.[12]

In addition to these programs, Kentucky also has interconnection standards and net metering to facilitate the development of distributed generation (DG), a localized system of electricity production and consumption. This system lends itself favorably to the development of a localized agricultural biomass-to-energy supply chain, since transportation costs associated with long-distance shipping of biomass feedstocks and pellets can be prohibitively high.[13]

Facilities generating for than 30 kW of renewable electricity in Kentucky can also be considered as a Qualifying Facility, which offers the right to sell energy to utilities, purchase certain services from utilities (e.g. supplementary power, back-up power, maintenance power and interruptible power), and relief from certain regulatory burdens.[14]

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[10] DSIRE – Database of State Incentives for Renewable and Energy Efficiency. Federal Incentives/Policies for Renewables and Efficiency. http://www.dsireusa.org/incentives/index.cfm?State=US&ee=1&re=1

[11] DSIRE – Database of State Incentives for Renewable and Energy Efficiency – Kentucky. http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=KY

[12] Commonwealth of Kentucky – Department of Energy Development and Independence, Division of Renewable Energy. http://energy.ky.gov/renewable/Pages/default.aspx

[13] DSIRE – Database of State Incentives for Renewable and Energy Efficiency – Kentucky. http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=KY

[14] Commonwealth of Kentucky – Department of Energy Development and Independence, Division of Renewable Energy. http://energy.ky.gov/renewable/Pages/default.aspx

Missing from Kentucky's toolkit of policies and incentives is a Renewable and Efficiency Portfolio Standard (REPS) that would require electric utilities to generate a certain minimum quantity of power from clean, renewable sources, like biomass. Currently 29 states have passed REPS.[15] Closely related to this program is the Feed-In Tariff system that would require utilities to pay a higher rate for electricity generated from renewables as a means of offsetting the higher cost of production. Feed-in tariffs could guarantee higher rates for renewable energy for a "development period" to encourage the development of renewable sources, while at the same time decreasing these rates over time to encourage technological innovation, competition and efficiencies of operation.[16] Neither of these programs is likely to be favored by the utility industry as they both place added costs on the utility companies through specific purchasing requirements.

The recent passage of the EPA's Mercury and Air Toxics Standard for Power Plants, and the Cross-State Air Pollution Rule, could be just the regulatory drivers to increase demand for clean fuel alternatives in the state. The Mercury and Air Toxics Standard for Power Plants set standards to limit mercury, acid gases and other toxic pollution from power plants.[17] The Cross-State Air Pollution Rule requires power plants in Kentucky and 22 other states to reduce their annual sulfur dioxide and nitrogen oxide emissions to help improve the air quality of downwind areas.[18] Co-firing ag-biomass (pelletized or non-pelletized) offers state power plants a solution to reducing these harmful emissions and meeting the new standards.

Converting Agricultural Biomass to Renewable Energy

For thousands of years biomass has been burned to make heat. Since the industrial revolution biomass burned for heat has produced steam power, and even more recently this biomass-fired steam power has been used to generate electricity.

- ***Biomass to Heat –*** the biomass is burned through direct combustion to create heat. LEI Products (www.leiprod.com) in Kentucky has a biomass boiler capable of burning agricultural biomass.
- ***Biomass to Electricity*** – the biomass is burned through direct combustion and the steam produced is used to turn a turbine which then produces electricity.
- ***Co-firing Biomass*** – involves mixing the biomass with coal for combustion in a power plant designed for coal; benefits include reduction in harmful emissions like sulfur and mercury. In 2010 the Spurlock Power Station in Maysville, Kentucky, co-fired 265 tons of pelletized switchgrass as an early step in understanding ways to mitigate carbon emissions in its facility.[19]
- ***Combined Heat and Power (CHP)*** – direct combustion of biomass produces heat, in addition to steam, that can be used to heat buildings or for industrial purposes; since this heat energy would otherwise be wasted CHP facilities can be significantly more efficient that direct combustion systems. Cox Interior's facility in Campbellsville, Kentucky is burning wood waste in a wood waste boiler to generate steam power and electricity in a CHP system.[20]

Two thermochemical processes for converting biomass to energy are gasification and pyrolosis. Gasification has been employed with coal for years; pyrolosis has been used since ancient times to make coal. In the newer field of renewable energy development work has been ongoing in public and private sectors to optimize these processes for application with various forms of biomass:

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[15] Kentucky Sustainable Energy Alliance – Renewable and Efficiency Portfolio Standard. http://www.kysea.org/legislative-policy-work/2011-legislative-goals/renewable-and-efficiency-portfolio-standard

[16] Kentucky Conservation Committee. (2009). 'Feed-In Tariffs'. http://www.kyconservation.org/production-incentives12.pdf

[17] U.S. Environmental Protection Agency – Regulatory Actions. Mercury and Air Toxics Standards. http://www.epa.gov/mats/actions.html

[18] U.S. Environmental Protection Agency – Regulatory Actions. Cross-State Air Pollution Rule. http://www.epa.gov/airtransport/basic.html.

[19] University of Kentucky – College of Agriculture. East Kentucky Power Cooperative. (April 1, 2010). 'Kentucky-Grown Switchgrass Tested as Power Plant Fuel.' http://www.ekpc.coop/pressreleases/2010%20press%20releases/2010-04-01__Switchgrass_test_burn.pdf

[20] Southeast CHP Application Center – Cox Interior. http://www.chpcentermw.org/rac_profiles/southeast/CoxInterior.pdf.

- ***Gasification*** – involves heating the biomass under pressure with about one-third the oxygen used for combustion to produce syngas, a mixture of carbon monoxide and hydrogen; the syngas can then be used in combustion engines and gas turbines. CSA Energy, Inc. (www.csaenergy.org) in Kentucky has a gasification technology in the early stages of commercialization.
- ***Pyrolosis*** – involves heating the biomass in the absence of oxygen to produce a fuel oil.

Market Description

Unlike the wood pellet industry, there is no existing commercial scale market for ag-biomass pellets. This is due to the challenging economics of competing with low price coal in the utility market. It is also due to an absence of demand for low quality ag-biomass pellets that do not meet even utility-grade (the lowest grade) pellet requirements. The low quality of ag-biomass pellets – primarily determined by ash and chloride content (see the next section for details) - can potentially reduce the effectiveness and longevity of existing heating appliances used in residential and commercial markets.

One of the major barriers to market development for ag-biomass pellets is the rate of adoption of new combustion technologies that can utilize lower quality feedstock sources (i.e. agricultural biomass). As more of these technologies come online (like LEI Products' Bio-Burner – www.leiprod.com) the demand for solid fuels will increase. High-quality wood waste will likely be the preferred initial feedstock. However, 99 percent of the wood and bark residues in Kentucky are already used for industrial fuel, fiber products, charcoal, particleboard and other markets.[21] Once demand for solid fuels increases to a point that exhausts market supply from existing wood residue sources opportunities could open up for introduction of agricultural biomass. In this event sufficient, affordable agricultural biomass – even if blended with wood residue - could broaden the base of the fuel supply, drive down the cost for the end-user and potentially expand the market for solid fuel application.

In the absence of a current market for ag-biomass pellets it is instructive to examine existing markets for wood pellets, as well as potential markets that could develop as new combustion technologies emerge to create a more accommodating market for lower grade materials.

Wood pellet production in the U.S. reached 1.8 million metric tons in 2008, representing 66 percent of installed capacity. The majority of raw material for wood pellet manufacturing comes from residue from sawmills, plywood mills, and secondary woodworking plants.[22] Around 95 percent of U.S. wood pellets are consumed in the residential heating market with the remainder used as utility grade pellets in school boilers, commercial office buildings, and industrial plants.[23] There are three wood pellet facilities in Kentucky: Anderson Hardwood Pellets (Louisville), Southern Kentucky Hardwood Flooring (Gamaliel), and Somerset Pellet Fuel (Somerset). Collectively they produce 82,000 metric tons of wood pellets.[24]

In addition to residential and commercial markets in the U.S. there is a fast growing market in the European Union as a result of European tax policies and regulations that have shifted the economics in favor of biomass over coal to accomplish energy and environmental objectives. Just as in the U.S. markets though the solid fuel pellet opportunities in Europe are dominated by high-quality wood pellets. Wood pellets are commonly burned alone or co-fired with coal in heating and electric generation.[25] For U.S. wood pellet producers the main trading partners in the EU are Belgium and the Netherlands, which import 173,000 tons per year and 359,000 tons per

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[21] Cooper, Jason, et al. (June 2011). 'Kentucky's Timber Industry – An Assessment of Timber Product Output and Use, 2009.' USDA Forest Service. http://www.srs.fs.usda.gov/pubs/rb/rb_srs177.pdf.

[22] Spelter, Henry and Daniel Tosh. 2009. 'North America's Wood Pellet Sector.' USDA Forest Service. http://www.fpl.fs.fed.us/documnts/fplrp/fpl_rp656.pdf.

[23] Hilliard, Randy (Agricultural Utilization Research Institute). (2009). 'Biomass Utilization Study for Aitkin County, MN.' BBI International. http://www.co.aitkin.mn.us/Departments/Economic-Dev/AURI-Aitkin-Co-Biomass-Utilization-Report.pdf.

[24] Spelter, Henry and Daniel Tosh. (2009). 'North America's Wood Pellet Sector.' USDA Forest Service. http://www.fpl.fs.fed.us/documnts/fplrp/fpl_rp656.pdf.

[25] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

year respectively.[26] In addition to the absence of demand for lower-grade ag-biomass pellets in the EU, this market is also not considered a feasible market opportunity for West Kentucky biomass pellet producers because of the geographic challenge and high logistical costs associated with shipping pellets from a non-coastal location (to say nothing of questions of the energy balance associated with such trans-Atlantic shipments).

Potential Markets for Agricultural Biomass Pellets

Market opportunities for ag-biomass pellets will change as new biomass combustion technologies come online. New technologies, like LEI Products Bio-Burner and CSA Energy's gasification technology (both companies are based in Kentucky), can burn lower quality materials and thus offer potential market opportunities for ag-biomass pellets. As these and other technologies penetrate the market the economic landscape will shift:

- The demand for solid fuels will expand in both existing and new markets
- Supply of wood pellets and woody residue will no longer be sufficient to meet fuel demand
- Demand for lower quality agricultural biomass pellets (and conceivably non-pelletized bulk agricultural biomass that has been ground or chopped) will increase to fill the gap in solid fuel demand, since the new boilers, stoves and furnaces will not be vulnerable to the same quality issues as previous technologies

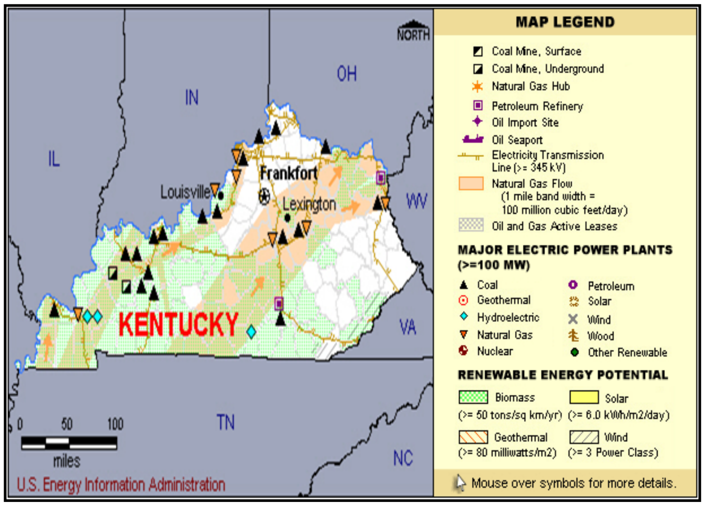
As these events take place ag-biomass pellets will have the opportunity to gain market access not only in existing wood pellet markets, but also in potential markets currently using higher cost fossil fuels like natural gas and propane.

Therefore, based on new combustion technologies and volatile fossil fuel prices the potential market opportunities for ag-biomass pellets include:

- Utility companies capable of co-firing pellets with coal
- Residential heating with pellet stoves
- Commercial and institutional operations with boilers capable of burning pellets alone or co-fired with coal to produce electricity or combined heat and power
- Greenhouses
- Tobacco farms fire-curing tobacco
- Poultry houses

Utility Companies

The West Kentucky region has six coal power plants, one natural gas and one hydro electric.[27] For a complete list of power companies in the region please refer to ***Appendix 3 - West Kentucky Power Plants***. Coal is the dominant source of energy in the state. The majority of current U.S. coal-fired power plants use pulverized coal boilers, which are the type that can handle the highest percentage of biomass.[28] However, without renewable energy mandates or incentives in Kentucky ag-biomass pellets are not an economically feasible alternative to coal under its existing price structure. Debates are ongoing about the real costs (private and public) of extracting and burning coal. A shift in policy at the state and federal level that led



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[26] ETA Florence Renewable Energies. (December 2009). 'Projections on Future Development of European Pellet Market and Policy Recommendations.' Pellet Atlas. http://www.pelletsatlas.info/pelletsatlas_docs/showdoc.asp?id=100111120623&type=doc&pdf=true.

[27] U.S. Energy Information Administration. Kentucky Electricity Profile. http://www.eia.gov/cneaf/electricity/st_profiles/kentucky.html.

[28] Mann, M.K. and P.L. Spath. (2001). 'A life cycle assessment of biomass cofiring in a coal-fired power plant.' National Renewable Energy Laboratory. https://www.bioenergykdf.net/sites/default/files/zpdfzholderz/NREL_Data/KC_091102094512.pdf.

either to increased prices for coal or reduced costs for alternative fuels like ag-biomass pellets could change this dynamic.

The recent passage of the EPA's Mercury and Air Toxics Standard for Power Plants, and the Cross-State Air Pollution Rule, could be just the regulatory drivers to increase demand for clean fuel alternatives in the state. The Mercury and Air Toxics Standard for Power Plants set standards to limit mercury, acid gases and other toxic pollution from power plants.[29] The Cross-State Air Pollution Rule requires power plants in Kentucky and 22 other states to reduce their annual sulfur dioxide and nitrogen oxide emissions to help improve the air quality of downwind areas.[30] Co-firing ag-biomass (pelletized or non-pelletized) offers state power plants a solution to reducing these harmful emissions and meeting the new standards.

Residential Heating

There are three wood pellet mills in Kentucky, with a cumulative capacity to produce 82,000 tons of wood pellets per year:

- Anderson Hardwood Pellets – capacity 18,000 tons (Louisville; Jefferson County)
- Southern Kentucky Hardwood Flooring – capacity 18,000 tons (Gamaliel; Monroe County)
- Somerset Pellet Fuel – capacity 46,000 tons (Somerset; Pulaski County)

According to the U.S. Department of Energy homeowners who use a pellet appliance as a main source of heat use two to three tons of pellet fuel per year.[31] Assuming all pellets are used in-state and Kentucky pellet appliance users are on the lower end of this range there are about 41,000 pellet appliances in the state.

Not until the demand for residential pellets exceeds the supply of mill residue for wood pellets will it be likely that agricultural biomass is a viable feedstock source for pellets in this market. If demand for pellets for residential heating increased pellet producers would prefer to source more wood residue, not agricultural biomass, because of quality concerns and unfamiliarity with pelletizing agricultural biomass material. Even if they were interested in using agricultural biomass, the feedstock transportation costs would limit them to sourcing within their locations, which are outside of the West Kentucky region.

Commercial and Institutional Operations

Co-firing biomass with existing coal-fired boiler units is a potential option for generating renewable energy and creating a market for solid biomass. Co-firing biomass with coal has been successfully demonstrated in all boiler types: pulverized coal boilers, cyclone boilers, stoker boilers, and bubbling and circulating fluidized bed boilers. To accommodate this type of system would require a few modifications for fuel handling, storage and feeding systems.[32]

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[29] U.S. Environmental Protection Agency – Regulatory Actions. Mercury and Air Toxics Standards. http://www.epa.gov/mats/actions.html

[30] U.S. Environmental Protection Agency – Regulatory Actions. Cross-State Air Pollution Rule. http://www.epa.gov/airtransport/basic.html.

[31] U.S. Department of Energy. Energy Efficiency and Renewable Energy. http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12570.

[32] Mann, M.K. and P.L. Spath. (2001). 'A life cycle assessment of biomass cofiring in a coal-fired power plant.' National Renewable Energy Laboratory. https://www.bioenergykdf.net/sites/default/files/zpdfzholderz/NREL_Data/KC_091102094512.pdf.

For a complete list of commercial and institutional operations with boilers in the West Kentucky region please refer to ***'Supplement A: Companies, Institutions and Organizations with Boilers in West Kentucky'***. High energy use operations with the potential for biomass pellets include: animal and dairy farms, elementary schools, high schools, colleges and universities, healthcare facilities, manufacturing facilities, government offices, laboratories, military facilities, multi-family housing, museums, national parks, office buildings, pipelines, pulp and paper facilities, refineries, supermarkets, transportation, waste and wastewater treatment facilities, wineries, breweries, correctional facilities, data centers, district energy plants, ethanol plants, forest products, health clubs, and hotels.[33]

Greenhouses

There are over 250 greenhouses in the state, with 49 in the West Kentucky region. These greenhouse operations use a variety of energy sources – wood, liquid propane, natural gas and fuel oil. There is very limited information on energy consumption in greenhouses though and any interest in market development for ag-biomass pellets in this sector would require further research.[34]

Fire-Curing Tobacco

There are two types of tobacco grown in Kentucky – dark and burley. Only the dark tobacco is fire-cured, using hardwood (oak and hickory) slabs and sawdust from local mills. The wood gives a certain aroma and flavor to the tobacco. It is estimated that for every pound of tobacco six pounds of wood is required for the curing process. Fire-curing operations prefer at least 80-85% hardwood since sappy softwoods like pine and cedar impact the tobacco's flavor.[35] In 2010 over 27 million pounds of dark fire-cured tobacco was produced in West Kentucky. The estimated wood requirement for fire-curing this tobacco was 81,405 tons. Replacing 15 percent of this wood with agricultural biomass would require 12,200 tons of pellets.

Poultry Houses

In addition to the potential to access certain wood pellet markets with ag-biomass pellets, there may also be an opportunity to create a new market for biomass furnaces to heat poultry houses, which are currently using liquid propane. Poultry is Kentucky's number one agricultural commodity, and energy bills are one of the major expenses for poultry providers.[36] According to the 2007 Census of Agriculture, there were 5,126 poultry farms in Kentucky.[37] While the majority of commercial poultry farms are in 42

County	Tobacco Farms	Greenhouses
Ballard	8	-
Caldwell	21	-
Calloway	102	-
Carlisle	11	2
Christian	83	4
Crittenden	-	6
Fulton	-	-
Graves	100	-
Henderson	9	6
Hickman	1	-
Hopkins	11	5
Livingston	-	-
Lyon	11	-
Marshall	9	6
McCracken	7	2
Muhlenberg	27	-
Todd	84	16
Trigg	23	2
Union	2	-
Webster	23	-
West Kentucky	***532***	***49***
State of Kentucky	***5034***	***251***

Sources:

USDA Census of Agriculture. 'Farms by North American Industry Classification System.' (2007)

USDA Census of Agriculture. 'Nursery, Greenhouse, Floriculture, Sod, Mushrooms, Vegetable Seeds, and Propagative Materials Grown for Sale.' (2007).

Fire-Cured Tobacco in West Kentucky (2010)

County	Harvested (acres)	Production (lbs)
Calloway	1820	6,680,000
Carlisle	200	735,000
Graves	1650	6,030,000
Lyon	160	475,000
Trigg	1080	3,300,000
Caldwell	250	700,000
Christian	1830	5,560,000
Muhlenberg	290	885,000
Todd	910	2,770,000
TOTAL	**8,190**	**27,135,000**

Source: USDA National Agricultural Statistics Service.

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[33] U.S. Department of Energy. Energy Efficiency and Renewable Energy. 'Industrial Distributed Energy.' http://www1.eere.energy.gov/industry/distributedenergy/projects_sector.html.

[34] Based on interview with University of Kentucky extension specialists for greenhouse crops (January 2012).

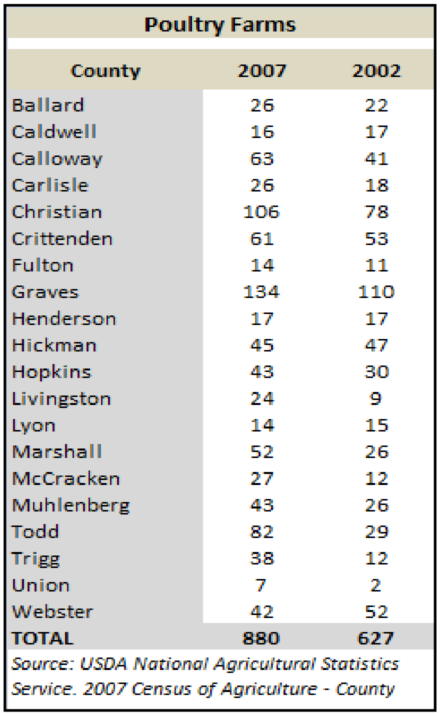
[35] Based on interview with University of Kentucky tobacco specialist (January 2012).

[36] University of Kentucky – College of Agriculture. Poultry Science. http://www2.ca.uky.edu/afspoultry/.

[37] U.S. Department of Agriculture. 2007 Census of Agriculture. Kentucky. Poultry – Inventory and Sales. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Kentucky/index.asp.

counties east of Interstate 65 (based on an interview with a poultry extension specialist at the University of Kentucky), there are still 880 poultry farms in the West Kentucky region (includes layers, broilers, pullets, turkeys, ducks and geese), a 40 percent increase over 2002 levels.[38]

According to Jim Wimberly in ‘A Review of Biomass Furnaces for Heating Poultry Houses in the Northwest Arkansas Region’ each commercial poultry house consumes 4000 - 7000 gallons of propane per year.[39] It is difficult to assess the level of propane consumption of the poultry houses in West Kentucky without knowing more about their size. Even so, the use of biomass furnaces in Kentucky poultry houses could create a viable local market opportunity for agricultural biomass pellet producers in the region. In addition to stimulating local energy production, this model would provide poultry farm operators with a more stable energy alternative to the volatility of fossil fuel prices.



Poultry Farms

County	2007	2002
Ballard	26	22
Caldwell	16	17
Calloway	63	41
Carlisle	26	18
Christian	106	78
Crittenden	61	53
Fulton	14	11
Graves	134	110
Henderson	17	17
Hickman	45	47
Hopkins	43	30
Livingston	24	9
Lyon	14	15
Marshall	52	26
McCracken	27	12
Muhlenberg	43	26
Todd	82	29
Trigg	38	12
Union	7	2
Webster	42	52
TOTAL	**880**	**627**

Source: USDA National Agricultural Statistics Service. 2007 Census of Agriculture - County

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[38] Interview with University of Kentucky professor with background in poultry production and management (January 2012).

[39] Wimberly, Jim (BioEnergy Systems). ‘A Review of Biomass Furnaces for Heating Poultry Houses in the Northwest Arkansas Region.’ 2008. Winrock International. http://pelletheat.org/pdfs/winrock-us-programs-biomass-report.pdf.

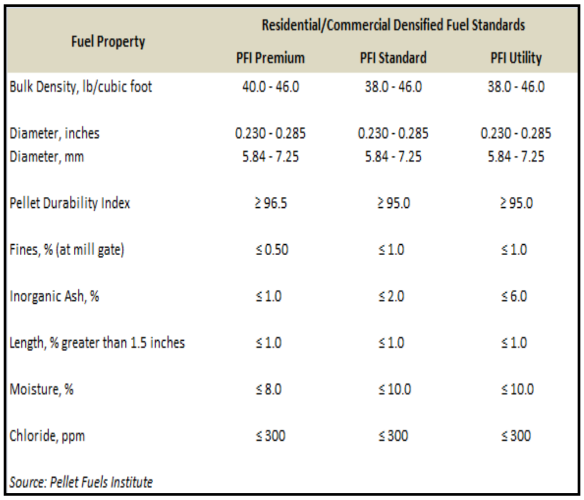
Agricultural Biomass Pellet Quality

Market options for biomass pellets are affected by pellet quality. The Pellet Fuels Institute has developed standardized specifications for the quality of residential and commercial-grade pellets in North America. These specifications are used by pellet producers, pellet fuel appliance manufacturers, and users of residential/commercial fuel pellets to select the grade most suitable to their appliances.

Currently, there is only limited information about the pellet quality of dedicated energy crops which further inhibits the scope of market planning activities for ag-biomass pellets. It is strongly recommended that further research be done to better understand and analyze the pellet quality of different materials. This approach would be most useful conducted within the context of a coordinated research platform that tested crops under different production approaches, pelletized the different materials (individually or blended) and tested burn characteristics on different appliances, or as part of a pilot system. This kind of integrated research strategy would enable researchers to understand key factors affecting the full supply chain, from crop to energy.

Bulk Density

The density of the pellet is expressed in pounds per cubic foot. The density of a pellet is greater than that of raw biomass. This allows for a greater amount of fuel (in the form of a pellet) to be transported by truck and stored on site, thus reducing the total transport and storage cost per Btu.



Fuel Property	Residential/Commercial Densified Fuel Standards		
	PFI Premium	PFI Standard	PFI Utility
Bulk Density, lb/cubic foot	40.0 - 46.0	38.0 - 46.0	38.0 - 46.0
Diameter, inches	0.230 - 0.285	0.230 - 0.285	0.230 - 0.285
Diameter, mm	5.84 - 7.25	5.84 - 7.25	5.84 - 7.25
Pellet Durability Index	≥ 96.5	≥ 95.0	≥ 95.0
Fines, % (at mill gate)	≤ 0.50	≤ 1.0	≤ 1.0
Inorganic Ash, %	≤ 1.0	≤ 2.0	≤ 6.0
Length, % greater than 1.5 inches	≤ 1.0	≤ 1.0	≤ 1.0
Moisture, %	≤ 8.0	≤ 10.0	≤ 10.0
Chloride, ppm	≤ 300	≤ 300	≤ 300

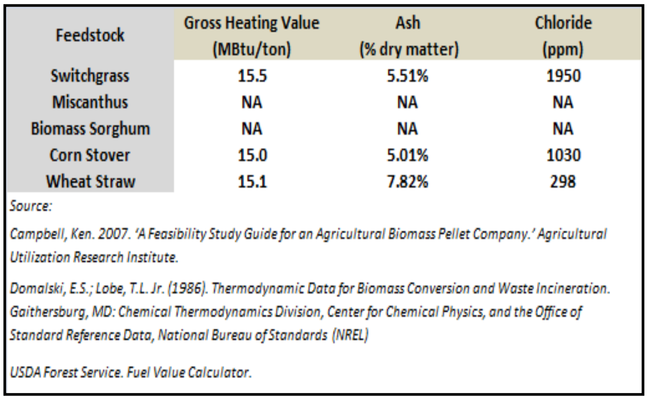
Source: Pellet Fuels Institute

Diameter

The uniformity of shape and size of the pellets helps to reduce the handling cost of the fuel feed system.

Durability and Fines

Durability is an important factor in pellet quality because it provides a measurement of fines (dust, particles and small fragments) caused during transportation and handling. Users prefer a minimum of fines because they are likely to be dropped into the ash pan without being burned. Durability is determined by the pellet production process as well as the natural binding qualities of the feedstock.[40]



Feedstock	Gross Heating Value (MBtu/ton)	Ash (% dry matter)	Chloride (ppm)
Switchgrass	15.5	5.51%	1950
Miscanthus	NA	NA	NA
Biomass Sorghum	NA	NA	NA
Corn Stover	15.0	5.01%	1030
Wheat Straw	15.1	7.82%	298

Source:

Campbell, Ken. 2007. 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute.

Domalski, E.S.; Lobe, T.L. Jr. (1986). Thermodynamic Data for Biomass Conversion and Waste Incineration. Gaithersburg, MD: Chemical Thermodynamics Division, Center for Chemical Physics, and the Office of Standard Reference Data, National Bureau of Standards (NREL)

USDA Forest Service. Fuel Value Calculator.

Moisture Content

Moisture content refers to the percent of water in the pellet. Less moisture means higher energy content.

Ash Content

Ash is made up of minerals and salts. Ash content is the weight of all non-combustibles in fuel pellets as a percentage of the total weight of the pellets. Ash content is important for several reasons:

- Inorganic ash is not combustible and therefore lowers the overall energy value of the pellet.
- Higher ash content increases the handling cost of

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[40] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

the system due to more frequent dumping of the ash pan.

- Ash can reduce air flow when it builds up on the burn pot surface.
- Ash can reduce the delivery of heat by coating the heat exchange tubes.
- Ash can shut down the pellet appliance when the ash tray is full or when chunks of melted ash, known as “clinkers”, are formed.

Volume and other characteristics of ash may be more important than the percentage ash content. For instance, since light, flaky ash is more voluminous it does not stay in the burn pot and ash tray, but is instead deposited throughout the appliance, thus reducing its overall efficiency and making cleaning more difficult.

Ash and chloride characteristics of the agricultural biomass feedstock will depend on the plant, as well as environmental influences from soil and water. Each potential agricultural biomass feedstock sourced for pellet manufacturing needs to be tested in order to fully understand the suitability of any particular feedstock for fuel pellets. Variations in ash content values for each feedstock create an uncertainty about quality that will need to be addressed in order to develop consistent high-quality pellets. These variations may also suggest that there is some potential ability to control ash levels.

Some stove manufacturers – like LEI Products (Bio-Burner) and CSA Energy - are designing their appliances to use fuels other than premium wood pellets, including agricultural biomass. These multi-fuel appliances can accommodate fuels with different moisture, fines and ash content. The opportunity for agricultural biomass pellets to be used as a substitute for wood pellets in the residential heating sector will depend on the successful marketing of these appliances. [41]

Chloride Content

Chloride is measured in parts per million (ppm). Chloride causes corrosion of metals. Potassium chloride and sodium chloride cause slagging (depositing of a glass-like residue) and fouling (accumulation of unwanted materials) in a combustion system. The chloride content of most agricultural biomass feedstocks is well above the current requirement of 300 parts per million. One of the causes of the higher chloride content of agricultural biomass feedstock sources is the use of potassium chloride – potash – as a fertilizer. According to the Agricultural Utilization Research Institute the extent to which the higher chloride content actually causes more corrosion, slagging and fouling in pellet appliances and venting is not well-documented. Multi-fuel appliances with corrosion-resistant stainless steel could potentially mitigate these concerns.[42]

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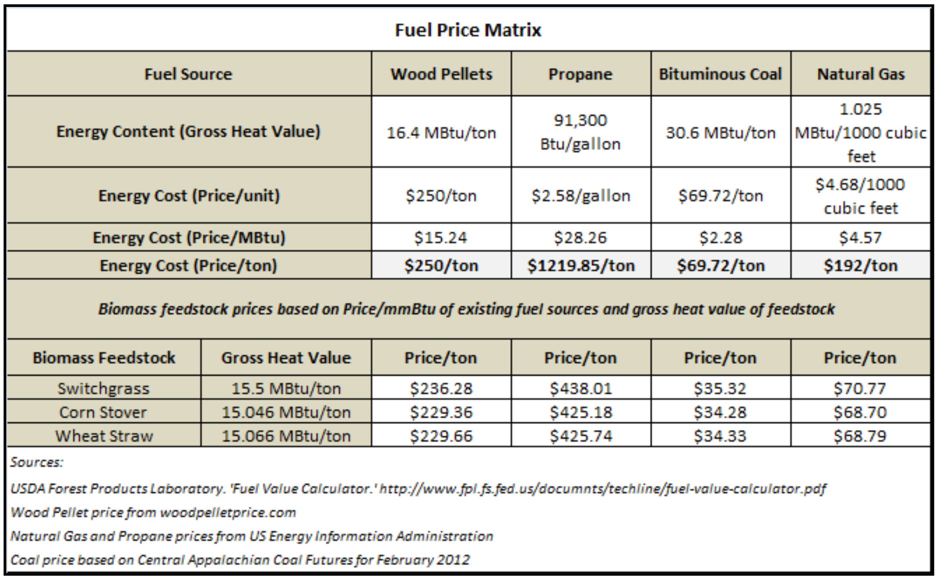
[41] Campbell, Ken. (2007). ‘A Feasibility Study Guide for an Agricultural Biomass Pellet Company.’ Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

[42] Campbell, Ken. (2007). ‘A Feasibility Study Guide for an Agricultural Biomass Pellet Company.’ Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

Agricultural Biomass Pellet Pricing

Because there is no existing market for agricultural biomass pellets, there is no structure to determine their price. Therefore certain assumptions must be made in order to begin to project potential price scenarios for agricultural biomass pellets. The principle assumption, related to pellet quality, is that agricultural biomass pellets are - theoretically – of a quality sufficient for utilization in each of the previously described markets. There are clearly a number of issues associated with biomass pellet quality that need to be addressed before accessing any of these markets. Please refer to the '*Recommendations*' section for programmatic suggestions for addressing these issues.



Fuel Price Matrix

Fuel Source	Wood Pellets	Propane	Bituminous Coal	Natural Gas
Energy Content (Gross Heat Value)	16.4 MBtu/ton	91,300 Btu/gallon	30.6 MBtu/ton	1.025 MBtu/1000 cubic feet
Energy Cost (Price/unit)	$250/ton	$2.58/gallon	$69.72/ton	$4.68/1000 cubic feet
Energy Cost (Price/MBtu)	$15.24	$28.26	$2.28	$4.57
Energy Cost (Price/ton)	**$250/ton**	**$1219.85/ton**	**$69.72/ton**	**$192/ton**

Biomass feedstock prices based on Price/mmBtu of existing fuel sources and gross heat value of feedstock

Biomass Feedstock	Gross Heat Value	Price/ton	Price/ton	Price/ton	Price/ton
Switchgrass	15.5 MBtu/ton	$236.28	$438.01	$35.32	$70.77
Corn Stover	15.046 MBtu/ton	$229.36	$425.18	$34.28	$68.70
Wheat Straw	15.066 MBtu/ton	$229.66	$425.74	$34.33	$68.79

Sources:

USDA Forest Products Laboratory. 'Fuel Value Calculator.' http://www.fpl.fs.fed.us/documnts/techline/fuel-value-calculator.pdf

Wood Pellet price from woodpelletprice.com

Natural Gas and Propane prices from US Energy Information Administration

Coal price based on Central Appalachian Coal Futures for February 2012

Assuming that there are opportunities in each of the target markets, it is then possible to peg the price of the agricultural biomass pellet to the price of the existing fuel source(s) in that particular market, by making fuel price comparisons based on energy content.

Based on the fuel price matrix, it is clear that the most lucrative markets for biomass pellets are in Residential Heating and Poultry House Heating where the existing feedstocks – wood pellets and propane respectively - are both relatively high cost energy sources. The least valuable market opportunities for biomass pellets are in the utility, commercial and institutional markets, which utilize low-cost energy sources. In order to be able to access any of these markets more information on pellet quality and application in heating appliances in these markets is required. For instance, in 2010, the East Kentucky Power Cooperative paid $40 per ton (close to the estimate in the matrix) for 256 tons of switchgrass used at its Spurlock Station in Maysville.[43]

Comparing these potential market prices to the estimated cost of production for each type of biomass pellet, it is possible to determine which markets are worth pursuing for biomass pellets.

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[43] University of Kentucky – College of Agriculture. East Kentucky Power Cooperative. (April 1, 2010). 'Kentucky-Grown Switchgrass Tested as Power Plant Fuel.' http://www.ekpc.coop/pressreleases/2010%20press%20releases/2010-04-01__Switchgrass_test_burn.pdf.

Agricultural Biomass Feedstock Sources for Pelletizing

Biomass refers to any organic matter that can be converted into electricity, heat or fuel. Biomass resources include agricultural residues, animal manure, logging residue, mill residue from the pulp and paper industry, municipal green waste, industrial waste, wastewater, dedicated energy crops, starch crops (corn and wheat), sugar crops (sugarcane, beets, and sweet sorghum) and oilseed crops (soybeans, canola, and palm oil).[44]

Organic matter can be transformed into usable energy by combustion, gasification, pyrolysis, extraction, fermentation, and anaerobic digestion. Wet biomass like animal manure and wastewater/sewage sludge is used in anaerobic digestion. Solid residues, wastes and bagasse are used for heat and power generation. Sugar, starch and oilseed crops are primarily used for liquid fuel production (e.g. ethanol and biodiesel). Solid biomass is converted into energy through the first three processes – combustion, gasification and pyrolysis.

The primary forms of biomass considered for pelletizing are:

- Crop residues
- Wood residues
- Dedicated energy crops

The model for feedstock development for ag-biomass pellets is based on a philosophy of sustainable production that, in its simplest form, could be defined as a production system that does not cause harm to natural ecological cycles or negatively affect food production. For instance, agro-processing by-products, like soybean meal (used as animal feed), are not considered candidate sources for energy production. By that same token, land used for crop production is also not considered for production of bioenergy crops. From an economic perspective this decision makes sense as well, since low value crops (which bioenergy crops must inevitably be if the processing system is to be viable) should be grown on low value acres where there economic return exceeds the opportunity cost of the next best alternative foregone.

Crop Residues *(in metric tons)*

COUNTY	Barley	Corn	Sorghum	Soybeans	Wheat
Ballard	0	85,131	580	74,247	16,863
Caldwell	0	63,867	626	38,719	15,464
Calloway	0	92,579	0	71,760	23,323
Carlisle	0	73,651	2,197	56,331	7,451
Christian	245	232,451	0	117,629	90,516
Crittenden	0	31,567	1,334	17,658	2,641
Fulton	0	83,607	627	107,736	22,823
Graves	0	180,779	0	120,597	28,274
Henderson	0	226,837	7,408	167,217	9,174
Hickman	0	132,777	0	90,184	26,629
Hopkins	0	82,220	7,089	65,778	5,990
Livingston	0	25,037	0	21,661	1,413
Lyon	0	17,472	0	9,479	1,662
McCracken	0	43,694	1,517	45,325	3,924
Marshall	0	24,546	0	24,730	3,263
Muhlenberg	0	36,444	908	30,757	2,621
Todd	2,690	142,598	0	82,498	51,521
Trigg	0	57,678	0	31,687	22,895
Union	0	271,709	6,111	123,870	21,923
Webster	0	112,732	5,892	79,958	2,823
TOTAL	**2,935**	**2,017,374**	**34,286**	**1,377,819**	**361,193**

Source: National Renewable Energy Laboratories and USDA National Agricultural Statistics Service; 5-yr average (2003-2007); accounts for amount of residue left in the field for soil protection, grazing, and other agricultural activities.

Crop Residues

Crop residues include stalks and leaves from corn (referred to as stover), as well as straw and stubble from other grains like wheat, barley, oats and sorghum.

According to the National Renewable Energy Laboratories (NREL) quantities of crop residue that must remain in the field for soil erosion protection vary by crop type, soil type, weather conditions, and tillage systems. NREL assumes that 30 percent is reasonable for soil protection, 20-25 percent for grazing, and 10-15 percent for other purposes. That leaves about 35 percent of the total crop residue in the field available for collection as biomass.[45]

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[44] International Energy Agency. (January 2007). 'IEA Energy Technology Essentials.' http://www.iea.org/techno/essentials3.pdf.

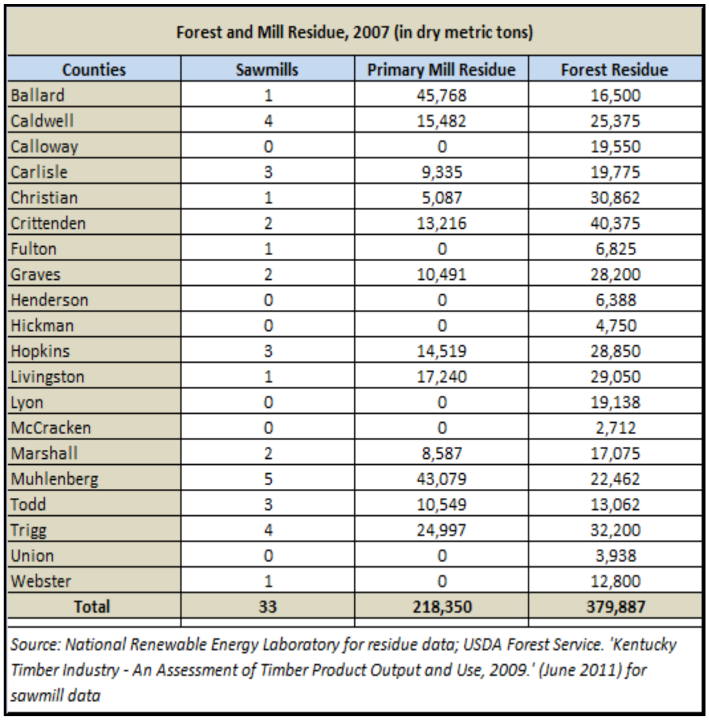
[45] Milbrandt, A. (December 2005). 'A Geographic Perspective on the Current Biomass Resource Availability in the United States.' National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy06osti/39181.pdf.

The primary crops grown in the West Kentucky region are wheat (93,933 acres), tobacco (13,892 acres), soybeans (776,400 acres), corn (647,600 acres), alfalfa hay (7,133 acres), and other hay (177,5333 acres).[46]

Based on crop production patterns in West Kentucky the primary opportunities for crop residue in the region are for corn stover and wheat straw. Soybean crop residue needs to be left in the ground to meet soil conservation requirements.[47]

Since crop residues - if left to decompose in the field - are a source of nutrients for future crops, grower payments for residue are based on the value of the nutrients removed. According to regional nutrient payments calculated by researchers in the 'U.S. Billion-Ton Update' the price of corn stover is valued at $26.60 per ton, and the price for wheat straw is valued at $25.90 per ton.[48]

Crop residues left in the field play an important role in controlling and protecting soil against wind and water erosion. Before pursuing the utilization of corn stover or wheat straw as a source for biomass pellets more research needs to be conducted to better understand the potential adverse effects of crop residue removal on soil erosion, soil organic carbon, pests, pesticides, diseases and stand establishment.



Forest and Mill Residue, 2007 (in dry metric tons)

Counties	Sawmills	Primary Mill Residue	Forest Residue
Ballard	1	45,768	16,500
Caldwell	4	15,482	25,375
Calloway	0	0	19,550
Carlisle	3	9,335	19,775
Christian	1	5,087	30,862
Crittenden	2	13,216	40,375
Fulton	1	0	6,825
Graves	2	10,491	28,200
Henderson	0	0	6,388
Hickman	0	0	4,750
Hopkins	3	14,519	28,850
Livingston	1	17,240	29,050
Lyon	0	0	19,138
McCracken	0	0	2,712
Marshall	2	8,587	17,075
Muhlenberg	5	43,079	22,462
Todd	3	10,549	13,062
Trigg	4	24,997	32,200
Union	0	0	3,938
Webster	1	0	12,800
Total	**33**	**218,350**	**379,887**

Source: National Renewable Energy Laboratory for residue data; USDA Forest Service. 'Kentucky Timber Industry - An Assessment of Timber Product Output and Use, 2009.' (June 2011) for sawmill data

Wood Residue

Wood residues come from two sources:

- Forest residue
- Mill residue

Forest residue includes logging residues after removal. Logging residues are the unused portion of trees cut or killed by logging and left in the woods. Forest residue also includes deadwood, trees cut or killed by pre-commercial trimming, thinning, weeding, and land clearing. Due to the often remote location of this residue source and the present challenges of harvesting, processing and transporting at a reasonable cost, forest residue is not presently considered an economical source of biomass feedstock.

Mill residue includes sawdust, bark, and wood scraps from paper, lumber, and furniture manufacturing operations. In 2009 there was an estimated 65 million cubic feet of wood and bark residues produced in Kentucky's 217 sawmills and 2 pulp mills. There are 33 sawmills in West Kentucky, and 1 pulp mill (in Ballard

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[46] USDA National Agricultural Statistics Service. Data and Statistics. http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp. (Figures based on 3-year average from 2008-2010).

[47] Oak Ridge National Laboratory. (August 2011). 'U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry.' U.S. Department of Energy – Energy Efficiency and Renewable Energy. http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf.

[48] Oak Ridge National Laboratory. (August 2011). 'U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry.' U.S. Department of Energy – Energy Efficiency and Renewable Energy. http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf.

County).[49] According to a 2009 USDA Forest Service assessment of Kentucky's timber industry 99 percent of the wood and bark residues are used for product. The uses of that residue were as follows - 30 percent for industrial fuel, 21 percent for fiber products, 23 percent for charcoal/chemical wood, 4 percent for particleboard, and 21 percent for miscellaneous.[50]

Wood residue, particularly hardwood residue is the preferred source for current wood pellet manufacturing. Increased demand for solid fuel pellets to a point that exceeds market supply from existing wood residue sources could open up the opportunity for introduction of agricultural biomass. In this event it could be possible to blend wood residue with agricultural biomass to broaden the base of fuel supply, drive down the cost for the end-user and potentially expand the market for solid fuel application.

Dedicated Energy Crops

Dedicated energy crops can come from woody and non-woody sources. The production and utilization of these crops as renewable energy sources offers a number of benefits – energy independence, mitigating rising energy costs, reducing carbon footprint, and creation of local jobs and economic development opportunities. Burning these crops for renewable energy is considered a carbon-neutral process since the resulting CO_2 emissions are equal to the amount of CO_2 that the plant used up from the atmosphere during its growing phase (excluding any establishment or production inputs). Additionally, the deep root system of non-woody energy crops can improve soil and water quality. Over the past decade there has been significant investment into germplasm and seed development for energy crops with favorable biomass characteristics, notably in switchgrass and biomass sorghum with Ceres (www.ceres.net), and Miscanthus with Mendel Biotechnology, Inc. (www.mendelbio.com). Both companies have research trials and farm plots in the West Kentucky region.

This report focuses on three non-woody, high-yielding annual and perennial crops for pelletizing:

- Switchgrass
- Miscanthus
- Biomass Sorghum

Switchgrass

Switchgrass (*Panicum virgatum*) is a tall-growing, warm-season, perennial bunchgrass indigenous to the North American prairie. The crop can grow over 10 feet in height. Once a major component of the Midwestern prairies, switchgrass stands have dwindled as natural grasslands have given way to expanding farms and developments.[51]

There are two distinct forms of switchgrass, an upland type adapted to the Northern U.S. and a lowland type adapted to the Southern U.S. It is readily propagated by seed and has been the subject of much research. Moreover, it is already being used in the Midwest to produce burnable biomass and is being touted as a likely source of ethanol.[52]

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[49] Cooper, Jason, et al. (June 2011). 'Kentucky's Timber Industry – An Assessment of Timber Product Output and Use, 2009.' USDA Forest Service. http://www.srs.fs.usda.gov/pubs/rb/rb_srs177.pdf.

[50] Cooper, Jason, et al. (June 2011). 'Kentucky's Timber Industry – An Assessment of Timber Product Output and Use, 2009.' USDA Forest Service. http://www.srs.fs.usda.gov/pubs/rb/rb_srs177.pdf.

[51] Cooperative Extension Service. (November 2009). 'Switchgrass for Biomass.' University of Kentucky – College of Agriculture. http://www.uky.edu/Ag/CDBREC/introsheets/switchgrass.pdf.

[52] Pyter, Rich, et al. 'Growing Giant Miscanthus in Illinois.' University of Illinois. http://miscanthus.illinois.edu/wp-content/uploads/growersguide.pdf.

Switchgrass is a low input perennial that can be grown in a variety of soil types and climates. It can be grown on marginal lands, but it is most productive when grown on moderately to well-drained fields with medium fertility.[53] Because of its ability to extract nitrogen from unfertilized soils, the crop can be grown on soils of moderate fertility and still maintain productivity with little or no additional fertilizer.[54] Conventional farming equipment for seeding, crop management and harvesting can be used.[55]

It can be planted using till or no-till practices. Stand establishment generally takes 2-3 years, with reseeding necessary in some cases to produce a full and uniform stand. Once established, switchgrass can grow productively for ten years or more. Switchgrass is a hardy plant with resistance to a wide variety of insects and diseases. Until the stand is well-established, it does not compete well with weeds and other grasses.[56]

Harvesting is recommended after frost. Switchgrass can be harvested once or twice a year with conventional hay equipment. Covered storage is recommended.[57] Yields for switchgrass vary by location and variety but typically are in the range of 3-7 dry tons per acre in the South.[58]

Miscanthus

Miscanthus is a large perennial grass native to Asia and parts of Africa. It can grow over 12 feet in height. It is a non-invasive, low input, high yield crop well suited for use in energy production.

Miscanthus can be established from seed, rhizomes, micropropogated plantlets (derived from tissue culture), and stem cuttings. Stand establishment with rhizomes has been the preferred method for achieving the highest survival rate for the crop.[59] Much work is also being done to improve seed planting, which will help bring down the cost production.


Source: Mendel Biotechnology

Miscanthus can be grown on a wide variety of soil types, including marginal land, CRP land and pasture land.[60] The crop can tolerate temperate climates, although lower temperatures affect growth rate. Water availability has an effect on the success rate of stand establishment in the first year. It has been noted in Europe that in locations with under 20 inches of rainfall irrigation is necessary.[61]

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[53] University of Kentucky Cooperative Extension Service. (November 2009). ' Switchgrass for Biomass.' University of Kentucky – College of Agriculture. http://www.uky.edu/Ag/CDBREC/introsheets/switchgrass.pdf.

[54] Rinehart, L. (2006). 'Switchgrass as a Bioenergy Crop.' ATTRA National Sustainable Agricultural Information Service.

[55] Vogel, K.P.; Brejda, J.J.; Walters, D.T.; & Buxton, D.R. (2002). ' Switchgrass Biomass Production in the Midwest USA: Harvest and nitrogen management.' *Agronomy Journal*, 94, 413-420.

[56] University of Kentucky – College of Agriculture. Cooperative Extension Services. (2009). 'Switchgrass for Biomass'. http://www.uky.edu/Ag/CDBREC/introsheets/switchgrass.pdf

[57] University of Kentucky Cooperative Extension Service. (November 2009). ' Switchgrass for Biomass.' University of Kentucky – College of Agriculture. http://www.uky.edu/Ag/CDBREC/introsheets/switchgrass.pdf.

[58] Comis, D. (2006). 'Switching to Switchgrass Makes Sense.' USDA-ARS. http://www.ars.usda.gov/is/AR/archive/jul06/grass0706.htm?pf=1.

[59] Teoh, Keat; Devaiah, Shivakumar Pattada; Requesens, Deborah Vicuna; and Hood, Elizabeth. (2011). 'Dedicated Herbaceous Energy Crops.' Plant Biomass Conversion. (Wiley-Blackwell).

[60] Teoh, Keat; Devaiah, Shivakumar Pattada; Requesens, Deborah Vicuna; and Hood, Elizabeth. (2011). 'Dedicated Herbaceous Energy Crops.' Plant Biomass Conversion. (Wiley-Blackwell).

[61] Clifton-Brown, J.C.; Lewandowski, I.; et al. (2001). 'Performance of 15 *Miscanthus* genotypes at five sites in Europe.' *Agronomy Journal*.

Once the crop has been established it can grow for 15-20 years. *Miscanthus* cultivation can be done with existing farm machinery. Because the crop requires no tillage and very little fertilizer to support growth it helps minimize environmental issues associated with soil erosion, water pollution and run-off. Weed control is important during the establishment period of *Miscanthus* because of the slow initial growth of the crops.[62]

Miscanthus grown in warmer climates can be harvested in late fall to avoid biomass losses due to adverse winter conditions. Alternatively, it can be harvested in early spring when the moisture content is at its lowest. This option can lead to significant yield reduction due to winter biomass loss of leaves and upper stem parts. *Miscanthus* can be dried with mechanical ventilation during storage, industrial dryers, or left in the field to dry naturally. It can be stored in the field, with or without covering, or in covered, open-air buildings.[63]

Miscanthus is normally harvested from the second season onwards, since the first year biomass yields are not sufficient to cover the cost of harvesting. Ceiling yields can be reached in two years under good growing seasons, but can take up to five years. Ceiling yields are attained more quickly in warmer climates. Total yields are often higher in warmer climates than cooler. Extensive evaluation of *Miscanthus* production has been reported by researchers at the University of Illinois who have conducted field trials across the state. Based on their research the average *Miscanthus* yield after the third season is 12.1 dry tons per acre.[64]

Biomass Sorghum


Source: Ceres

Biomass sorghum is a quick-growing annual crop that can be rotated into existing cropping systems. The crop uses water and other inputs very efficiently, and can perform well on marginal lands. Biomass sorghum is highly productive in temperate climates and capable of growing to 20 feet in height.

Biomass Sorghum crop is established by seed and can be planted using till or no-till practices. Conventional farming equipment for seeding, crop management and harvesting can be used. Biomass sorghum performs best with at least 30 inches of rainfall, and is relatively drought tolerant. The crop favors deep soils to support its extensive root system, but performs well on a variety of soils. It is most productive on well-drained soils, since excessive moisture or waterlogging can reduce germination or cause plant death.

Pest pressures on sorghum include cutworm, nematodes, greenbugs, fall armyworm, panicles and sugarcane borers. Disease threats vary by geography and include anthracnose, downy mildew, and Fusarium.[65]

Biomass sorghum can produce high yields of biomass in 90-100 days. Depending on the variety, biomass sorghum can be harvested in a single cut, or in multiple cuts throughout the season to ensure continuous biomass feedstock supply. Agronomic practices for growing biomass sorghum are similar to those of forage or grain crop.

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[62] Teoh, Keat; Devaiah, Shivakumar Pattada; Requesens, Deborah Vicuna; and Hood, Elizabeth. (2011). 'Dedicated Herbaceous Energy Crops.' Plant Biomass Conversion. (Wiley-Blackwell).

[63] Teoh, Keat; Devaiah, Shivakumar Pattada; Requesens, Deborah Vicuna; and Hood, Elizabeth. (2011). 'Dedicated Herbaceous Energy Crops.' Plant Biomass Conversion. (Wiley-Blackwell).

[64] Heaton, E.A.; Dohleman, F.G.; & Long, S.P. (2008). 'Meeting US biofuel goals with less land: The potential of *Miscanthus*.' *Global Change Biology*, 14, 2000-2014.

[65] Blade Energy Crops. (2010). 'Managing High-Biomass Sorghum as a Dedicated Energy Crop.' http://www.bladeenergy.com/Bladepdf/Blade_SorghumMgmtGuide2010.pdf.

Land Use

Land use patterns in the West Kentucky region inform considerations for the location of biomass feedstock production, as well as the location for the pellet facility. Approximately 13,000 acres of switchgrass is required to meet the feedstock requirements of a 14 ton per hour pellet mill; about 620 acres for a 2 TPH farm-scale operation. Switchgrass is considered in this report as the only present feedstock option in light of limited data on other energy crops – which makes it difficult to make an informed decision - and the lingering ecological concerns associated with crop residues in the region.

Bioenergy crops must inevitably be low cost – i.e. low value for producers - if the processing system is to be viable and the pellets competitive against existing fossil fuels. From a producer's perspective low value crops should be grown on low value acres where there economic return exceeds the opportunity cost of not producing the next best alternative.

Within the 20 counties that comprise the West Kentucky region there are 1.65 million acres of cropland; 184,000 acres of pastureland; 1.5 million acres of timberland; and 167,000 acres of Conservation Reserve Program (CRP) land. As previously mentioned in this study, forest residues are not considered a viable biomass feedstock option for pelletization in the region. Therefore, timberland is not taken into consideration.

County	Cropland	Pastureland	Timberland	TOTAL
Ballard	70,700	5,754	34,253	**110,707**
Caldwell	55,285	13,881	55,529	**124,695**
Calloway	94,021	6,146	69,181	**169,348**
Carlisle	62,288	3,660	14,032	**79,980**
Christian	181,882	24,013	191,807	**397,702**
Crittenden	43,970	16,897	85,029	**145,896**
Fulton	76,271	1,759	44,402	**122,432**
Graves	140,067	19,255	78,050	**237,372**
Henderson	155,178	4,669	30,735	**190,582**
Hickman	95,910	2,825	36,419	**135,154**
Hopkins	79,835	7,804	158,832	**246,471**
Livingston	32,240	17,987	105,227	**155,454**
Lyon	20,117	3,283	79,290	**102,690**
Marshall	34,868	7,303	53,634	**95,805**
McCracken	43,272	8,912	37,188	**89,372**
Muhlenberg	55,467	8,479	149,067	**213,013**
Todd	111,567	11,043	55,962	**178,572**
Trigg	57,775	8,496	149,307	**215,578**
Union	158,047	5,998	29,430	**193,475**
Webster	82,492	6,134	42,655	**131,281**
TOTAL	**1,651,252**	**184,298**	**1,500,029**	**3,335,579**

Source: USDA Census of Agriculture (2007) for Cropland and Pastureland; USDA Forest Inventory and Analysis for Timberland, 5-year average (2005-2010)

Cropland

The primary crops grown in the West Kentucky region are wheat (93,933 acres), tobacco (13,892 acres), soybeans (776,400 acres), corn (647,600 acres), tobacco (13,892 acres), alfalfa hay (7,133 acres), and other hay (177,533 acres).[66] Other hay includes clover, timothy grass, lespedeza, fescue, Sudan, sorghum-Sudan crosses, grain hay and grass hay. For county level data please refer to ***Appendix 3 - Crop Production in West Kentucky***.

The model for feedstock development for biomass pellets in this study is based on a philosophy of sustainable production that, in its simplest form, could be defined as a production system that does not cause harm to natural bio-systems or negatively affect food production. For this reason, land used for crop production is not considered for the production of bioenergy crops for pelletization. From an economic perspective this decision makes sense as well, since it is not practical to consider production of low-value bioenergy crops on corn, soybean and wheat acres with crop prices near record highs.

A quick look at average farmland rental rates in the region further proves the point. Rental rates reflect producer expectations for returns on the land, in that a producer expects to make a profit that at least meets, and preferably exceeds the rental rate. While these rates vary by location, the average rental rate in 2011 for non-irrigated

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[66] USDA National Agricultural Statistics Service. Data and Statistics. http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp. (Figures based on 3-year average from 2008-2010).

cropland in the West Kentucky region was $113 per acre.[67] For county level rental payment data please refer to ***Appendix 4 - Land Rental Payments in West Kentucky***.

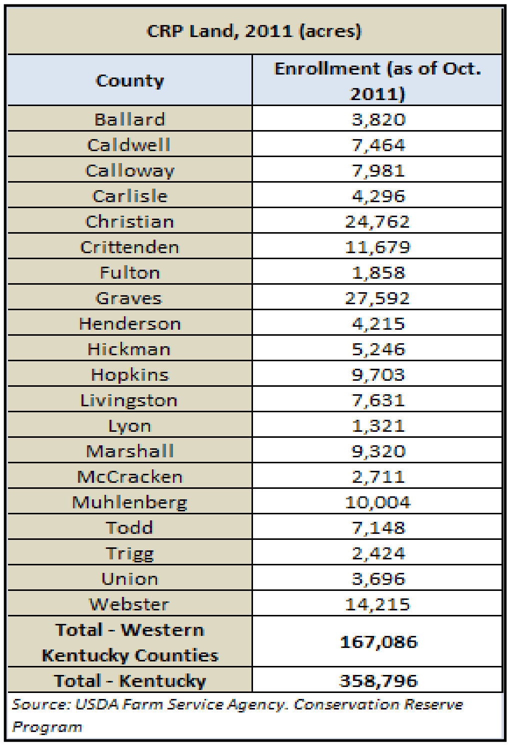
Marginal cropland acres perhaps merit consideration for bioenergy crop production. However, with corn, soybean and wheat prices near record highs farmers may still decide that they can make reasonable returns even with the depressed yields on marginal ground.

Pastureland

Farmland rental rates for pastureland in the region averaged $28 per acre.[68] For county level rental payment data please refer to ***Appendix 4 - Land Rental Payments for West Kentucky***. By applying the logic that rental rates reflect return expectations of the producer, it is clear that pastureland is one of the best options for consideration of biomass feedstock production. ***It is therefore recommended that location options for a pellet facility take into account the proximity to areas with large amounts of pastureland.***

CRP Land

There are approximately 167,000 acres of CRP (Conservation Reserve Program) land enrolled in the West Kentucky region. As of September 2011 there were 358,000 acres of CRP land enrolled on 9,463 farms in the state of Kentucky. Rental payments for that land totaled $39.8 M, or approximately $111 per acre.[69] While this rental payment rate is twice the national average, such a level is consistent with the above average fertility of the land in the state.



CRP Land, 2011 (acres)

County	Enrollment (as of Oct. 2011)
Ballard	3,820
Caldwell	7,464
Calloway	7,981
Carlisle	4,296
Christian	24,762
Crittenden	11,679
Fulton	1,858
Graves	27,592
Henderson	4,215
Hickman	5,246
Hopkins	9,703
Livingston	7,631
Lyon	1,321
Marshall	9,320
McCracken	2,711
Muhlenberg	10,004
Todd	7,148
Trigg	2,424
Union	3,696
Webster	14,215
Total - Western Kentucky Counties	**167,086**
Total - Kentucky	**358,796**

Source: USDA Farm Service Agency. Conservation Reserve Program

As with cropland, return expectations for CRP land make it challenging to create an economically viable scenario at both the farm and processing level – that is, one in which farmers receive adequate compensation from biomass feedstock production and the pellet mill can operate profitably.

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[67] USDA National Agricultural Statistics Service. Data and Statistics. http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats_1.0/index.asp.

[68] USDA National Agricultural Statistics Service. Data and Statistics. http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats_1.0/index.asp.

[69] USDA Farm Service Agency. Conservation Reserve Program. http://www.fsa.usda.gov/Internet/FSA_File/apportstate091311.pdf. (As of October 2011).

Pelletizing Process

Pelletizing biomass feedstock offers a number of benefits:

- Densification of the material increases the energy content per unit volume
- It lowers the moisture content, thus enhancing its heat value by reducing the heat of vaporization
- Lower moisture also allows pellets to burn hotter and more completely, thus removing harmful particle emissions
- Removing moisture and increasing bulk density also makes hauling more economical
- Material handling is simplified by the size of the pellets, thus enabling more automated feeding of heating appliances rather than the manual feeding system required of larger, bulkier and less consistent materials

The pelletizing process includes nine main steps: (1) Bale delivery to the receiving station; (2) Storage; (3) Bale breaking, chopping and primary grinding; (4) Feedstock drying; (5) Fine grinding with a hammermill; (6) Pelletizing; (7) Cooling; (8) Screening; (9) Bagging and palleting.

It has been reported that silica content in dedicated energy grasses can lead to enhanced wear of pellet equipment. This is certainly something that pellet plant operators need to be aware of and address during the optimization process.

Bale Delivery to Receiving Station

Large bales of biomass feedstock are delivered by semi-trailer truck or tractor to the plant's receiving station. The shape of the bale – square or round - effects both transport and storage. There are benefits to both shapes which should be taken into consideration in deciding the most efficient approach for biomass feedstock. Square bales are typically easier to stack and transport. Round bales are more moisture resistant and pack hay more densely. Harvest and storage methods need to ensure a consistent moisture level in the bales in order to efficiently manage the drying, grinding and pelletizing process.

Storage

The bales are first stored outside on the storage lot (120,000 ft^2 for a 14 TPH plant) and an enclosed storage facility (20,000 ft^2 for a 14 TPH plant). The storage lot should be asphalt, not crushed rock, dirt or grass, since crushed rock could end up in the pellet equipment and dirt or grass could add moisture and debris from the ground. A just-in-time delivery system is not recommended, despite the potential capital cost savings, because of the potential cost of unreliable deliveries and supply disruptions. [70]

Bale Breaking, Chopping and Primary Grinding

Large bales of grasses (energy crops like switchgrass), and crop residues (like corn stover or wheat straw) need to broken into smaller pieces. The grinding equipment for this process is typically a hammermill, tub grinder or shredder. The grinder is designed to process large chunks of material into smaller pieces, typically less than two inches in dimension.[71] It has been noted that bale type can affect throughput, with more time required to process large round bales than square bales because of the longer fiber length of material in round bales.[72]

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[70] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

[71] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

[72] Jannasch, R. (2001). 'A Process and Energy Analysis of Pelletizing Switchgrass.' Natural Resource Canada – Alternative Energy Division. Resource Efficient Agricultural Production (REAP-Canada). http://www.reap-canada.com/online_library/feedstock_biomass/11%20A%20Process.pdf.

Feedstock Drying

A dryer is used to reduce the feedstock moisture to levels suitable for pelletizing. Switchgrass moisture levels are usually 12-20 percent.[73] The feedstock needs to be dried to a moisture content of about 10 percent. It has been noted that feedstock entering the pellet mill at a moisture content of 13-15 percent is ideal, since the heat created in the pelletizing process will further dehydrate the material to desired levels. The target moisture content of the pellet is 6-10 percent.[74]

In a report for Natural Resource Canada it was noted that under certain circumstances switchgrass could be pelletized without the use of a dryer.[75] Even so, if the facility plans to handle different kinds of feedstock for pelletizing, it should also expect various moisture rates, increasing the need of a dryer.

Fine Grinding with Hammermill

A hammermill grinds the feedstock to a particle size that is suitable for pelletizing. The particle size is usually one-quarter (¼) inch or smaller and is adjusted by the screen, which is changeable. Generally, smaller particle size increases the density and hardness of the pellet, but if too finely ground the feedstock risks losing its fibrous characteristics and will not bind into a durable pellet.[76]

Pelletizing

Chopped feedstock is fed into the pelletizing chamber inside the die ring. The die ring rotates and the roller assembly turns, squeezing the feedstock into the die holes. Heat, moisture and pressure cause the feedstock to become compacted in the die holes and the particles bind together. The holes in the die are the diameter of the pellets to be produced. As pellets are extruded, adjustable knives cut the pellets off to the desired length.

Successful pelletizing depends on the moisture content of the feedstock, particle size, fiber strength, feedstock density, feedstock lubricating characteristics, and the natural binding qualities of the feedstock.

High temperature steam (220-240 degrees Fahrenheit) can be used during this stage to activate natural lignins and lubricants in the feedstock. These lignins then bind the pellet together after pelletizing and cooling. This type of conditioning requires either a boiler unit, or alternatively, a method of spraying the feedstock with water.

Additives, such as binders or chemicals used to offset chloride content, can be blended into the feedstock at the conditioning stage. The use of additives depends on the natural binding qualities of the feedstock. It has been noted that switchgrass is a difficult material to pelletize because it lacks natural binding properties.[77]

Cooling

Pellets exit from the pellet mill at a high temperature (over 200 degrees Fahrenheit) and are immediately delivered to the cooler. In this stage hot pellets are spread on a bed and cooled with forced air to evaporate excess moisture and cool the pellets (to about 80 degrees Fahrenheit). This process allows the lignins to solidify, thus improving

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[73] Jannasch, R. (2001). 'A Process and Energy Analysis of Pelletizing Switchgrass.' Natural Resource Canada – Alternative Energy Division. Resource Efficient Agricultural Production (REAP-Canada). http://www.reap-canada.com/online_library/feedstock_biomass/11%20A%20Process.pdf.

[74] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

[75] Jannasch, R. (2001). 'A Process and Energy Analysis of Pelletizing Switchgrass.' Natural Resource Canada – Alternative Energy Division. Resource Efficient Agricultural Production (REAP-Canada). http://www.reap-canada.com/online_library/feedstock_biomass/11%20A%20Process.pdf.

[76] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

[77] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

the hardness and durability of the pellets. It will also help prevent the pellets from "sweating" once they are bagged.[78]

Screening

After the pellets are cooled they are conveyed to a pellet screener/shaker which separates dust, particles and fragments from the whole pellets. These fines - i.e. fragments of material – are collected and returned for re-pelletizing.[79]

Bagging and Palleting

From the screening process the pellets are conveyed to the bag-out bin for bagging and palleting, the final step in the process. Pellets can be packaged in 40 pound bags, with 50 bags stacked on a pallet for a one-ton load. The pellets may also be bagged into one-ton totes, which can reduce the cost of more frequent bagging into 40 pound units. [80],[81]

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[78] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

[79] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

[80] Jannasch, R. (2001). 'A Process and Energy Analysis of Pelletizing Switchgrass.' Natural Resource Canada – Alternative Energy Division. Resource Efficient Agricultural Production (REAP-Canada). http://www.reap-canada.com/online_library/feedstock_biomass/11%20A%20Process.pdf.

[81] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

Financial Models for Agricultural Biomass-to-Energy Systems

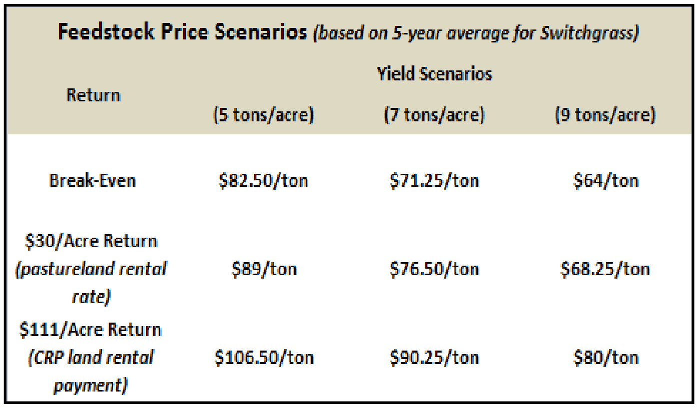
This report examines the financial viability of producing switchgrass on pasture ground for agricultural biomass pellets. The selection of switchgrass is based on existing information on the crop. At this point more research is recommended before considering crop residues and other dedicated energy crops for commercial production. Produced on pastureland (considered the most feasible and sustainable option), switchgrass has the potential to create about 100 MBtu per acre. If 10% of West Kentucky's pastureland were used for switchgrass production, this would create roughly 1,840,000 MBtu of energy per year, enough energy for over 19,300 homes.[82]

Financial models were created for a 2 ton per hour (TPH) farm-scale pellet mill and a 14 TPH commercial-scale facility. There are advantages to each. A 2 TPH facility on the farm in close proximity to the feedstock source will benefit from reduced transport costs and provide a local, alternative energy supply for on-farm operations. A 14 TPH operation appreciates certain economies of scale that reduce the marginal cost of production, thus allowing the marketing of the pellets at a lower price than 2 TPH pellet producers.

As a third option, this report also includes a localized 14 TPH non-pelletizing operation in which the switchgrass is chopped/ground/hammermilled and sold to customers in this non-pelletized bulk form. This model assumes the presence of emerging combustion technologies that are capable of utilizing this type of ag-biomass feedstock. In such an operation, local farmers would grow, harvest and bale the crop. Depending on the timing and the feedstock management, they may store it on-farm or deliver it to the facility. Additionally, since many farmers may already own bale grinders or silage choppers, they could do some of the chopping/grinding themselves. In bale form, or ground/chopped it is delivered to the central collection point where the final chopping/grinding, drying, and hammermilling is done. It is then sold in bags, pallets or truckloads to local commercial, institutional or residential users. In this situation, the crop is grown and processed locally, and the end-product is used for local energy. Although bulkier than pellets, the localized nature of the production and distribution system reduces the overall transport costs (and thus the overall cost of energy). Also, because it is less capital intensive than the 14 TPH pellet mill, this system would appreciate similar economies of scale and even lower marginal cost of production, thus allowing the marketing of the ground/chopped/hammermilled biomass at a lower price than pellets. The main challenge to this system is that it requires the adoption of new combustion technologies at a significant enough scale in the area to create a market for non-pelletized ag-biomass feedstock.

Feedstock Price

The feedstock price scenarios are based on the 5-year average cost of production for switchgrass and the feedstock price required to yield specific outcomes – Break-Even, $30/acre return and $111/acre return. The last two return outcomes are based on land rental payments for pastureland in Kentucky (~$30/acre) and land rental payments for CRP land in Kentucky (~$111/acre). As previously mentioned, pastureland is the best option for consideration to plant energy crops since this land requires the lowest return incentive. Cropland is not considered for energy crop production in this report because such an approach would negatively impact food production. For a five-year cost of production estimate for switchgrass please refer to ***Appendix 2 - Switchgrass Budget***.



Feedstock Price Scenarios *(based on 5-year average for Switchgrass)*

Return		Yield Scenarios	
	(5 tons/acre)	(7 tons/acre)	(9 tons/acre)
Break-Even	$82.50/ton	$71.25/ton	$64/ton
$30/Acre Return *(pastureland rental rate)*	$89/ton	$76.50/ton	$68.25/ton
$111/Acre Return *(CRP land rental payment)*	$106.50/ton	$90.25/ton	$80/ton

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[82] US Energy Information Administration estimates that in 2005, energy use per household was 95 million British thermal units (Btu). http://205.254.135.7/consumption/residential/reports/2009overview.cfm.

Three yield scenarios are used to demonstrate the changes in feedstock price associated with increases/decreases in yield. Since higher yields have the potential to substantially decrease feedstock costs for a pelletizing facility, further research is recommended to help continue to improve yields for dedicated energy crops.

Electricity

Electricity is a major expense for the operation. Electricity rates for Kentucky were used, based on U.S. Energy Information Administration data.[83] The results show that the larger pellet plant achieves certain economies of scale. It is also clear that the 14 TPH non-pelletized operation requires operates at a lower electricity cost/ton of product.

Natural Gas

Natural gas is used to dry the feedstock from a moisture level of 20% down to 10%. If the operation accepts feedstocks with higher moisture content natural gas usage, and final cost, are likely to increase. The natural gas price for Kentucky is based on U.S. Energy Information Administration data.[84]

Electricity	**2 TPH**	**14 TPH**	**14 TPH (w/out pelletizing)**
End Product (tons/yr)	4,000	84,000	84,000
Total Operating Hours	2,000	6,000	6,000
Electricity Rate ($/kWh)	$0.0652	$0.0652	$0.0652
Horsepower, kW, and kWh			
Primary Grinder	-	225	225
Dryer	-	360	360
Hammermill	75	200	200
Boiler	50	-	-
Pellet Mill	100	800	-
Bagging/Palleting	-	50	-
Building Boiler, Lights, etc.	20	150	150
Miscellaneous	50	180	180
Total HP	295	1,965	1,115
Total kW	220	1,466	832
Total kWh per Year	440,140	8,795,340	4,990,740
Annual Electricity Cost	**$28,697**	**$573,456**	**$325,396**
Electricity Cost per Ton of Product	**$7.17**	**$6.83**	**$3.87**

Natural Gas	**2 TPH**	**14 TPH**	**14 TPH (w/out pelletizing)**
End Product (tons/yr)	4,000	84,000	84,000
Natural Gas Rate ($/MBtu)	$4.66	$4.66	$4.66
Tons of Feedstock/Year	4,320	90,720	90,720
Natural Gas to reduce 20% moisture content to 10%			
Btu to evaporate 1 lb of water	1,760	1708	1708
Pounds of water to evaporate per ton of feedstock	200	200	200
Btu per ton of feedstock	390,720	379176	379176
MMBtu per year	1,688	34,399	34,399
Annual Natural Gas Cost	**$7,873**	**$160,439**	**$160,439**
Natural Gas Cost per Ton of	**$1.97**	**$1.91**	**$1.91**

Source: Campbell, Ken. Agricultural Utilization Research Institute. 'A Feasability Study Guide for an Agricultural Biomass Pellet Company' (2007).

Labor

Labor requirements and cost are the most significant operating expense, excluding the feedstock cost and taxes. Personnel requirements are based on Ken Campbell's 2007 report 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company'. Wage data for personnel at the plant is taken from the U.S. Department of Labor - Bureau of Labor Statistics.[85]

For the 2 ton per hour pellet plant the assumption is that total labor expenses would be equal to $15/hr for 3 workers at 2,000 total hours of production per year (total of $90,000 per year). This expense would include wages (for sales, general, administrative, production and maintenance) paid to the owner and family members as well as to hired labor.[86] For the 2 TPH pellet operation, total labor cost represents 12.5 % of the total costs of the business.

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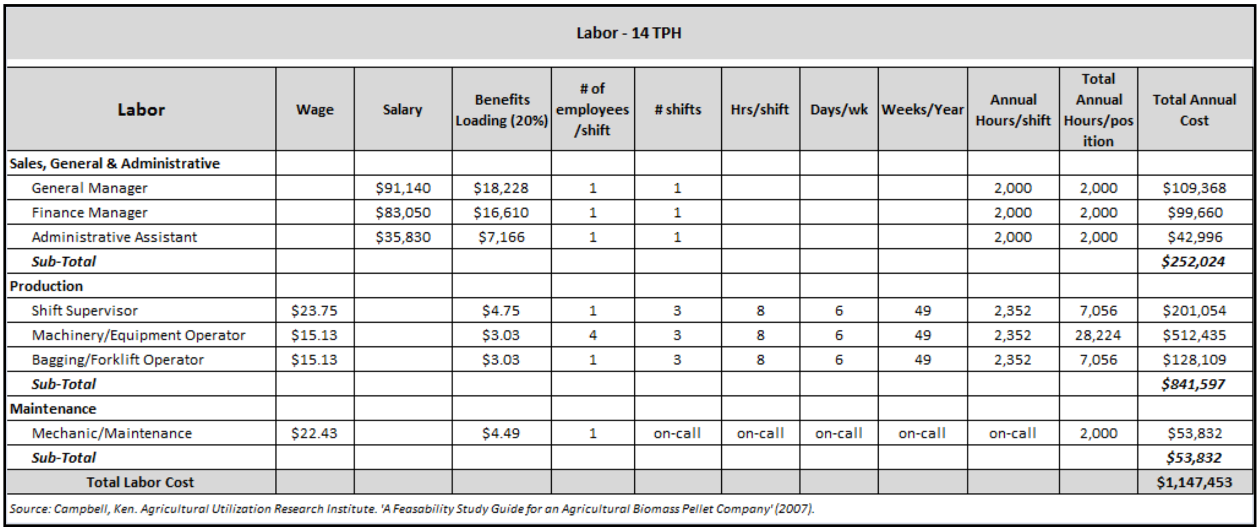
[83] U.S. Energy Information Administration. State Electricity Profiles. http://www.eia.gov/cneaf/electricity/st_profiles/e_profiles_sum.html.

[84] U.S. Information Administration. Kentucky Natural Gas Prices. http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_SKY_m.htm.

[85] U.S. Department of Labor. Bureau of Labor Statistics. Wage Data by Area and Occupation. Wage Data by State. 'Kentucky'. http://www.bls.gov/oes/current/oes_ky.htm.

[86] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

The labor requirement for the 14 TPH pellet mill and the 14 TPH non-pelletized operation are considered the same for the purposes of this model. The total labor cost is $1.15 million per year, or $13.66 per ton of end product. This cost represents7.4% (14 TPH) and 7.6% (14 TPH non-pelletized) of the total cost of the operations.



Labor - 14 TPH

Labor	Wage	Salary	Benefits Loading (20%)	# of employees /shift	# shifts	Hrs/shift	Days/wk	Weeks/Year	Annual Hours/shift	Total Annual Hours/position	Total Annual Cost
Sales, General & Administrative											
General Manager		$91,140	$18,228	1	1				2,000	2,000	$109,368
Finance Manager		$83,050	$16,610	1	1				2,000	2,000	$99,660
Administrative Assistant		$35,830	$7,166	1	1				2,000	2,000	$42,996
Sub-Total											***$252,024***
Production											
Shift Supervisor	$23.75		$4.75	1	3	8	6	49	2,352	7,056	$201,054
Machinery/Equipment Operator	$15.13		$3.03	4	3	8	6	49	2,352	28,224	$512,435
Bagging/Forklift Operator	$15.13		$3.03	1	3	8	6	49	2,352	7,056	$128,109
Sub-Total											***$841,597***
Maintenance											
Mechanic/Maintenance	$22.43		$4.49	1	on-call	on-call	on-call	on-call	on-call	2,000	$53,832
Sub-Total											***$53,832***
Total Labor Cost											**$1,147,453**

Source: Campbell, Ken. Agricultural Utilization Research Institute. 'A Feasability Study Guide for an Agricultural Biomass Pellet Company' (2007).

Transportation

This report assumes that all feedstock, pellets, and bulk product are transported by semi-truck, hauling a maximum capacity of 25 tons. The financial models in this report also assume that the processing facility pays for the cost of transporting feedstock from farm to factory, and the customer pays for the cost of shipping from the factory. Total cost depends on the transport rate and distance. The transport rate is $1.75 per mile.[87]

For the 2 TPH pellet mill, all feedstock is sourced from within a 5-mile radius of the facility (10 miles round-trip). At that rate and distance the average transport cost is $0.70 per ton. The total cost is $2,800 per year. For the 14 TPH operations (pelletizing and non-pelletizing) feedstock is sourced from within 50 miles of the facility (100 miles round-trip). At that rate and distance, the average transport cost is $7 per ton. The total transport cost is $588,000 per year. Depending on the positions of farmers and customers, plant operators may consider alternative arrangements for defraying some of this expense.

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[87] Transport costs are based on quotes from Fullen Dock and Warehouse in Memphis, Tennessee (taken December 2011).

Capital Expenditure Requirements

Capital expenditure requirements are determined by the scale and extent of processing. For instance, for the 2 TPH plant, since it is a farm-scale pelletizing facility, it is assumed that this facility is added to an existing farming operation and certain infrastructure and equipment will already be in place. Hence the zero cost figures for particular items in the capital budget. For the 14 TPH non-pelletizing operation, since the feedstock is not pelletized, equipment requirements are nearly $1.5 million less than the 14 TPH pellet plant.

Also indicated in the capital expenditure table is 'Capitalized Interest'. This interest expense is added to the cost of the project, instead of being expensed on Year 1 Interest in the Income Statement. It covers the interest expense from debt to pay for the assets during the initial period of operations immediately following construction and prior to receipt of sales revenue. This capitalized interest will be part of the asset's cost reported on the balance sheet, and will be part of the asset's depreciation expense.

Capital Expenditures	**2 TPH**	**14 TPH**	**14 TPH (w/out pelletizing)**
Site Preparation	**0**	**216,000**	**216,000**
Plant Building & Offices	**0**	**1,020,000**	**1,020,000**
Receiving Station & Scale	**0**	**130,000**	**130,000**
Feedstock Storage			
Storage Lot	0	360,000	360,000
Storage Warehouse	0	280,000	280,000
Total Feedstock Storage	**0**	**640,000**	**640,000**
Pellet (Product) Storage			
Pallet Warehouse	0	350,000	350,000
Loose Storage Building	0	1,480,000	1,480,000
Total Pellet Storage	**0**	**1,830,000**	**1,830,000**
Plant Equipment			
Primary Grinder	0	650,000	650,000
Dryer	0	426,000	426,000
Hammermill	31,200	47,000	47,000
Conditioner/Feeder	43,900	87,900	87,900
Boiler	45,000	51,000	51,000
Pellet Mill	96,300	442,600	-
Pellet Cooler	31,800	69,800	-
Pellet Shaker/Screener	18,300	18,300	-
Bagging/Palleting System	0	450,000	-
Conveyer, Tanks, etc.	200,000	1,356,000	850,000
Total Plant Equipment	**466,500**	**3,598,600**	**2,111,900**
Other Equipment/Tools			
Wheel Loader	0	110,000	110,000
Fork Lift	0	30,000	30,000
Plant & Office Equipment/Tools	0	100,000	100,000
Total Other Equipment/Tools	**0**	**240,000**	**240,000**
Installation			
Engineering	20,000	75,000	75,000
Project Management	10,000	100,000	100,000
Freight	19,000	144,000	144,000
Mechanical Installation	40,000	660,000	660,000
Electrical Installation	30,000	480,000	480,000
Total Installation	**119,000**	**1,459,000**	**1,459,000**
Capitalized Interest	**25,000**	**400,000**	**400,000**
Total Capital Budget	**610,500**	**9,533,600**	**8,046,900**

Source: Campbell, Ken. Agricultural Utilization Research Institute. 'A Feasability Study Guide for an Agricultural Biomass Pellet Company' (2007).

Total Investment

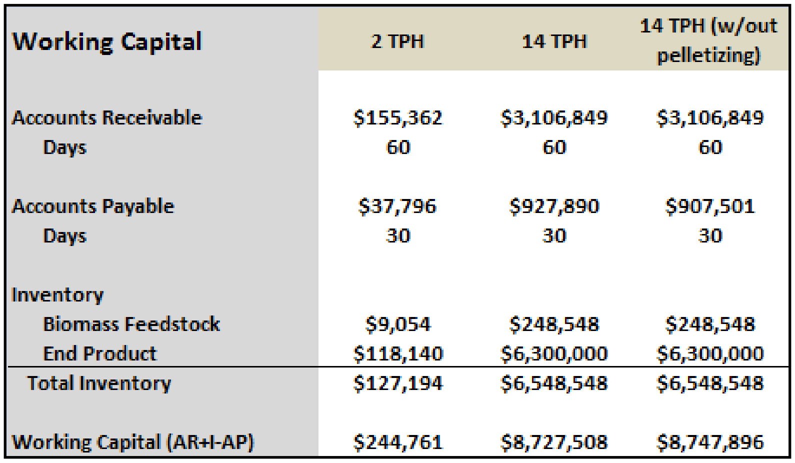
The total investment cost includes the capital expenditure budget (with capitalized interest). It does not account for cost of working capital.

- 2 TPH - $610,500
- 14 TPH - $9,533,600
- 14 TPH (non-pelletized) - $8,046,900

Working Capital

Working capital is a measure of business liquidity. Working Capital is equal to Accounts Receivable, plus Inventory, less Accounts Payable. Any biomass-to-energy operation will need to ensure adequate working capital to manage cashflow and make payments for operations that will occur in advance of sales receipts. The assumptions used to project working capital requirements are described below. The business model for each operation assumes that the company will obtain a short-term line of credit, and use one-year loans at a 7% borrowing rate to cover the annual cost associated with working capital.

Accounts Receivable represents outstanding sales receipts for the final product (pellets or bulk-processed biomass). The report assumes a 60-day payback period for outstanding sales receipts. Accounts Payable represents outstanding bills – i.e. feedstock, utilities, transport and labor. The report assumes a payback period for expenses of 30 days. Inventory represents the value of all feedstock and end product held by the business at the time of reporting. This report assumes ten (10) days of feedstock inventory are stored for each of the operations. For the 2 TPH mill, it is assumed that the farm operation has capacity to store 500 tons of pellets (12.5% of total annual output); for the 14 TPH pellet mill, the pellet inventory is 28,000 tons (33% of total annual output); and for the 14 TPH bulk-processed biomass, the end product inventory is also 28,000 tons (also 33% of total annual output).



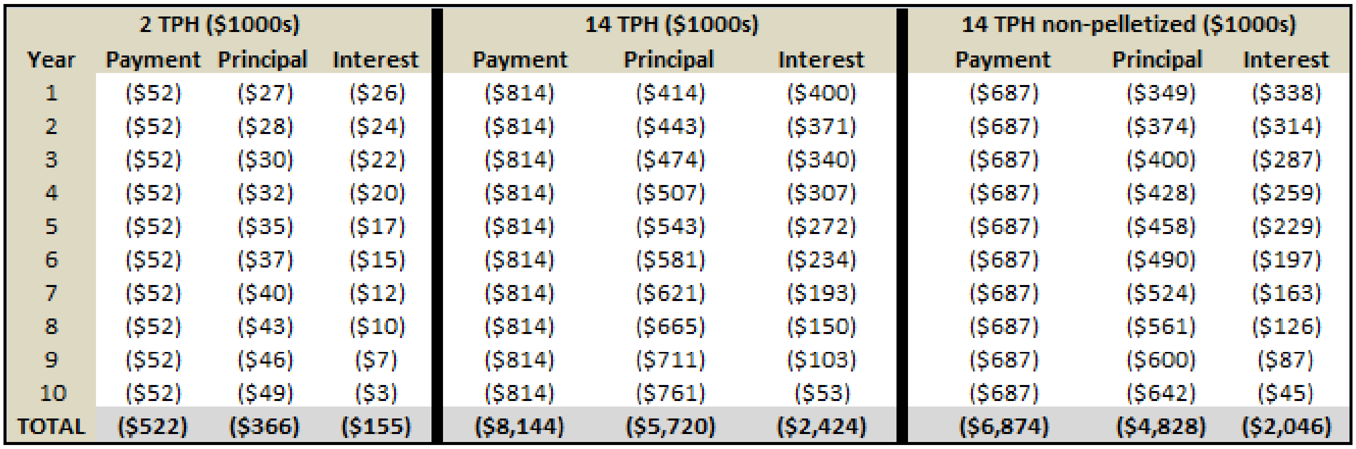
Working Capital	**2 TPH**	**14 TPH**	**14 TPH (w/out pelletizing)**
Accounts Receivable	**$155,362**	**$3,106,849**	**$3,106,849**
Days	**60**	**60**	**60**
Accounts Payable	**$37,796**	**$927,890**	**$907,501**
Days	**30**	**30**	**30**
Inventory			
Biomass Feedstock	**$9,054**	**$248,548**	**$248,548**
End Product	**$118,140**	**$6,300,000**	**$6,300,000**
Total Inventory	**$127,194**	**$6,548,548**	**$6,548,548**
Working Capital (AR+I-AP)	**$244,761**	**$8,727,508**	**$8,747,896**

The greater the accounts receivable, and the inventory held, the higher the working capital requirement (holding accounts payable fixed). It is therefore advisable for the plant manager to consider approaches to improving terms of sales receipts, and managing the logistics of feedstock delivery and product sales, so as to minimize inventory without jeopardizing operations.

Long-Term Debt

Long-term debt is used to purchase capital equipment (and cover the capitalized interest expense). It is not used for working capital. This report assumes a 60-40 debt-equity split for each of the operations. The terms of borrowing are: 10 year loans at 7 % APR. The debt load for the three models is as follows:

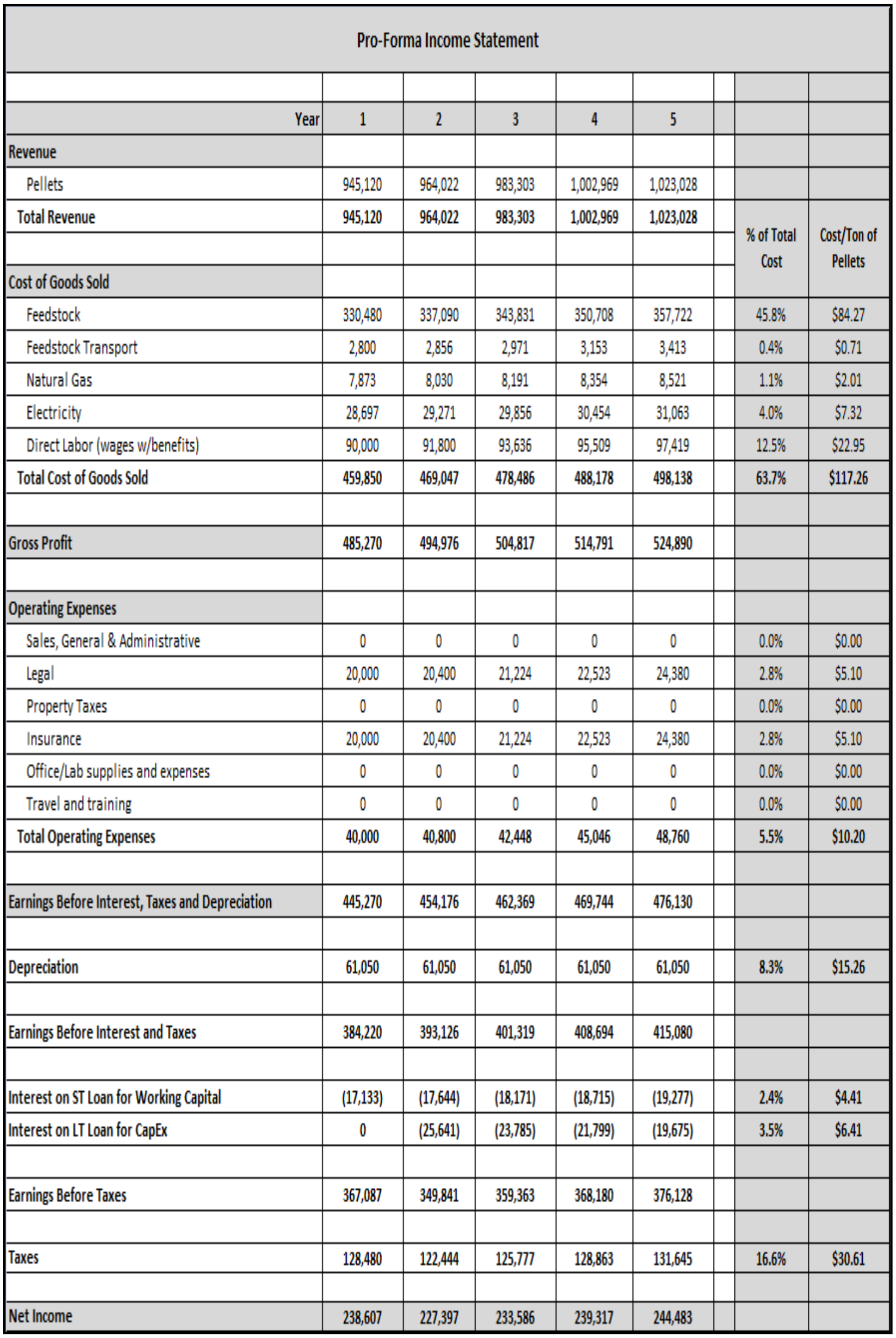
- 2 TPH - $366,300
- 14 TPH - $5,720,160
- 14 TPH (non-pelletized) - $4,828,140



	2 TPH ($1000s)			**14 TPH ($1000s)**			**14 TPH non-pelletized ($1000s)**		
Year	**Payment**	**Principal**	**Interest**	**Payment**	**Principal**	**Interest**	**Payment**	**Principal**	**Interest**
1	($52)	($27)	($26)	($814)	($414)	($400)	($687)	($349)	($338)
2	($52)	($28)	($24)	($814)	($443)	($371)	($687)	($374)	($314)
3	($52)	($30)	($22)	($814)	($474)	($340)	($687)	($400)	($287)
4	($52)	($32)	($20)	($814)	($507)	($307)	($687)	($428)	($259)
5	($52)	($35)	($17)	($814)	($543)	($272)	($687)	($458)	($229)
6	($52)	($37)	($15)	($814)	($581)	($234)	($687)	($490)	($197)
7	($52)	($40)	($12)	($814)	($621)	($193)	($687)	($524)	($163)
8	($52)	($43)	($10)	($814)	($665)	($150)	($687)	($561)	($126)
9	($52)	($46)	($7)	($814)	($711)	($103)	($687)	($600)	($87)
10	($52)	($49)	($3)	($814)	($761)	($53)	($687)	($642)	($45)
TOTAL	**($522)**	**($366)**	**($155)**	**($8,144)**	**($5,720)**	**($2,424)**	**($6,874)**	**($4,828)**	**($2,046)**

Income Statement – 2 TPH Pellet Mill

- **Feedstock Price: $76.50/ton**
- **Pellet Price: $236.28/ton**
- **Hours of Production – 2,000 per year.** The assumption is that a 2 ton per hour plant will operate one shift per day, equivalent to 2,000 hours per year – 85% of 2,353 hours, the total number of scheduled operating hours.
- **Pellet Production – 4,000 tons per year** (assumes 10% moisture content)
- **Total Energy Output – 62,000 MBtu**
- **Feedstock Requirement – 4,320 tons of Switchgrass** (assumes 20% moisture content)
- **Acreage Requirement – 617 acres** (assumes 7 ton per year yield)
- **Property Taxes - $0;** assumes facility is co-sited on existing property; [88]
- **Cost of Production/ton of pellets - $69.27** (not including taxes or cost of feedstock)



Pro-Forma Income Statement

Year	1	2	3	4	5		% of Total Cost	Cost/Ton of Pellets
Revenue								
Pellets	945,120	964,022	983,303	1,002,969	1,023,028			
Total Revenue	**945,120**	**964,022**	**983,303**	**1,002,969**	**1,023,028**			
Cost of Goods Sold								
Feedstock	330,480	337,090	343,831	350,708	357,722		45.8%	$84.27
Feedstock Transport	2,800	2,856	2,971	3,153	3,413		0.4%	$0.71
Natural Gas	7,873	8,030	8,191	8,354	8,521		1.1%	$2.01
Electricity	28,697	29,271	29,856	30,454	31,063		4.0%	$7.32
Direct Labor (wages w/benefits)	90,000	91,800	93,636	95,509	97,419		12.5%	$22.95
Total Cost of Goods Sold	**459,850**	**469,047**	**478,486**	**488,178**	**498,138**		**63.7%**	**$117.26**
Gross Profit	**485,270**	**494,976**	**504,817**	**514,791**	**524,890**			
Operating Expenses								
Sales, General & Administrative	0	0	0	0	0		0.0%	$0.00
Legal	20,000	20,400	21,224	22,523	24,380		2.8%	$5.10
Property Taxes	0	0	0	0	0		0.0%	$0.00
Insurance	20,000	20,400	21,224	22,523	24,380		2.8%	$5.10
Office/Lab supplies and expenses	0	0	0	0	0		0.0%	$0.00
Travel and training	0	0	0	0	0		0.0%	$0.00
Total Operating Expenses	**40,000**	**40,800**	**42,448**	**45,046**	**48,760**		**5.5%**	**$10.20**
Earnings Before Interest, Taxes and Depreciation	**445,270**	**454,176**	**462,369**	**469,744**	**476,130**			
Depreciation	**61,050**	**61,050**	**61,050**	**61,050**	**61,050**		**8.3%**	**$15.26**
Earnings Before Interest and Taxes	**384,220**	**393,126**	**401,319**	**408,694**	**415,080**			
Interest on ST Loan for Working Capital	**(17,133)**	**(17,644)**	**(18,171)**	**(18,715)**	**(19,277)**		**2.4%**	**$4.41**
Interest on LT Loan for CapEx	**0**	**(25,641)**	**(23,785)**	**(21,799)**	**(19,675)**		**3.5%**	**$6.41**
Earnings Before Taxes	**367,087**	**349,841**	**359,363**	**368,180**	**376,128**			
Taxes	**128,480**	**122,444**	**125,777**	**128,863**	**131,645**		**16.6%**	**$30.61**
Net Income	**238,607**	**227,397**	**233,586**	**239,317**	**244,483**			

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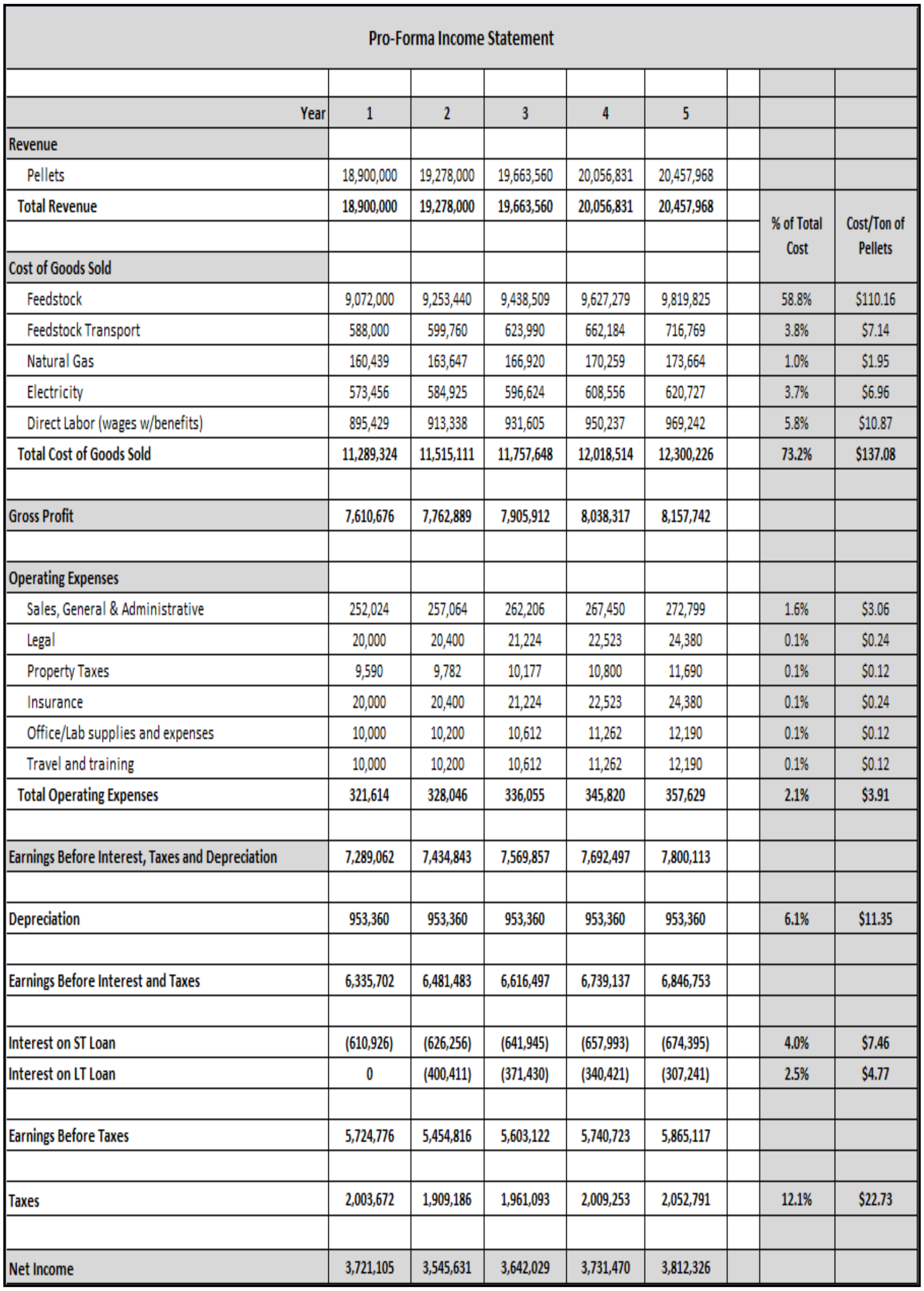
[88] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

Income Statement – 14 TPH Pellet Mill

- **Feedstock Price: $76.50/ton**
- **Pellet Price: $236.28/ton**
- **Hours of Production – 6,000 per year**. At full capacity it is assumed that the commercial-scale pellet plant would achieve full-production for the equivalent of 6,000 hours per year - 85% of 7,056 hours, the total number of scheduled operating hours. This lower number is intended to take into account all downtime, start-up time, shutdown time, and periods when the pellet plant is producing at less than full production capacity.[89]
- **Pellet Production – 84,000 tons per year** (assumes 10% moisture content)
- **Total Energy Output – 1,302,000 MBtu**
- **Feedstock Requirement – 90,720 tons of Switchgrass** (assumes 20% moisture content)
- **Acreage Requirement – 12,960 acres** (assumes 7 tons per year yield)
- **Property Taxes - $9,590;** assumes a market value for real property for a 14 TPH to be $3,836,000; [90] Property Tax Rate = 0.25 percent.[91]
- **Cost of Production/ton of pellets - $54.40** (not including taxes or cost of feedstock)


Pro-Forma Income Statement

Year	1	2	3	4	5	% of Total Cost	Cost/Ton of Pellets
Revenue							
Pellets	18,900,000	19,278,000	19,663,560	20,056,831	20,457,968		
Total Revenue	**18,900,000**	**19,278,000**	**19,663,560**	**20,056,831**	**20,457,968**		
Cost of Goods Sold							
Feedstock	9,072,000	9,253,440	9,438,509	9,627,279	9,819,825	58.8%	$110.16
Feedstock Transport	588,000	599,760	623,990	662,184	716,769	3.8%	$7.14
Natural Gas	160,439	163,647	166,920	170,259	173,664	1.0%	$1.95
Electricity	573,456	584,925	596,624	608,556	620,727	3.7%	$6.96
Direct Labor (wages w/benefits)	895,429	913,338	931,605	950,237	969,242	5.8%	$10.87
Total Cost of Goods Sold	**11,289,324**	**11,515,111**	**11,757,648**	**12,018,514**	**12,300,226**	**73.2%**	**$137.08**
Gross Profit	**7,610,676**	**7,762,889**	**7,905,912**	**8,038,317**	**8,157,742**		
Operating Expenses							
Sales, General & Administrative	252,024	257,064	262,206	267,450	272,799	1.6%	$3.06
Legal	20,000	20,400	21,224	22,523	24,380	0.1%	$0.24
Property Taxes	9,590	9,782	10,177	10,800	11,690	0.1%	$0.12
Insurance	20,000	20,400	21,224	22,523	24,380	0.1%	$0.24
Office/Lab supplies and expenses	10,000	10,200	10,612	11,262	12,190	0.1%	$0.12
Travel and training	10,000	10,200	10,612	11,262	12,190	0.1%	$0.12
Total Operating Expenses	**321,614**	**328,046**	**336,055**	**345,820**	**357,629**	**2.1%**	**$3.91**
Earnings Before Interest, Taxes and Depreciation	**7,289,062**	**7,434,843**	**7,569,857**	**7,692,497**	**7,800,113**		
Depreciation	**953,360**	**953,360**	**953,360**	**953,360**	**953,360**	**6.1%**	**$11.35**
Earnings Before Interest and Taxes	**6,335,702**	**6,481,483**	**6,616,497**	**6,739,137**	**6,846,753**		
Interest on ST Loan	**(610,926)**	**(626,256)**	**(641,945)**	**(657,993)**	**(674,395)**	**4.0%**	**$7.46**
Interest on LT Loan	**0**	**(400,411)**	**(371,430)**	**(340,421)**	**(307,241)**	**2.5%**	**$4.77**
Earnings Before Taxes	**5,724,776**	**5,454,816**	**5,603,122**	**5,740,723**	**5,865,117**		
Taxes	**2,003,672**	**1,909,186**	**1,961,093**	**2,009,253**	**2,052,791**	**12.1%**	**$22.73**
Net Income	**3,721,105**	**3,545,631**	**3,642,029**	**3,731,470**	**3,812,326**		

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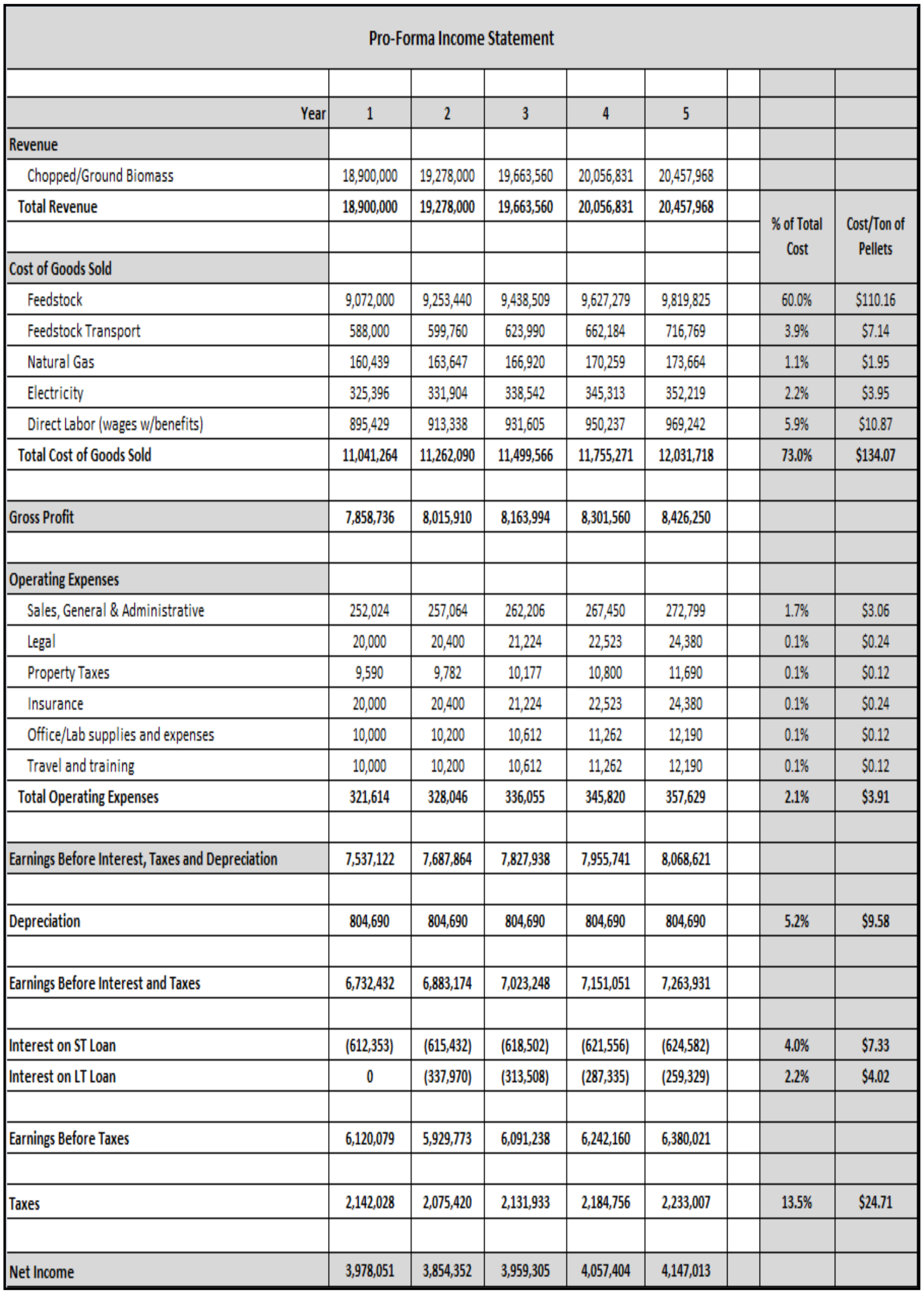
[89] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

[90] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

[91] Commonwealth of Kentucky. Department of Revenue - Office of Property Evaluation. Average Real Estate Rate in Counties. 2007.

Income Statement – 14 TPH (non-pelletized)

- **Feedstock Price: $76.50/ton**
- **Pellet Price: $236.28/ton**
- **Hours of Production – 6,000 per year**. At full capacity it is assumed that the commercial-scale pellet plant would achieve full-production for the equivalent of 6,000 hours per year - 85% of 7,056 hours, the total number of scheduled operating hours. This lower number is intended to take into account all downtime, start-up time, shutdown time, and periods when the pellet plant is producing at less than full production capacity.[92]
- **Pellet Production – 84,000 tons per year** (assumes 10% moisture content)
- **Total Energy Output – 1,302,000 MBtu**
- **Feedstock Requirement – 90,720 tons of Switchgrass** (assumes 20% moisture content)
- **Acreage Requirement – 12,960 acres** (assumes 7 tons per year yield)
- **Property Taxes - $9,590;** assumes a market value for real property for a 14 TPH to be $3,836,000; [93] Property Tax Rate = 0.25 percent.[94]
- **Cost of Production/ton of pellets - $48.75** (not including taxes or cost of feedstock)



Pro-Forma Income Statement

Year	1	2	3	4	5		% of Total Cost	Cost/Ton of Pellets
Revenue								
Chopped/Ground Biomass	18,900,000	19,278,000	19,663,560	20,056,831	20,457,968			
Total Revenue	**18,900,000**	**19,278,000**	**19,663,560**	**20,056,831**	**20,457,968**			
Cost of Goods Sold								
Feedstock	9,072,000	9,253,440	9,438,509	9,627,279	9,819,825		60.0%	$110.16
Feedstock Transport	588,000	599,760	623,990	662,184	716,769		3.9%	$7.14
Natural Gas	160,439	163,647	166,920	170,259	173,664		1.1%	$1.95
Electricity	325,396	331,904	338,542	345,313	352,219		2.2%	$3.95
Direct Labor (wages w/benefits)	895,429	913,338	931,605	950,237	969,242		5.9%	$10.87
Total Cost of Goods Sold	**11,041,264**	**11,262,090**	**11,499,566**	**11,755,271**	**12,031,718**		**73.0%**	**$134.07**
Gross Profit	**7,858,736**	**8,015,910**	**8,163,994**	**8,301,560**	**8,426,250**			
Operating Expenses								
Sales, General & Administrative	252,024	257,064	262,206	267,450	272,799		1.7%	$3.06
Legal	20,000	20,400	21,224	22,523	24,380		0.1%	$0.24
Property Taxes	9,590	9,782	10,177	10,800	11,690		0.1%	$0.12
Insurance	20,000	20,400	21,224	22,523	24,380		0.1%	$0.24
Office/Lab supplies and expenses	10,000	10,200	10,612	11,262	12,190		0.1%	$0.12
Travel and training	10,000	10,200	10,612	11,262	12,190		0.1%	$0.12
Total Operating Expenses	**321,614**	**328,046**	**336,055**	**345,820**	**357,629**		**2.1%**	**$3.91**
Earnings Before Interest, Taxes and Depreciation	**7,537,122**	**7,687,864**	**7,827,938**	**7,955,741**	**8,068,621**			
Depreciation	**804,690**	**804,690**	**804,690**	**804,690**	**804,690**		**5.2%**	**$9.58**
Earnings Before Interest and Taxes	**6,732,432**	**6,883,174**	**7,023,248**	**7,151,051**	**7,263,931**			
Interest on ST Loan	**(612,353)**	**(615,432)**	**(618,502)**	**(621,556)**	**(624,582)**		**4.0%**	**$7.33**
Interest on LT Loan	**0**	**(337,970)**	**(313,508)**	**(287,335)**	**(259,329)**		**2.2%**	**$4.02**
Earnings Before Taxes	**6,120,079**	**5,929,773**	**6,091,238**	**6,242,160**	**6,380,021**			
Taxes	**2,142,028**	**2,075,420**	**2,131,933**	**2,184,756**	**2,233,007**		**13.5%**	**$24.71**
Net Income	**3,978,051**	**3,854,352**	**3,959,305**	**4,057,404**	**4,147,013**			

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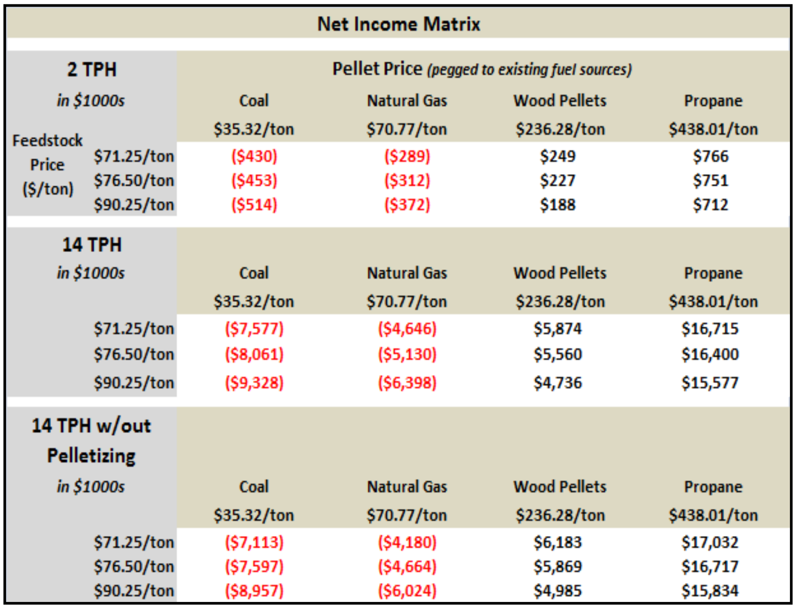
[92] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

[93] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

[94] Commonwealth of Kentucky. Department of Revenue - Office of Property Evaluation. Average Real Estate Rate in Counties. 2007.

Net Income Scenarios

The net income scenarios are based on the previously mentioned feedstock prices, and four pellet prices based on the 'Fuel Price Matrix' in the 'Pellet Price' section of the report. It is clear that the most lucrative markets for biomass pellets are in Residential Heating and Poultry House Heating where the existing feedstocks – wood pellets and propane respectively - are both relatively high cost energy sources. On the other hand, the utility, commercial and institutional markets, which utilize low-cost coal and natural gas energy sources, are not profitable outlets for biomass pellets (without generous incentives and/or subsidies).

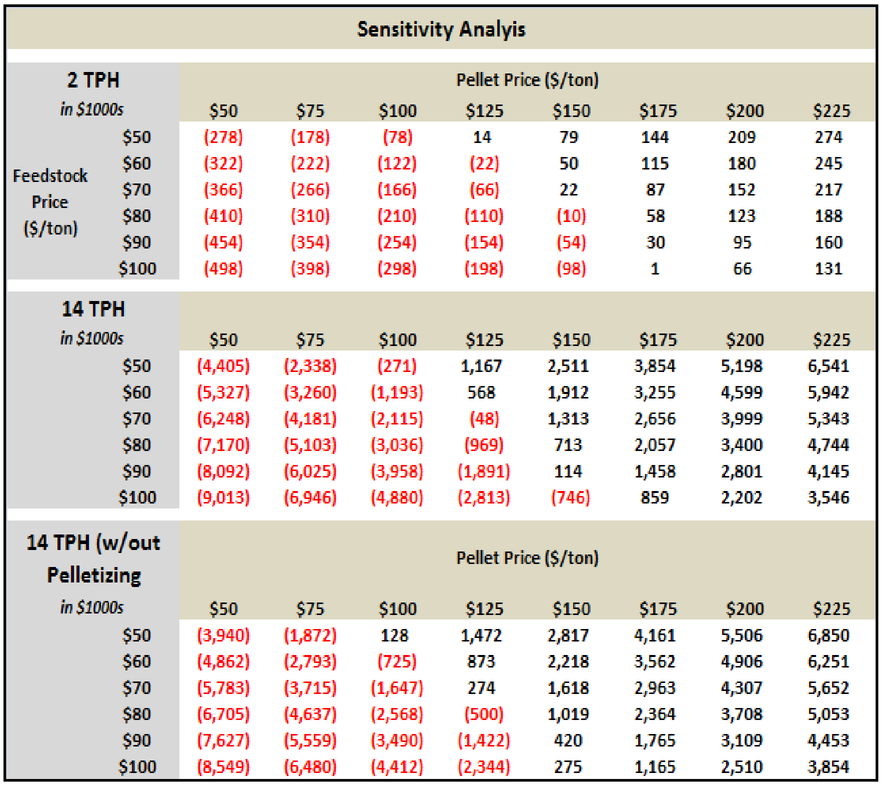


Net Income Matrix

		Pellet Price *(pegged to existing fuel sources)*			
2 TPH *in $1000s*		Coal $35.32/ton	Natural Gas $70.77/ton	Wood Pellets $236.28/ton	Propane $438.01/ton
Feedstock Price ($/ton)	$71.25/ton	($430)	($289)	$249	$766
	$76.50/ton	($453)	($312)	$227	$751
	$90.25/ton	($514)	($372)	$188	$712
14 TPH *in $1000s*		Coal $35.32/ton	Natural Gas $70.77/ton	Wood Pellets $236.28/ton	Propane $438.01/ton
	$71.25/ton	($7,577)	($4,646)	$5,874	$16,715
	$76.50/ton	($8,061)	($5,130)	$5,560	$16,400
	$90.25/ton	($9,328)	($6,398)	$4,736	$15,577
14 TPH w/out Pelletizing *in $1000s*		Coal $35.32/ton	Natural Gas $70.77/ton	Wood Pellets $236.28/ton	Propane $438.01/ton
	$71.25/ton	($7,113)	($4,180)	$6,183	$17,032
	$76.50/ton	($7,597)	($4,664)	$5,869	$16,717
	$90.25/ton	($8,957)	($6,024)	$4,985	$15,834

Sensitivity Analysis

Based on the sensitivity analysis, and the assumption that agricultural biomass feedstock prices are likely to be around $70-80 per ton, the 2 TPH pellet mill will only be profitable if pellet prices are greater than or equal to $150 per ton. On the other hand, the 14 TPH operations (pellet and non-pellet) can maintain profitability at prices greater than or equal to $125 per ton.



Sensitivity Analyis

		Pellet Price ($/ton)							
2 TPH *in $1000s*		$50	$75	$100	$125	$150	$175	$200	$225
Feedstock Price ($/ton)	$50	(278)	(178)	(78)	14	79	144	209	274
	$60	(322)	(222)	(122)	(22)	50	115	180	245
	$70	(366)	(266)	(166)	(66)	22	87	152	217
	$80	(410)	(310)	(210)	(110)	(10)	58	123	188
	$90	(454)	(354)	(254)	(154)	(54)	30	95	160
	$100	(498)	(398)	(298)	(198)	(98)	1	66	131
14 TPH *in $1000s*		$50	$75	$100	$125	$150	$175	$200	$225
	$50	(4,405)	(2,338)	(271)	1,167	2,511	3,854	5,198	6,541
	$60	(5,327)	(3,260)	(1,193)	568	1,912	3,255	4,599	5,942
	$70	(6,248)	(4,181)	(2,115)	(48)	1,313	2,656	3,999	5,343
	$80	(7,170)	(5,103)	(3,036)	(969)	713	2,057	3,400	4,744
	$90	(8,092)	(6,025)	(3,958)	(1,891)	114	1,458	2,801	4,145
	$100	(9,013)	(6,946)	(4,880)	(2,813)	(746)	859	2,202	3,546
14 TPH (w/out Pelletizing *in $1000s*		Pellet Price ($/ton)							
		$50	$75	$100	$125	$150	$175	$200	$225
	$50	(3,940)	(1,872)	128	1,472	2,817	4,161	5,506	6,850
	$60	(4,862)	(2,793)	(725)	873	2,218	3,562	4,906	6,251
	$70	(5,783)	(3,715)	(1,647)	274	1,618	2,963	4,307	5,652
	$80	(6,705)	(4,637)	(2,568)	(500)	1,019	2,364	3,708	5,053
	$90	(7,627)	(5,559)	(3,490)	(1,422)	420	1,765	3,109	4,453
	$100	(8,549)	(6,480)	(4,412)	(2,344)	275	1,165	2,510	3,854

It is clear that larger operations enjoy certain economies of scale that make them more competitive. Lower marginal costs of production at the 14 TPH facility helps make the operation competitive at price points that are still unprofitable for the farm-scale operation. It is also apparent that the 14 TPH non-pelletizing facility is even more competitive than the 14 TPH pellet mill. This is primarily a function of the lower capital costs, lower electricity cost, lower debt and interest payments, and reduced working capital requirements.

Cost of operations is not the only factor in determining the size of the plant though. Local market size, pellet price, availability of capital, availability and price of feedstock supply, interest in energy security and reduced exposure to energy price volatility, public policies, public and private supports, and myriad other factors must also be taken into account.

Strategic Recommendations

Crop Research

This report strongly recommends continued (and perhaps expanded) crop research in West Kentucky for the three main dedicated energy crops – switchgrass, miscanthus and biomass sorghum. As previously mentioned, Murray State University is already managing research trials and farm plot for switchgrass, biomass sorghum and Miscanthus. The goal of crop research for bioenergy crops is to optimize crop production, harvest and storage under conditions that are practical and applicable to local farmers and local opportunities. For this research to be most useful to farmers it needs to include all key aspects of crop management:

- Soil types and land selection – particular attention should be given to pastureland, CRP land and marginal lands
- Recommended varieties
- Planting – dates and methods
- Reseeding
- Agronomic inputs – fertilizer and chemical treatments
- Equipment
- Pest/weed/disease control
- Water management
- Harvesting and storage – to ensure high sustainable yields year to year, reduce costs, optimize moisture content, and manage supply logistics from farm to factory

Currently, there is only limited information about the pellet quality of dedicated energy crops which further inhibits the market planning activities for ag-biomass pellets. There is a correlation between soil, water and fertility management and the chemical composition (ash and chloride content) of the feedstock (and pellets).[95] Harvest timing may also affect the chemical composition. A better understanding of these effects in production systems in West Kentucky would be instructive. It is therefore recommended that the scope of crop research include examination and analysis of this relationship to understand how best to grow healthy, high-yielding, low cost energy crops while at the same time controlling for ash and chloride levels.

This research should also help to enhance the level of knowledge about miscanthus and biomass sorghum in the region. While there is ample data on switchgrass, presently there is insufficient public information about these other crops, particularly with regards to yields, cost of production, and pellet quality (e.g. Btu, ash, chloride) - thus making it hard to advocate for their production in the region or their use as bioenergy crops for pelletization. Further research on these crops will fill the gaps of knowledge and help farmers and pellet mill operators to make informed decisions about their potential value in the renewable energy supply chain for densified pellets.

Crop Residue Research

Before pursuing the utilization of corn stover or wheat straw as a source for ag-biomass pellets more research needs to be conducted to better understand the potential adverse effects of crop residue removal on soil erosion, soil organic carbon, pests, pesticides, diseases and stand establishment. This research will help to determine acceptable quantities that can be removed given the specific regional issues

Agro-processing Co-Product Research

The rising cost of sugar and its use in the production of advanced biofuels has led to renewed interest in sugar crop production across the U.S. In addition to sugarcane and sugar beets, sweet sorghum is being introduced for commercial scale production in the South. The processing of sweet sorghum yields two products – juice (often

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[95] Blade Energy Crops. (2010). 'Managing High-Biomass Sorghum as a Dedicated Energy Crop.' http://www.bladeenergy.com/Bladepdf/Blade_SorghumMgmtGuide2010.pdf.

reduced to molasses) and bagasse. Sweet sorghum bagasse is a fibrous cellulosic material. Although high in moisture content immediately after processing, it can be stored to dry. This bagasse has some commercial value as a livestock feed; however this market is not well developed and it is unclear if this would be the highest value opportunity. Preliminary testing of the material in Whiteville, Tennessee has demonstrated bagasse's suitability as a feedstock source for pelletization.

Further testing and analysis of sweet sorghum bagasse as a feedstock for pelletization is recommended. Included in this testing would be: pellet quality, chemical composition, energy content, and processing efficiency. Since crop research is also necessary, it is also recommended that sweet sorghum crop research be conducted, along similar lines as that recommended above in the 'Crop Research' section. Murray State currently has ongoing sweet sorghum trials.

New Technology Assessment

Market opportunities for ag-biomass pellets will change as new biomass combustion technologies come online. New technologies, like LEI Products Bio-Burner and CSA Energy's straw-fired boilers and gasification technology (both companies are based in Kentucky), can burn lower quality materials and thus offer potential market opportunities for ag-biomass pellets (as well as bulk biomass) from dedicated energy crops and other raw materials.

This report recommends collaborating with these new technology manufacturers, as well as others, to test the viability of ag-biomass pellets, and non-pelletized material, as well as the capacity of the equipment itself. Such collaboration would be well suited for Murray State University, and would tie-in perfectly with the agriculture research for crops, crop residues and ag-processing by-products previously described.

Existing Technology Assessment

Volume and other characteristics of ash may be more important than the percentage ash content. For instance, since light, flaky ash is more voluminous it does not stay in the burn pot and ash tray, but is instead deposited throughout the appliance, thus reducing its overall efficiency and making cleaning more difficult. In the Agricultural Utilization Research Institute's feasibility study guide for agricultural biomass pellets it is noted that an agricultural biomass pellet, or mixed biomass pellet composed of wood and agricultural biomass, with low and benign ash content (i.e. ash that is grainy and not flaky, with a high ash fusion temperature) has potential to be burned without problem in existing pellet stove appliances that currently recommend premium wood pellets. This study guide also notes that the extent to which the higher chloride content actually causes more corrosion, slagging and fouling in pellet appliances and venting is not well-documented. Additionally, for co-firing models it is important to understand how the chloride content in ag-biomass pellets may impact the quality of coal ash, which is used to make concrete and cement.[96]

To properly assess the true risks of ash and chloride levels in ag-biomass pellets, this report recommends that more work be done to assess the burn quality in existing pellet stoves, boilers and other appliances of ag-biomass pellets, and mixed biomass pellets composed of wood and agricultural biomass. This could be done in collaboration with boiler and pellet stove manufacturers. For a list of pellet stove manufacturers please refer to ***Appendix 5 – Pellet Stove Manufacturers.*** Among those producing stoves for agricultural biomass are Harman, Quadra-Fire and Paromax. For a list of boiler manufacturers please refer to ***Supplement A: Companies, Institutions and Organizations with Boilers in West Kentucky.***

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[96] Campbell, Ken. (2007). 'A Feasibility Study Guide for an Agricultural Biomass Pellet Company.' Agricultural Utilization Research Institute. http://www.auri.org/research/FINAL%20FEASIBILITY%20STUDY%20GUIDE%2011-26-07.pdf.

Integrated Research, from crop to energy product

In light of the need for further research at every stage of the supply chain for agricultural biomass-to-energy systems, this report recommends an integrated research platform that coordinates crop research, technology research and market assessment. Under such an approach relevant departments at Murray State University (School of Agriculture, College of Science and Engineering, College of Business, and the Regional Business and Innovation Center) would collaborate to address particular gaps in knowledge and information that are critical to developing an agricultural biomass supply chain from farm to end-use. Crops, crop residues, and crop processing by-products would be examined under different approaches, pelletized (individually and blended), and tested on different technologies to better understand the burn characteristics of each pellet type on each type of appliance. At the same time, market development activities could be conducted to assist in the commercialization of opportunities identified during the course of the research.

Pilot Study

The recommendation above for integrated research would perhaps best be served through a pilot study. The pilot study would include the previously stated research recommendation. It would also include a pellet mill, which would create the opportunity for pellet production. A pilot mill will open up research into optimizing the pelletization process for the different agricultural biomass feedstock sources being considered. For instance, it has been reported that silica content in dedicated energy grasses can lead to enhanced wear of pellet equipment. It has also been reported that switchgrass pellets have poor binding and durability. A pilot study would provide the ideal platform to address these issues and others through an organized learning and demonstration process.

Optimizing a pellet mill for processing more than one agricultural biomass feedstock source will also require experimentation with different pellet dies and settings. According to Mr. Jeremy Karwandy in 'Pellet Production from Sawmill Residue: a Saskatchewan Perspective':

> Depending on the material being pelletized…a delicate refining and balancing of settings is needed… A die works by providing the appropriate amount of resistance as the press wheel attempts to push the raw material through the holes in the plate. The appropriate amount of resistance allows the raw material to heat up and soften so that it can be reshaped and compacted into the desired shape. If a die provides too much resistance, the material being pelletized can become scorched. If too little resistance is provided the raw material will nto be compressed and simply pass through the holes.[97]

A pilot facility would also allow for testing post-harvest logistics systems to optimize storage and delivery to the mill. In addition to the research benefits of this arrangement, an integrated research platform with a pilot mill would also build interest and raise awareness of the opportunities for agricultural biomass-to-energy systems among the broader farming community in West Kentucky. Since the farmers in the region will lead the production of the feedstock crops, it is critical that they understand and appreciate the system and the value of the opportunity. Under such an integrated model it is also worth considering potential collaboration with one or more of these farmers (perhaps identified through the West Kentucky Farmer Network) to meet the feedstock production requirements for the pilot mill.

Partnership with End-Market

In order for integrated research and a pilot study to work, there needs to be a market outlet for the ag-biomass product (pellets or non-pelletized, ground material). This report therefore recommends the formation of a partnership with an organization in one or more of the applicable markets – residential heating, commercial/institutional operation, poultry house, greenhouse and tobacco curing.

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[97] Karwandy, Jeremy. (March 2007). 'Pellet Production from Sawmill Residue: a Saskatchewan Perspective.' Forintek Canada Corporation.

For a complete list of commercial and institutional operations with boilers in the West Kentucky region please refer to ***Supplement A: Companies, Institutions and Organizations with Boilers in West Kentucky.*** High energy use operations with the potential for biomass pellets include: animal and dairy farms, elementary schools, high schools, colleges and universities, healthcare facilities, manufacturing facilities, government offices, laboratories, military facilities, multi-family housing, museums, national parks, office buildings, pipelines, pulp and paper facilities, refineries, supermarkets, transportation, waste and wastewater treatment facilities, wineries, breweries, correctional facilities, data centers, district energy plants, ethanol plants, forest products, health clubs, and hotels.[98] Murray State University might be an ideal partner for this type of project.

There are a number of experimental projects in the U.S. in which a power plant has tested co-firing biomass with coal. At the Spurlock Power Station in Maysville, Kentucky, a clean coal generating unit has been modified to burn alternative fuels like switchgrass. Small percentages of switchgrass – less than 10 percent - can be co-fired with coal in existing power plants; however burning higher percentages will require modification to current boiler designs.[99]

The Chariton Valley Biomass Project in southern Iowa is a multi-stakeholder collaboration to demonstrate the technical and commercial feasibility of producing power from switchgrass and other grasses. This effort included Chariton Valley Resource Conservation and Development Inc, Alliant Energy, Prairie Lands Biomass LLC, and the U.S. Department of Energy.[100]

Both of these examples are for the utility sector, a market segment described in the report as likely offering the lowest value for the agricultural biomass pellet. For this reason partnerships are also recommended with people, organizations and businesses that would potentially pay more for this fuel source, since it would potentially replace higher-value energy sources like wood, wood pellets and propane. For instance, the Catskill Grass Bioenergy Project, run out of Cornell University, is developing a pilot project which includes research of grass biomass production and processing, as well as demonstration of combustion technologies for residential and small business applications.[101]

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[98] U.S. Department of Energy. Energy Efficiency and Renewable Energy. 'Industrial Distributed Energy.' http://www1.eere.energy.gov/industry/distributedenergy/projects_sector.html.

[99] University of Kentucky – College of Agriculture. Cooperative Extension Service. (November 2009). 'Switchgrass for Biomass.' http://www.uky.edu/Ag/CDBREC/introsheets/switchgrass.pdf.

[100] Prairie Lands Biomass Project. http://iowaswitchgrass.com/.

[101] Cornell University – Cooperative Extension of Delaware County. 'Catskill Grass Bioenergy Project.' http://www.ccedelaware.org/Agriculture-Natural-Resources/CatskillGrassBioenergy.aspx.

Appendix 1 – West Kentucky Power Providers[102]

Western Kentucky Power Plants

Utility	Plant Name	City	County	Megawatt
Cash Creek Generating LLC	Cash Creek	Henderson	Henderson	0
Grane Creek LLC	Henderson Generating Station	Henderson	Henderson	0
Henderson City Utility Comm	Henderson I	Henderson	Henderson	46.2
Western Kentucky Energy Corp	Henderson Municipal Power & Light	Henderson	Henderson	365
USCE-Nashville District	Barkley	Lyon	Lyon	130
Air Products and Chemicals Inc	Calvert City	Marshall	Marshall	26.7
Calvert City Power I LLC	Calvert City Power I LLC	Marshall	Marshall	0
Cinergy Solutions OandM LLC	Marshall Energy Facility	Marshall	Marshall	688
Enviro Power LLC	Kentucky Western Power LLC	Marshall	Marshall	0
Tennessee Valley Authority	Kentucky Dam	Marshall	Marshall	197.4
Westlake Energy Corp	Westlake Energy	Marshall	Marshall	0
Paducah Energy LLC	Paducah Energy Center	West McCracken	McCracken	0
Tennessee Valley Authority	Shawnee	McCracken	McCracken	1750
Kentucky Utilities Co	Green River	Muhlenberg	Muhlenberg	263.6
Tennessee Valley Authority	Paradise	Muhlenberg	Muhlenberg	2558.2
Thoroughbred Generating Station Co	Thoroughbred Generating Station	Muhlenberg	Muhlenberg	0
Western Kentucky Energy Corp	Robert A Reid	Webster	Webster	194.8
Western Kentucky Energy Corp	R D Green	Webster	Webster	528

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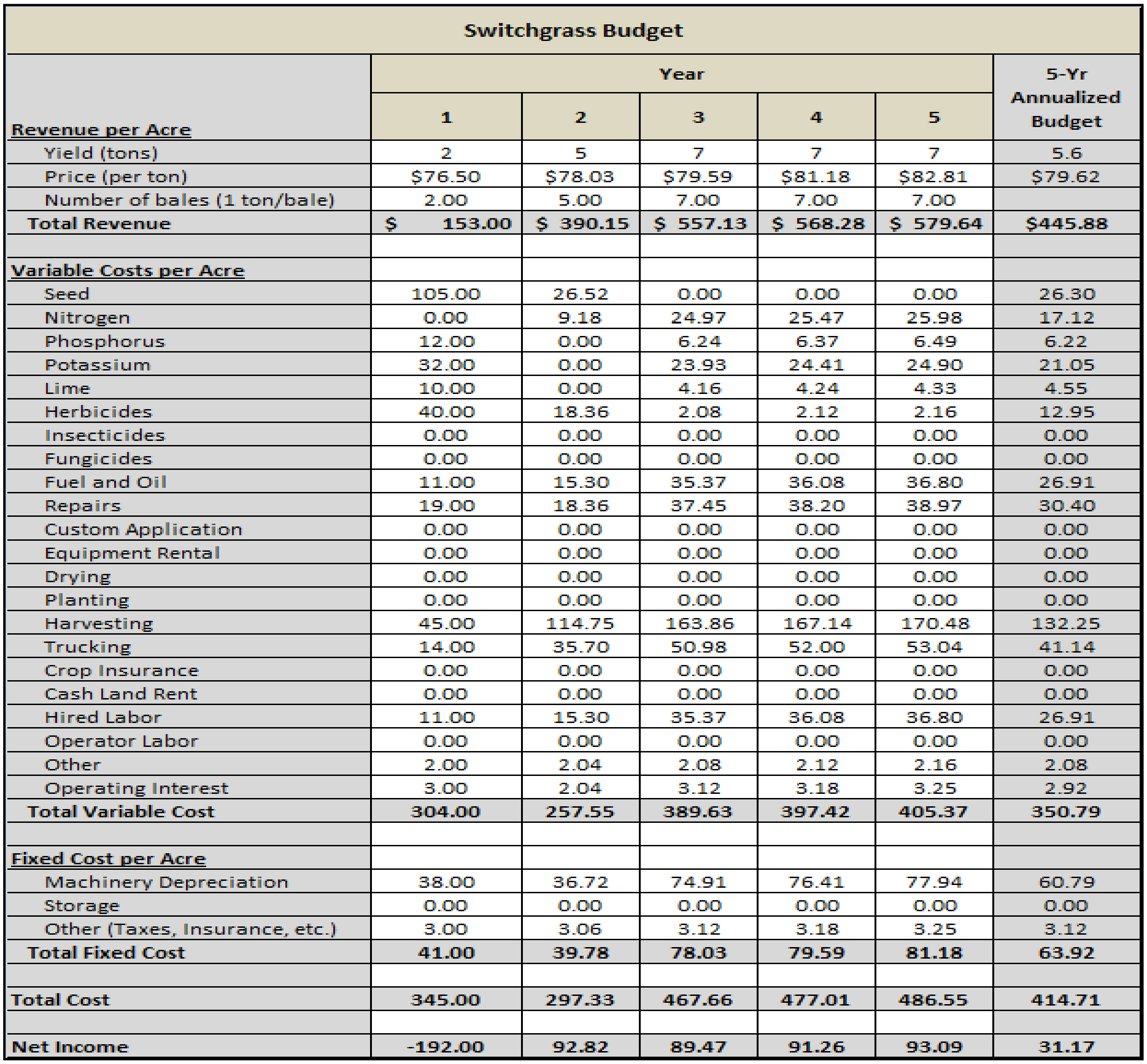
[102] Power Plants in Kentucky. http://powerplantjobs.com/ppj.nsf/powerplants1?openform&cat=ky&Count=500.

Appendix 2 – Switchgrass Budget[103]

- Harvesting rate based on custom hire rates provided in 'Custom Machinery Rates Applicable to Kentucky (2011)[104]
- Includes annual inflation rate of 2%



Switchgrass Budget

	Year					5-Yr Annualized Budget
Revenue per Acre	**1**	**2**	**3**	**4**	**5**	
Yield (tons)	2	5	7	7	7	5.6
Price (per ton)	$76.50	$78.03	$79.59	$81.18	$82.81	$79.62
Number of bales (1 ton/bale)	2.00	5.00	7.00	7.00	7.00	
Total Revenue	**$ 153.00**	**$ 390.15**	**$ 557.13**	**$ 568.28**	**$ 579.64**	**$445.88**
Variable Costs per Acre						
Seed	105.00	26.52	0.00	0.00	0.00	26.30
Nitrogen	0.00	9.18	24.97	25.47	25.98	17.12
Phosphorus	12.00	0.00	6.24	6.37	6.49	6.22
Potassium	32.00	0.00	23.93	24.41	24.90	21.05
Lime	10.00	0.00	4.16	4.24	4.33	4.55
Herbicides	40.00	18.36	2.08	2.12	2.16	12.95
Insecticides	0.00	0.00	0.00	0.00	0.00	0.00
Fungicides	0.00	0.00	0.00	0.00	0.00	0.00
Fuel and Oil	11.00	15.30	35.37	36.08	36.80	26.91
Repairs	19.00	18.36	37.45	38.20	38.97	30.40
Custom Application	0.00	0.00	0.00	0.00	0.00	0.00
Equipment Rental	0.00	0.00	0.00	0.00	0.00	0.00
Drying	0.00	0.00	0.00	0.00	0.00	0.00
Planting	0.00	0.00	0.00	0.00	0.00	0.00
Harvesting	45.00	114.75	163.86	167.14	170.48	132.25
Trucking	14.00	35.70	50.98	52.00	53.04	41.14
Crop Insurance	0.00	0.00	0.00	0.00	0.00	0.00
Cash Land Rent	0.00	0.00	0.00	0.00	0.00	0.00
Hired Labor	11.00	15.30	35.37	36.08	36.80	26.91
Operator Labor	0.00	0.00	0.00	0.00	0.00	0.00
Other	2.00	2.04	2.08	2.12	2.16	2.08
Operating Interest	3.00	2.04	3.12	3.18	3.25	2.92
Total Variable Cost	**304.00**	**257.55**	**389.63**	**397.42**	**405.37**	**350.79**
Fixed Cost per Acre						
Machinery Depreciation	38.00	36.72	74.91	76.41	77.94	60.79
Storage	0.00	0.00	0.00	0.00	0.00	0.00
Other (Taxes, Insurance, etc.)	3.00	3.06	3.12	3.18	3.25	3.12
Total Fixed Cost	**41.00**	**39.78**	**78.03**	**79.59**	**81.18**	**63.92**
Total Cost	**345.00**	**297.33**	**467.66**	**477.01**	**486.55**	**414.71**
Net Income	**-192.00**	**92.82**	**89.47**	**91.26**	**93.09**	**31.17**

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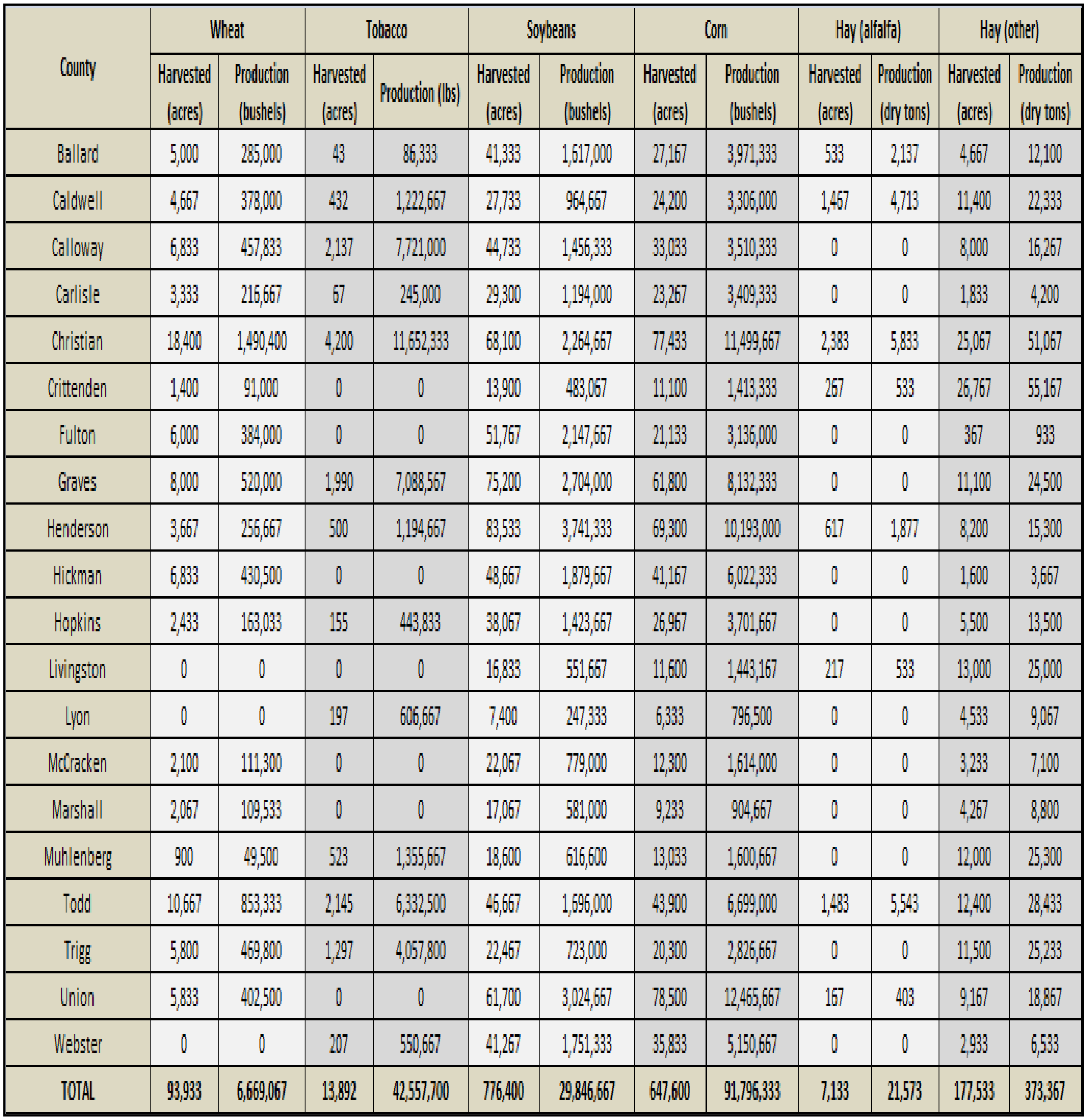
[103] University of Kentucky – College of Agriculture. (2010). 'Switchgrass vs Hay - Comparative Budgets - 2010.' http://www.ca.uky.edu/agecon/index.php?p=29.

[104] University of Kentucky – College of Agriculture. (2011). 'Custom Machinery Rates Applicable to Kentucky.' http://www.ca.uky.edu/cmspubsclass/files/ghalich/CustomMachineryRatesKentucky2011.pdf.

Appendix 3 – Crop Production in West Kentucky[105]



County	Wheat		Tobacco		Soybeans		Corn		Hay (alfalfa)		Hay (other)	
	Harvested (acres)	Production (bushels)	Harvested (acres)	Production (lbs)	Harvested (acres)	Production (bushels)	Harvested (acres)	Production (bushels)	Harvested (acres)	Production (dry tons)	Harvested (acres)	Production (dry tons)
Ballard	5,000	285,000	43	86,333	41,333	1,617,000	27,167	3,971,333	533	2,137	4,667	12,100
Caldwell	4,667	378,000	432	1,222,667	27,733	964,667	24,200	3,306,000	1,467	4,713	11,400	22,333
Calloway	6,833	457,833	2,137	7,721,000	44,733	1,456,333	33,033	3,510,333	0	0	8,000	16,267
Carlisle	3,333	216,667	67	245,000	29,300	1,194,000	23,267	3,409,333	0	0	1,833	4,200
Christian	18,400	1,490,400	4,200	11,652,333	68,100	2,264,667	77,433	11,499,667	2,383	5,833	25,067	51,067
Crittenden	1,400	91,000	0	0	13,900	483,067	11,100	1,413,333	267	533	26,767	55,167
Fulton	6,000	384,000	0	0	51,767	2,147,667	21,133	3,136,000	0	0	367	933
Graves	8,000	520,000	1,990	7,088,567	75,200	2,704,000	61,800	8,132,333	0	0	11,100	24,500
Henderson	3,667	256,667	500	1,194,667	83,533	3,741,333	69,300	10,193,000	617	1,877	8,200	15,300
Hickman	6,833	430,500	0	0	48,667	1,879,667	41,167	6,022,333	0	0	1,600	3,667
Hopkins	2,433	163,033	155	443,833	38,067	1,423,667	26,967	3,701,667	0	0	5,500	13,500
Livingston	0	0	0	0	16,833	551,667	11,600	1,443,167	217	533	13,000	25,000
Lyon	0	0	197	606,667	7,400	247,333	6,333	796,500	0	0	4,533	9,067
McCracken	2,100	111,300	0	0	22,067	779,000	12,300	1,614,000	0	0	3,233	7,100
Marshall	2,067	109,533	0	0	17,067	581,000	9,233	904,667	0	0	4,267	8,800
Muhlenberg	900	49,500	523	1,355,667	18,600	616,600	13,033	1,600,667	0	0	12,000	25,300
Todd	10,667	853,333	2,145	6,332,500	46,667	1,696,000	43,900	6,699,000	1,483	5,543	12,400	28,433
Trigg	5,800	469,800	1,297	4,057,800	22,467	723,000	20,300	2,826,667	0	0	11,500	25,233
Union	5,833	402,500	0	0	61,700	3,024,667	78,500	12,465,667	167	403	9,167	18,867
Webster	0	0	207	550,667	41,267	1,751,333	35,833	5,150,667	0	0	2,933	6,533
TOTAL	93,933	6,669,067	13,892	42,557,700	776,400	29,846,667	647,600	91,796,333	7,133	21,573	177,533	373,367

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[105] USDA National Agricultural Statistics Service. Data and Statistics. http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp. (Figures based on 3-year average from 2008-2010).

Appendix 4 – Land Rental Payments for West Kentucky[106]

County	Rental Payment	
	Non-Irrigated Cropland	Pastureland
Ballard	$81	$42
Caldwell	$106	$29
Calloway	$103	$23
Carlisle	$103	NA
Christian	$152	$32
Crittenden	$96	$18
Fulton	$119	NA
Graves	$106	$30
Henderson	$137	$44
Hickman	$104	NA
Hopkins	NA	$15
Livingston	$85	$21
Lyon	NA	$16
Marshall	NA	$18
McCracken	$82	NA
Muhlenberg	$83	$22
Todd	$155	$44
Trigg	$119	$32
Union	$161	$36
Webster	$131	$29
Average	**$113**	**$27**

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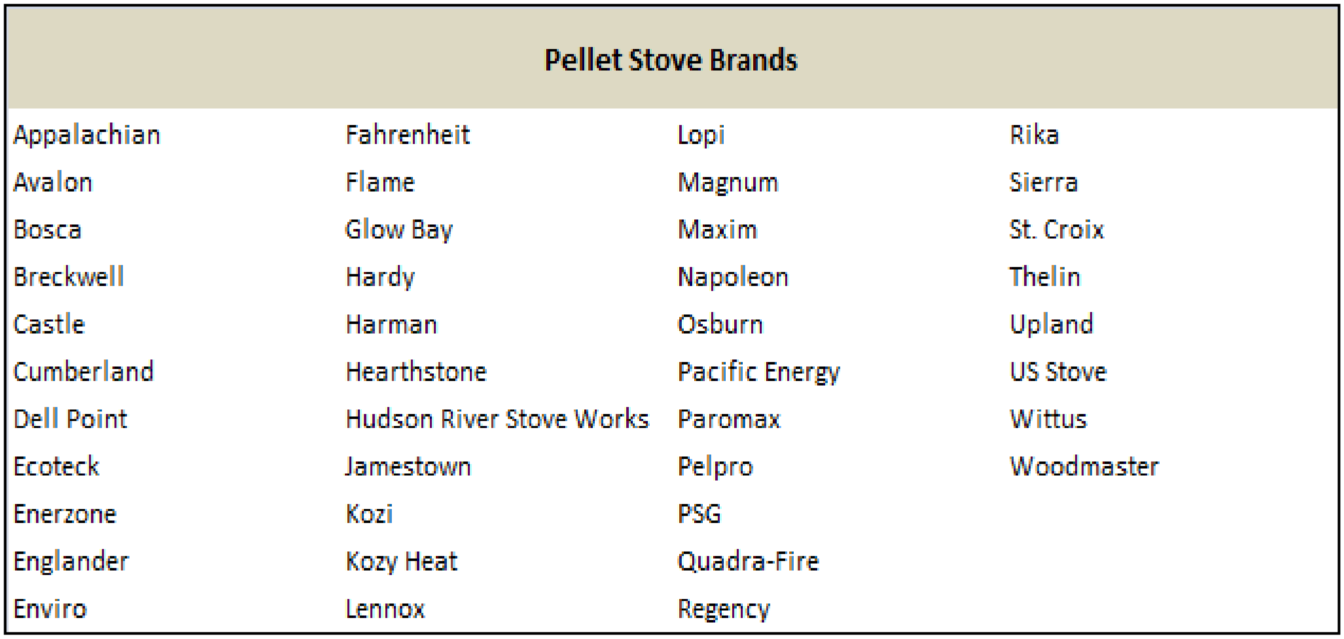
[106] USDA National Agricultural Statistics Service. Data and Statistics. http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats_1.0/index.asp.

Appendix 5 – Pellet Stove Brands[107]



Pellet Stove Brands

Appalachian
Avalon
Bosca
Breckwell
Castle
Cumberland
Dell Point
Ecoteck
Enerzone
Englander
Enviro
Fahrenheit
Flame
Glow Bay
Hardy
Harman
Hearthstone
Hudson River Stove Works
Jamestown
Kozi
Kozy Heat
Lennox
Lopi
Magnum
Maxim
Napoleon
Osburn
Pacific Energy
Paromax
Pelpro
PSG
Quadra-Fire
Regency
Rika
Sierra
St. Croix
Thelin
Upland
US Stove
Wittus
Woodmaster

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